E/3066/Rev. 1

INTEGRATED RIVER BASIN DEVELOPMENT

UNITED NATIONS

Department of Economic and Social Affairs

INTEGRATED RIVER BASIN DEVELOPMENT

Report of a Panel of Experts

Revised Edition

UNITED NATIONS
New York, 1970

NOTE

Symbols of United Nations documents are composed of capital letters combined with figures. Mention of such a symbol indicates a reference to a United Nations document.

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country or territory or of its authorities or concerning the delimitation of its frontiers.

E/3066/Rev.1

UNITED NATIONS PUBLICATION

Sales number: E.70.II.A.4

Price: $U.S. 1.50
(or equivalent in other currencies)

LETTER OF TRANSMITTAL TO THE SECRETARY-GENERAL

We have the honour to present to you our report on *Integrated River Basin Development.*

In this report we describe the challenge that is presented by the orderly development of the rivers of the world, and the lines along which we believe the United Nations and its specialized agencies might suitably move in dealing with it. Our study of these problems is in accordance with resolution 599 (XXI) of the Economic and Social Council.

The report is the outcome of meetings held in New York in January and November 1957 and of work by individual members during the interim.

We could not have carried out this study without the participation of the Department of Economic and Social Affairs. We are also grateful to the representatives of the United Nations Educational, Scientific and Cultural Organization, the Food and Agriculture Organization, the World Meteorological Organization, and the World Health Organization for their assistance.

Many people who are actively engaged in river basin development gave us valuable help. It is impractical to name all of them, but we would like especially to note the following, who took some direct part in our sessions: Mr. Gordon Clapp of Development and Resources Corporation; Mr. Pierre Danel of the Société grenobloise d'études et d'applications hydrauliques; Mr. David Jenkins of the United States Department of the Interior; Mr. Joseph C. Swidler of Knoxville, Tennessee; and Mr. A. de Vajda of the Food and Agriculture Organization of the United Nations. Their experience and advice are gratefully acknowledged.

Respectfully yours,

New York, 23 November 1957

FOREWORD TO THE SECOND EDITION

The Economic and Social Council, in its resolution 599 (XXI) of 3 May 1956 on international co-operation with respect to water resource development, requested the Secretary-General

"to constitute a panel of world-renowned experts for reviewing, with the assistance of the United Nations Secretariat, the administrative, economic and social implications of integrated river basin development, and for advising on the proper action — including, if they deem it advisable, the convening of an international conference — to be taken in order to ensure a world-wide exchange of experience and data in related domains".

Accordingly, a Panel was convoked which consisted of the following experts: Mohsin Ali, consultant, Planning Board, Karachi, Pakistan; Jean Aubert, Inspecteur général des ponts et chaussées, Paris, France; Arthur E. Griffin, consultant to Sir Murdoch MacDonald and Partners, chartered civil engineers, London, England; Carlos Lleras Restrepo, attorney, Bogotá, Colombia; Egbert de Vries, Rector, Institute of Social Studies, The Hague, the Netherlands; Gilbert F. White, Department of Geography, University of Chicago, United States of America; and Vasily V. Zvonkov, Academy of Sciences, Moscow, Union of Soviet Socialist Republics.

The report,[1] which embodied the results of the work contributed jointly and individually by those experts as well as selected contributions from other specialists, represented the common views of the Panel, together with their unanimous recommendations.

Since its publication in 1958 the report has found wide circulation among policy-makers and planners in both developing and industrialized countries. The demand for it has necessitated a number of reprintings; however, because more than ten years have elapsed since it was first published it was felt that a new edition was appropriate.

