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Interregional Water Transfers

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A Task Force, comprising well-known international experts, met at the International Institute of Applied Systems Analysis (IIASA), Laxenburg, Austria, during 11–14 October, 1977, to discuss and review current status of interregional water transfers (IWT) in the world, and to make some recommendations about possible future directions of work. Specialists on IWT from Canada, India, Mexico, Soviet Union and the United States attended the meeting under the chairmanship of Professor Genady Golubev of IIASA; Dr. Asit K. Biswas of Canada was the General Rapporteur.

In his opening address, Dr. Roger Levien, Director of IIASA, briefly described the current research of the Institute, and stressed the importance of IWT within the framework of the existing research activities in the area of water.

The Chairman of the meeting, Professor Golubev, then set the scene for the 4-day meeting by raising some principal questions with regard to IWT projects. He pointed out five major considerations. These were:

(1) The size of IWT projects has been growing exponentially with respect to time. Now the largest ones can transfer up to 10 km^3/yr. Projects for the next 20–30 years are of the next order of magnitude.

(2) Some groups of problems arise because of the growing size of IWT projects: (a) water demand/supply relationships as a starting point for IWT; (b) uncertainty; (c) efficiency; (d) links with other major problems (energy, resources, capital investment, food, etc.); (e) impacts; and (f) other, non-conventional ways of water supply.

(3) In the USSR and the USA, IWT projects have stemmed from: (a) serious demand/supply situations in southern USSR and south-western USA; (b) decrease of river run-off due to human activity; and (c) deterioration of hydrologic regimes of lakes and seas.

(4) The IWT problem consists of three main blocks: technology, socio-economic, and environment. They are subdivided into sub-blocks of a lower level. There is a strong interrelation not only *within* the main blocks but also *between* them.

(5) As a general rule, as the size of IWT projects increases, the complexity increases as well. Uncertainty is in turn connected with complexity and is also growing. Comparison of the curve of uncertainty and the curve of efficiency as functions of the projects' size has been demonstrated. With these considerations in mind, it can be concluded that there is a certain size limitation above which uncertainty is greater than efficiency, and very big IWT projects are not appropriate for the time-being. With the progress of science the critical size of projects will increase.

Dr. Asit K. Biswas, Director of Biswas & Associates, Ottawa, Canada, provided an overview of the interregional water transfer projects in North America. He pointed out that three

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factors must be analyzed before IWT could be considered. These are availability of water, both in terms of space and time, nature of demand functions and current efficiency of water use. In many parts of North America, especially in northern Canada and parts of Mexico, adequate data on surface and groundwater supplies do not exist. In many other parts of Canada, the United States and Mexico data are available only for a short period of time and hence reliable forecasts of water availability on a probabilistic basis are difficult to make. The situation is much worse when water demands are considered. Demand functions are difficult to construct, and in the context of water planning demands are often synonymous with requirements. Finally, efficiency of water use is very low in certain sectors, especially in agriculture. On a global basis, 80% of total water used is for agriculture: the corresponding figure for the United States is about 40%. Currently, 223 million ha of land are irrigated in the world, 93 million ha of which are in developing countries. Irrigated crops currently require 1.3 million million m^3 of water, but because of losses in distribution systems, 3 million million m^3 of water have to be withdrawn. The efficiency of global irrigation is even much less since there is a universal tendency to over-irrigate. Thus, in most cases, before major IWT schemes can be considered, it would make better sense to improve the water use efficiency of present systems.

The most ambitious IWT plan in North America was the North American Water and Power Alliance (NAWAPA), first proposed in 1964. The general approach of this scheme was to distribute the surplus water of the high precipitation areas of the north-western part of the North America to water scarce areas of Canada, the United States and Mexico. The immensity of the plan stirred the imagination of many engineers and economists, and within the 5 years of NAWAPA being proposed, a whole series of IWT schemes was put forward to redistribute the waters of North America.

However, as these new massive diversion schemes were being proposed, a new era dawned in North America. Toward the end of the 1960s, environmental considerations became increasingly more important, and this culminated in the development of a completely new process – that of environmental impact assessment – within the overall planning framework. Politically, environmentalists became a major force, and they opposed construction of massive water development projects on environmental and ecological grounds. The growth of environmental awareness, to a large extent, contributed to the decline of interest in IWT in Canada and the United States. At the present time, it is hard to foresee the construction of any new major IWT in Canada and the United States before the end of this century.

Prof. G. Voropaev, Director of the Water Problems Institute, Moscow, reviewed the Soviet experiences in IWT. The long-term economic planning in the USSR foresees considerable growth of water demands. By the end of the present century, water demands will exceed the present level by two to three times. The existing resources will not be enough to meet the growing water demands in the southern parts of the USSR. To meet these demands, it is necessary to undertake complex measures that will include the following:

(1) the improvement of the technology of the water use and the substitution of water-consuming industries by less consuming ones;

(2) fuller use and the increase of water supply from local water resources by run-off regulation;

(3) the territorial redistribution of water resources by redirecting run-off of the northern rivers to the southern side.