The Secretary-General therefore requested the Chairman of the Panel of Experts, Professor Gilbert F. White of the University of Chicago, to review the report and, in consultation with United Nations agencies and other experts on the subject, to prepare a preface which would summarize the major technological and management developments in the field during the past ten years and to suggest as appropriate, changes and additions to the annexes attached to the report. Consequently, in addition to minor editorial changes and certain clarifying footnotes,[2] the following alterations have been made to the original version of the report: annex III now contains excerpts from a statement of the President of the United States of America's Water Resources Council on Policies, Standards and Procedures in the Formulation, Evaluation and Review of Plans for Use and Development of Water and Related Land Resources, which replace the excerpts from a project report of the United States Bureau of the Budget contained in the original annex III. The original annex IV, "Selected list of scientific and technical problems involved in integrated use of water resources", has been omitted from this edition. Instead, two new annexes have been added: annex IV on health implications of water-related parasitic diseases in water development schemes, and annex V on problems of reservoir development. The original annex V, "Saline and brackish water conversion" has been replaced by annex VI, which consists of a new text with the same title.

In order to reflect the work of various non-governmental organizations which have concerned themselves with the legal problems of the development of international water resources, and in view of the growing importance of international water resources for meeting increasing water demands, the Helsinki Rules on the Uses of the Waters of International Rivers, as adopted by the International Law Association at its fifty-second Conference in Helsinki in 1966 have been included in this edition as annex VII.

The United Nations is indebted to Professor Gilbert F. White for having reviewed the text of the report and for having prepared the preface to the present edition and for his suggestions concerning and his review of the changes in the annexes to the report.

[1] United Nations publication, Sales No.: 58.II.B.3.

[2] Footnotes added to this edition of the report are identified with an asterisk.

FOREWORD TO THE FIRST EDITION

In writing the present report and in preparing its recommendations, the Panel was guided not only by the terms of resolution 599 (XXI) of the Economic and Social Council, but also by the view that it should take into account the continuing concern of the Council to further more effective use of water resources in view of the increase in the world's population, its rapidly expanding industrialization and the need for improving living conditions.

In its meetings, the Panel attached special importance to acquiring thorough information on the work already done by the United Nations and its specialized agencies concerned with water resource utilization, control and development, as well as on the previous resolutions which have guided their actions and on the co-operation among the various interested bodies regarding their technical assistance activities.

Although the Council resolution speaks in general terms, requesting advice on proper action to be taken in order to ensure a world-wide exchange of experience and information, the Panel felt that it should give particular attention to conditions prevailing in those areas of the world which in common usage are called technically or industrially "less developed".

Throughout the report, the expression "less developed" is used in a sense which requires a few words of interpretation. From very early days, peoples in the arid zones of both hemispheres and in some tropical areas have built magnificent water projects — primarily but not exclusively for irrigation. To call them less developed is an anomaly, but in this century modern techniques and widened means of transferring knowledge and capital throughout the world have opened new possibilities even in areas where the art of using water resources was highly developed. Their realization, however, depends upon data, knowledge, diversified skills and capital, which often are not available or can be made available only through international co-operation. More vital even is the need to adjust existing social, economic and administrative structures to any system of integrated river basin development.

At the same time, Governments and nations, in the less developed areas more than anywhere else, have set their hopes on development of their natural resources for improving living conditions, and among their resources water ranks as one of the more important. It is with this goal particularly in mind that this report has been written.

The report is divided into five chapters of a general nature, to which five more specialized annexes are appended. The first chapter defines in broad terms the concept of integrated river basin development, and describes the evolution of techniques which have led to the feasibility of such development, and the challenge which confronts the world in this respect. The following chapter deals with the major steps to be taken once an integrated development programme is envisaged. Problems of an economic, administrative and social nature are then reviewed in more detail. The report proceeds to examine next the co-operation to be promoted among the countries concerned in the case of an international river basin. Finally, lines of action at national and international levels are suggested, both to governmental and non-governmental agencies, within the broad framework of United Nations policy.

PREFACE TO THE SECOND EDITION

by

GILBERT F. WHITE

During the decade that has passed since the publication in 1958 of the report of a Panel of Experts on *Integrated River Basin Development* [1] the pace of public investment in water management has accelerated and United Nations involvement in promoting both national and international action in river development has expanded widely. Even in the light of that mounting experience with studies, construction and operation of works on the world's rivers, much of the 1958 report still seems sound and timely. However, the march of science, the increasing demands for water and the growth of government commitment make it seem likely that if a new Panel were to be convened it would place different emphasis on some points and add others. The events of the decade suggest that several fresh aspects of water policy would be stressed, that certain recent advances in scientific research and training would be noted and that account would be taken of major changes in the activities of the national and international agencies involved in water management.

That most of the suggestions in the Panel's report seem appropriate ten years later testifies to the breadth of the earlier appraisal of river basin problems. The changing emphasis and activity reflect basic changes in the technical tools of water planning and in the views of the role of such work in advancing human welfare.

As with most national ventures in river basin development, there is relatively little critical appraisal of work accomplished in terms of the economic returns, engineering reliability or the effectiveness of administrative organization. Each regional economic commission of the United Nations seeks to keep informed of the efforts at water planning in its region, to assess the availability of basic data and to promote the exchange of experience among the member countries (1).[2] Beyond a few assessments of completed projects, descriptions of projects such as the Kitakami in the area of the Economic Commission for Asia and the Far East (2), and a series of evaluations by the International Bank for Reconstruction and Development of selected power and irrigation enterprises financed by the Bank (3), the emphasis is heavily on the planning of new ventures rather than on lessons from the past. For this reason much of the judgement offered by the Panel still can be compared only with the judgement of other experts: systematic examination of the actual results of earlier work on river development is largely lacking.

[1] United Nations publication, Sales No.: 58.II.B.3.

[2] The figures in parentheses refer to the numbered references at the end of this preface.

NEW PERSPECTIVES

One major shift in perspective of river basin planning has to do with the view of what constitutes integrated development. In many parts of the world attention continues to centre on single-purpose control of water for hydroelectric power, irrigation, navigation or domestic supply, but where multiple purposes are sought there is a tendency to broaden consideration of the means taken to reach those ends. Human factors loom larger than heretofore.

As the Panel noted, engineering measures are not likely to bring the desired improvements in level of living unless they are accompanied by secondary measures affecting other aspects of resource use. The essential storage and canal facilities of an irrigation project must be supplemented by alterations in credit, marketing, transport, fertilizer, seed supply and similar services if they are to bring genuine gains in farm production. An electric power generator and transmission line must be tied into adequate facilities for distributing power to the customers. The importance of the secondary measures is emphasized by the unhappy experience of completed projects which failed to provide expected benefits. In a larger sense, however, water control activities are seen as only one aspect of natural resource development, and it is recognized that there may be other, more effective ways of promoting economic growth and social welfare than by storing or conveying water (4).

When the enlarged perspective is adopted, the process of water planning changes. It becomes more important to relate basin plans to the national economic plans, as in the Lower Mekong where efforts are made to have regular consultation among the international planning group and the central planning agencies of the member countries (5). A scheme for waterway improvement is examined in comparison with other possible programmes to provide low-cost and effective transportation, as in the Soviet Union (6). A proposal for reducing water pollution by stream flow dilution is compared with possible measures for additional waste treatment, for diversion of the waste effluent or for oxygenating the stream, as in the Potomac Basin. A national programme for reducing flood losses, as in the United States of America (7) and in Japan, is designed to include, along with reservoir and embankment protection, measures to promote flood-proofing, emergency removal, land use planning, flood insurance and flood hazard information. Under this view of water planning as encompassing analysis of alternative means of reaching similar economic, social or political goals, greater weight is given than before to defining precisely what goals are held and to canvassing a wide range of water management and other development techniques. So far, the concrete examples of this approach are few, but the interest is wide and the necessity for giving it more attention is clear. Measures to prevent flood plain encroachment and heavy pollution loads from expanding also may be important in developing countries.