The most important matter in solving the problem of water needs of the national economy will be the territorial redistribution of water resources. The choice of the alternatives and the sequence in taking measures on the territorial redistribution are possible only by indepth study of the problem. Such a study will provide predictions of the long-term impacts on ecological, physio-geographical, and socio-economical processes by water redistribution measures. It is critical to realize the interrelations between these processes in order to understand their regional estimation, to study the dynamics of their development, and to see the global aspects of the problem. Studies of this kind have already been initiated in the USSR. Their methodological foundation is based on the systems approach to the problem.

The complexity of this problem solution is also conditioned by a number of specific factors such as a wide range of climatic changes over the vast territory of the USSR, extremely uneven distribution of surface and groundwater resources, the existence of large water bodies (seas) in the south, synchronous or asynchronous river run-off oscillations over big territories of the country, water demands in various regions, etc.

At the same time in the USSR there are a number of objective prerequisites for successful solution of this problem, two of which are: general state planning of the whole economic and social life of the society and people's property of land and water resources; and the high economic power of the country and large experience in conducting large-scale water projects on irrigation, hydroenergetics and water transport.

H. Garduño of the Comisión del Plan Nacional Hidráulico, Mexico City, described the current plans for large-scale transfers within the master water plan for Mexico. Water resources planning in Mexico is carried on by the National Water Plan Commission (NWPC), from the Agriculture and Water Resources Ministry. In a 5-year period, a special planning process was designed and the National Water Plan (NWP) 1975 was completed.

The methodology consists of an iterative process with both national and regional approaches. Each iteration starts with alternative socio-economic scenarios and its main results are national and regional objectives, goals, policies and programs for each basic (e.g. irrigation, flood control, etc.) and supportive activity (e.g. research, water inventories, etc.).

It is within this context that the need for water transfers appears. In Mexico, a country of 200 million ha, with a population of 60 million in 1975 and a mean annual run-off of 410 km^3, agricultural soil, water and population are unevenly distributed and they do not coincide geographically. The total irrigated area is 5 million ha, 900,000 of which lie in the northwestern regions, where there still is a surface of 1.5 million ha of good idle land. Eighty per cent of this surface is located in the northern part, while the rivers which are still uncontrolled lie in the south. To irrigate about 900,000 new ha by the turn of the century, a combination of aquifer mining during 10 years and water transfers to irrigate new lands and to rescue the lands irrigated with mined groundwater will be developed. The system will include the construction of eight dams, conduits of 1500 km and some 600 Wh per year of energy to raise the water 500 m.

The NWPC is presently working on linking some models it has developed during the last 3 years so that, once a national goal is set up by the government (e.g. food self-sufficiency) the evaluation procedures help to decide which projects are better to achieve that goal.

The other water transfer project for the near future is needed to supply water for Mexico with a present population of more than 10 million. The supply will have to increase from 42 m^3/sec to 110 m^3/sec in the year 2000, with pumping heads of more than 1000 m to reach the Mexican capital at 2240 m above sea level. The huge investments needed, and the population estimates (by the year 2000, 30 million) make it clear that higher efficiency is needed in water use and that effective decentralization measures should be taken to reach a more balanced regional development in the country.

Robin R. Reynolds, Deputy Director of the California Department of Water Resources, Sacramento, reviewed the Californian experience in the operation of IWT projects.

Using California and California's State Water Project as an example, the phases in the history of the development and use of water resources were reviewed. Several of the examples of systems analysis used in the planning and operation of the Project were reviewed, especially those relating to operations in the Sacramento–San Joaquin Delta where there is intense technical and political controversy. The operation scheme using off-peak power also was described. In addition, a possible ultimate pattern of water development for a nation or a large international region was discussed. It was suggested that some insight into the characteristics of one such possibility of an ultimate phase can be gained by considering the characteristics of a large power grid system. On this basis, the characteristics of a water grid were described. The most significant characteristics are large interbasin and interregional aqueducts and a central coordination and management.

Mr. K.S. Murthy of the Central Water Commission of the Government of India, New Delhi, India, reviewed the current status and future plans of IWT in India, a country that has a geographical area of over 800 million acres. The cropped area is about 400 million acres. Current irrigation covers nearly 100 million acres. The ultimate irrigation potential is estimated at over 200 million acres.

India lies in the tropical and sub-tropical region. Rainfall is confined to the monsoon months of June–September (nearly 90%). It is erratic – not dependable in most parts of the country. Agriculture is the main occupation of the people – over 70% are engaged in it. It contributes over 50% of the GNP but successful agriculture is not possible in most areas of the country without irrigation.