A second major shift in perspective is towards keener recognition of the full network of ecological impacts incurred by construction of water projects. These impacts include the effects of storage impoundments and water diversion on resettled human populations, terrestrial and aquatic ecosystems, stream sediment, ground-water supplies, disease vectors and water-borne diseases, as outlined in the earlier edition of the report (8). With the initiation of many huge reservoirs, particularly in tropical areas, the potentialities of those projects both to enhance and injure the life around them, quite aside from their primary purposes of power generation and flow regulation, have claimed the interest of a wide number of scientific disciplines.

Drawing upon the experience with reservoir construction in Europe, Asia and the Americas, a series of investigations is under way on the Kariba, Volta, Kainji and Sadd El Aali (High Aswan) projects to find the probable consequences of those new man-made lakes and to explore methods of managing them so as to increase social returns and minimize their social costs. Ways of enlarging fish production, cultivating the seasonally flooded reservoir margins, preventing the spread of schistosomiasis, and curbing the social dislocations from population resettlement are among the aims of the investigations carried out by the Food and Agriculture Organization of the United Nations and the World Health Organization under financing through the United Nations Development Programme. The problems of maintaining public health in these conditions are outlined in a report presented in annex IV by the World Health Organization and the Food and Agriculture Organization of the United Nations. Problems of life in the lakes and on adjoining lands are examined in the selections from the report by the Food and Agriculture Organization in annex V.

It seems increasingly clear that many of these problems could be minimized by more careful study while the projects are being planned, and this suggests the need for a kind of early warning system which would alert the competent agencies to the possible hazards before construction gets under way. Such warning may not in itself suffice to prevent later difficulties, for the press of time and shortage of funds may lead to neglect of desirable supplementary investigations even when they have been prescribed in advance. Thus, the monumental preliminary studies for the Volta River project identified questions of health, fisheries and resettlement which were given inadequate attention during the construction phase because political negotiations to finance the project took several years and the Government then became preoccupied with the urgency of building power generation and aluminium-smelting facilities (9).

The past decade has also seen a pronounced change in public concern for reducing the growing pollution of streams from the wastes of city, farm and factory (10). As pollution loads increase through rising population, new agricultural technologies and complexity of industrial processes, and as the standards of public health and of recreational and aesthetic uses of water are raised in industrial countries, the demands on water management schemes to take account of opportunities to eliminate, dilute or treat effluents become more exacting. These demands show themselves in enlarged attention to pollution abatement in basin development schemes, and in strengthened national programmes to cope with pollution problems. In Europe, waste management is strongly linked with plans for industrial and urban expansion. In North America, it is closely related as well to the restoration or maintenance of a natural habitat for recreation and aesthetic enjoyment. In developing countries, such considerations may appear less urgent by comparison with economic growth, but they are commanding increasing attention.

Where water management is not restricted to single-purpose projects, the tendency continues to be to seek to deal with river basins as a whole (11). Often, this is honoured more in theory than in practice. However, there are concurrent tendencies to investigate river development within the framework of the interests of major metropolitan and industrial areas or within areas having common ground-water resources. Improved methods of prospecting for ground water, pumping it and artificially recharging it have enlarged the opportunity to plan for ground and surface supplies jointly. Thus, unified treatment of the Khabour Basin in Syria requires management of both.

The Dubrovnik resolution of the International Law Association of 1956 was revised in 1966 at Helsinki to restate the general principles that were then regarded by the Association as deserving recognition by nations entering into action on international streams (12). The Helsinki Rules are reproduced as annex VII to this report. Among other changes from the earlier version, they recommend the use of the term "international drainage basin" in place of "international river", and, in the spirit af the Panel's report, define the basin as including the whole system of waters — surface and underground — flowing into a common terminus.

Scientific research, assistance and training

To an increasing degree the international scientific community is mobilizing to probe and to train personnel to assess the basic and global problems of water behaviour. The most comprehensive of the efforts to enlarge fundamental knowledge about water on the earth is the International Hydrological Decade launched in 1965 under the auspices of the United Nations Educational, Scientific and Cultural Organization (UNESCO) with the participation of other United Nations agencies and the International Council of Scientific Unions. Covering the whole gamut of questions from precipitation, evapotranspiration, ground-water distribution and chemical quality to watershed relationships and world water balance, the International Hydrological Decade is making available scattered data and research findings that will facilitate the study of individual river basins and the identification of regional or world trends in quantity and quality of the basic resource. Its publications vastly extend the range of scientific problems listed by the Panel in annex IV of its report, and that annex has been omitted from the present edition. Individual nations gain from the Decade in the stimulation it gives to the improvement of data collection and research, and in the information they are able to draw from other areas.

The United Nations specialized agencies extend their activities to foster international collaboration in several of the fields essential to sound water development. The World Meteorological Organization is involved in hydrometeorology and networks for surface hydrology (13). The Food and Agriculture Organization of the United Nations promotes co-operation in studies of aquatic biology, watershed influences and, in co-operation with UNESCO and the World Meteorological Organization, agro-climatology (14). The United Nations Educational, Scientific and Cultural Organization sponsors collaboration in basic investigation of geology, geochemistry, landforms, pedology and ecology. It has experimented with the design and conduct of integrated surveys for small areas, and with the stimulation of research stations relating to broad problems of arid and humid environments. The World Health Organization gives detailed support to problems of epidemiology and control of water-related disease. The United Nations takes special responsibility for studies of ground water and of the costs and value of water in different uses (15). The World Health Organization has launched a spearhead programme to improve community water supplies (16). Two of the surveys under the Secretary-General's programme on the development of natural resources deal with the potential for development of international rivers, and with the needs and resources in potentially water-short developing countries (17).

The United Nations and all agencies with responsibilities in water resources development enter into training programmes to enhance the quality of technical personnel for water management. It is in the middle levels of the data collection and study agencies of developing countries that the shortages are most acute, and bilateral aid has been directed at remedying some of them.

The net effect of extensions of specialized services is to make available to interested nations, or groups of nations having a river basin in common, the results of data collection and research from other areas, technical assistance in designing their own activities and aid in training personnel to make basic measurements, analyse the data, and join in research on unsolved problems. Thus, both data and professional skill are more widely shared than was the case a decade ago.

Techniques

Among the several advances in techniques for handling river development perhaps none is more significant than the refinement of methods for appraising the social consequences of development. Economic analysis provides somewhat more rigorous ways than formerly were available to examine prospective flows of gains and losses, and to compare them for suitable time periods and discount rates (18). A new example of national evaluation criteria is given in annex III. While much of the sophisticated analysis is aimed at tests of contributions which water projects would make to national economic efficiency, it permits helpful calculations to be made in several other directions (19). By estimating more accurately the benefits and costs of a given scheme in efficiency terms, public bodies are enabled to count the cost of adopting other schemes which may be less attractive in economic returns but more attractive from the standpoint of satisfying particular groups within the society, as when a project is located where it has greatest political support rather than greatest return. By quantifying the future gains and losses from relatively intangible uses, such as recreation or wildlife conservation, improved economic analysis may give a rough measure of their significance.

Such economic analysis may not be heeded by the government authorities, who may place political aims above economic efficiency. Even where it is taken seriously as a basis for judging the wisdom of heavy public investment, as in the case of the Zuider Zee scheme in the Netherlands, it may lead to diverse policies for financing and reimbursement; it may suggest placing the repayment burden on readily identified beneficiaries; or it may show that the gains are so widely shared as to warrant charging the costs to general tax revenues.

Whereas ten years ago the process of comparing the tentative estimates of probable economic effects of various alternative schemes for management of a river basin was highly cumbersome and time consuming, computer capacity and simulation models make it possible to examine thousand of schemes that differ in location, type and rules for operating the proposed structures. Such comparison of a huge number of proposals for one river basin can only be as precise as the basic data, and the assumptions as to value and social aims; but, rough as it is, it can encourage sound assessment of the perceived possibilities, and aid in selecting individual projects for detailed examination.