Since Independence (1947) the country has embarked on a massive irrigation development program. Over 70 million rupees have been spent so far. Current annual investment is over 10 billion rupees. One third of the country suffers from drought. Large sums of money are spent in relief works. To provide permanent relief, studies and investigations are now in progress for big irrigation projects for these areas. These involve interregional interbasin transfer of water. Obviously, drought areas have no waters of their own.

Under the Constitution of India, "water" is under state jurisdiction. The Central Government acts as a coordinator and provides technical and financial assistance, and in certain cases helps in construction as well. Inter-State agreements are necessary for interbasin and interregional water transfers, which take time. Proposals are under consideration to give the Centre greater authority in this matter.

Inter-linking of rivers has been under consideration for quite a few years – north to south, east to west, etc. This has generated a lot of passion and arguments. Current studies envisage interregional water transfer taking note of local needs and sentiments. But at the same time these are being so designed as to fit into an over-all national water grid at a future date. The main elements of such transfers are high-lift storage and long-distance movement.

Agronomic and economic aspects are equally important, especially for high-lift water uses. Political considerations should be given due consideration and public opinion is important for construction of these schemes. Once public opinion develops to support the schemes, the task becomes easier to accomplish.

Interregional water transfers are going to be crucial in the coming years. They are the answer to the "Two Faces of Water – Floods and Droughts". International cooperation, especially in the fields of shared knowledge and experience, can play a vital role in this field.

Professor Charles W. Howe of the Department of Economics, University of Colorado, Boulder, Colorado, reviewed the history of IWT in the USA, which is similar to other countries in its progression from smaller to larger projects. The high costs, uncertain environmental effects, and opposition from areas of origin led to reduced interest in IWT until the energy crisis of 1973. Some interest has arisen from potential energy industry demands such as shale oil production and coal gasification. Other current interest arises from "rescue operations" for regions dependent on fossil groundwater.

Six issues warrant discussion. (1) Agriculture is generally the largest user of proposed transfers but represents the lowest valued uses, reducing benefit–cost ratios. At the same time, low agricultural values imply the possibility of satisfying new demands with present sources of agriculture water rather than from IWT. (2) Limited world markets study the price effects of large expansions of irrigated production. (3) Possibilities of increasing use efficiency of existing supplies as a substitute for IWT or to defer the need for IWT construction must be studied. (4) The extent of energy recovery in IWTs which require pumping is important to economic feasibility. (5) Externalities in the exporting region such as foregone uses and increased salinity concentrations must be taken into account. (6) There is a tendency toward premature construction of IWTs. Several case studies (Arizona and Mexico) have shown that deferring IWT projects would not be costly to the importing region and would greatly reduce the present value of construction costs. These last two points relate closely to the major points of Professor Fisher.

Professor Anthony Fisher of the University of California, Berkeley, reviewed some theoretical and measurement problems in economic assessment of IWT projects. With recent increases in the size of proposed IWTs, careful consideration of their economics becomes particularly important. A number of proposals and propositions concerning the theory and measurement of the costs and benefits of an IWT were suggested. They can be stated briefly as follows:

(1) Commonly used methods of measuring the conventional economic impact, including input–output analysis, are not entirely adequate, in that they do not allow sufficiently for induced changes in the structure of the economies of the impacted regions, do not trace these changes through time, and do not relate them to maximizing behavior by economic agents. An econometric modeling approach may be used to accomplish these objectives.

(2) Calculations of the benefits and costs of an IWT ordinarily ignore its effects on the environment, yet these are likely to be substantial. The standard decision criterion can be modified to include the costs of environmental effects. Where the costs cannot be estimated, a technique was suggested for comparing an IWT to an alternative means of producing water, that still accounts for both conventional economic and environmental effects of each. Briefly, if both the economic and the environmental costs (even where these cannot be measured in money terms) are lower for one of the alternatives, it is said to *dominate*.

(3) It is possible that the environmental effects of an IWT may be both irreversible and uncertain. Where, however, the uncertainty diminishes over time, as better information about the effects and their costs becomes available, there is a kind of additional cost to proceeding "too soon" with the project. This represents a further modification of the standard benefit–cost criterion.

Discussion of the paper was brief, limited mainly to technical questions about part (3). The one important point of substance had to do with the practicality of the finding in part (3). That is, would it be practical to estimate the additional cost to proceeding "too soon"? Fisher's answer was, probably not; but the finding is still relevant, since it puts the burden of proof on marginal projects. A project that exhibits the characteristics of part (3) should not be undertaken (on economic efficiency grounds) if its expected present value is just barely positive.

Professor Leonard Ortolano of Stanford University, USA, discussed environmental assessments in water resources planning, with special reference to the United States. As a result of laws and regulations promulgated early in the 1970s, environmental assessments are required for studies carried out by the federal agencies responsible to water resources planning in the United States; a wide variety of impacts on both the natural and "social" environment are included in these assessments. The paper summarizes the nature of these impacts as well as the various methods being used for impact identification, prediction and evaluation. Documentation from case studies and mail questionnaire surveys is presented to support the notion that issues related to assessment methods *per se* are not the critical ones in ensuring that environmental factors receive adequate consideration in planning. Rather, the key issues relate to the ways in which the results from applying environmental assessment methods are used in water resources planning and decision making. An "iterative, open-planning process" is presented as providing a mechanism for assuring that environmental assessments are used in the formulation and ranking of alternative actions; such a process is now being used by the US Army Corps of Engineers, one of the principal water resources agencies in the United States. The discussion of the paper indicated that the use of an iterative, open-planning process in no way detracts from the efforts of economists to evaluate environmental effects in monetary terms and thereby increase the extent to which alternatives are evaluated on a rigorous, systematic basis.

Professor G. Golubev reviewed environmental issues of big IWT projects. With the increase of the size of IWT projects the complexity of environmental assessment is growing as well. It stems from the fact that the number of components and links in a geoecosystem are increasingly nonlinearly as a function of projects' size. Correspondingly, the greater the size, the greater the uncertainty in evaluation of environmental impacts. Above a certain size, uncertainty would be so high that it would not be feasible to carry out a project. Possibly it is true of very big IWT projects regarding present knowledge of environmental assessment. One of the approaches to decrease uncertainty may be the dividing of a complex project into parts.

A case study of environmental issues of big IWT projects has been done by the author using one of the proposals for reallocation of water in the USSR. (The mouth of the Ob River, Ural Mountains, Pechora River, Severnaya Dvina River, Volga River, Central Asia and Don River.) All this long way was divided by reaches. Environmental problems concerning IWT were expressed in the form of trees of consequences, or networks. The main problems have been discussed for each reach (Arctic Sea problem, change of regime in rivers, change of adjacent territories, impoundments and related effects, improvement of hydrologic regime of the Azov Sea, development of irrigation and related problems, etc.). The approach is regarded as being useful both for the first steps in the project's assessment and for better management of scientific studies for environmental forecast of IWT projects.

CONCLUSIONS AND RECOMMENDATIONS

The Task Force agreed on several conclusions. These are the following:

(1) Interregional water transfers are and will be one of the ways to increase water supply. However, they should not be regarded as the only means available to an end: rather it should be considered as one of several alternatives available to optimize water use. If, having analyzed

all these alternatives, IWT appears as a promising solution, it should be considered within the planning framework. The timing of an IWT project should be elaborated having in mind other alternatives of water supply.

(2) To assess a large IWT project it is not sufficient to apply conventional methods of an economic evaluation and much more broad, complex approach is required.

(3) The environmental and ecological costs of IWT could be many, and these should be carefully analyzed and evaluated. Adequate counter-measures must be taken to reduce such costs to a minimum. The least solved question within the IWT problem is a methodology to assess environmental costs of IWT's and to forecast their impacts on nature.

(4) Similarly, social costs of such schemes should also be evaluated.

(5) The feasibility of IWT varies from country to country and region to region. In other words, it is site-specific. Whereas it is unlikely that new IWT schemes could be developed in the United States and Canada because of economic, environmental and political reasons, at least within the next two decades, it seems that they are viable under certain situations in countries like the Soviet Union, India or Mexico.

The Task Force made the following recommendations:

(1) The papers prepared for the Task Force meeting should be published as soon as possible, since these provide an authoritative account of the present status of IWT in the world on an interdisciplinary basis. No such comparable work is currently available. It was agreed that Professor Genady Golubev and Dr. Asit K. Biswas will edit the proceedings, which would be published in both the English and Russian languages.

(2) IWT should be considered within the over-all context of other non-conventional means of water development like weather modification, iceberg towing, desalination, use of very large crude carriers (VLCC) to transport fresh waters, etc. An over-all state-of-the-art report, critically reviewing the present developments in such areas, is both necessary and desirable.

(3) Within the context of IIASA's present program on water demand modeling, IWT should be considered as one of several other alternatives, wherever desirable and feasible. Attempts should be made to develop general guide-lines for IWT and these then should be incorporated within a methodological context.

(4) IIASA can play a catalytic role in IWT, and the Institute can play a major role in terms of information exchange, on a global basis, in this field.

(5) It was suggested that another meeting be held in about 2 years' time. As far as there is no developed methodology to assess and forecast environmental implications of current and proposed IWT schemes, future meeting should consider this issue. Critical state-of-the-art reviews on the subject would be desirable.

If necessary, small *ad hoc* teams should be set up – comprising IIASA and external specialists – on specific sub-topics.