In addition to improvements in techniques for mass earth moving and for long-distance transmission of electric energy, several advances in technology over the past decade have altered the prevailing ideas as to the practices that can be applied in basin development. One advance is the perfection of waste-water treatment processes to the point where the effluent from an urban sewage disposal plant can be returned in a quality suitable for human consumption. By these means the technical possibilities of preventing downstream pollution as well as of re-using water in areas where natural supplies are meagre are increased immensely.

A second advance is in the methods of pumping and distributing water for overhead irrigation, a technique that enables many individual farmers to practise supplementary irrigation without depending upon heavy capital investment in common storage and canal facilities and that reduces the cost of land preparation.

Desalting of brackish water is the subject of elaborate research and development in a number of countries: in recent years more efficient and cheaper devices have been developed, but, even when the desalting process is combined with use of waste heat from large nuclear reactor power-generating stations, the unit costs of producing water are barely within the price range of supplies for municipalities and thus are far above current prices for delivered irrigation water (20). The earlier estimates are brought up to date in annex VI.

Sufficient improvements have been made in weather modification so that in certain favourable sites with orographic precipitation, annual rainfall may be augmented as much as 15 per cent by cloud seeding (21). This is not generally practicable, however, and the social complications are formidable.

Numerous other technical advances extend man's capacity to deal with water. Automated gauges, water quality monitoring and flow forecasting centres enhance hydrologic operations. New means are available to reduce water losses in agricultural, industrial and domestic uses.

Quite aside from the expansion of scientific assistance by the specialized agencies noted above, the organizations capable of dealing with river basin planning, construction and operation have increased notably, and particularly at the international level.

At the national level, both old and young countries tend to add to the numbers of agencies responsible in some fashion for water management, without moving to the device of comprehensive regional authorities or to national organizations encompassing all water-related activities. Valley authorities where they are tried, do not spread to more than one for a country. Under its new legislation, the United Kingdom of Great Britain and Northern Ireland provides for a national board treating with individual drainage basins as units. In the Federal Republic of Germany the emphasis shifts to maintenance of water quality, and the areas of study are those having common problems of industrial development. Similar changes are occurring in other western European countries. In the United States of America, a new water pollution control agency has been established and a Water Resources Council set up to co-ordinate the efforts of the special-purpose agencies. The Council encourages the joint undertaking of broad regional water studies and the organization of regional commissions having state and federal representation.

Among the younger countries, administrative organization continues to be largely for stated functions of power, irrigation, navigation and water supply. In a few cases, such as the Dez Valley of Iran and the Comisión Coordinadora de los Proyectos Multiples para la Gran Lima in Peru, a single agency has been given major responsibility, but the prevailing pattern is one of basin study under a national ministry which handles some but not all of the water-related functions. United Nations assistance is given to countries, such as Afghanistan, seeking unified water policy and administration. Some of the reasons for the persistent emphasis upon single-purpose administration in many areas were suggested by the Panel and still seem valid.

At the international level, an impressive number of new organizations now operate to support river basin development. Beginning with the establishment of the Committee for Co-ordination of Studies of the Lower Mekong in 1957, a series of basin-wide efforts has taken shape under United Nations auspices. The Lower Mekong Committee acts under authority of a treaty among the riverine nations of Cambodia, Laos, Thailand and the Republic of Viet-Nam, with staff provided initially by the Economic Commission for Asia and the Far East, and with support for its studies and recent construction coming from outside donor nations as well as from the United Nations Development Programme. Similarly, co-operative investigations are under way in the Senegal Basin and the Chad Basin. In each case, basic support is provided through projects financed by the Special Fund component of the United Nations Development Programme and executed through the United Nations, the Food and Agriculture Organization and other specialized agencies. Special studies have been undertaken by the United Nations in the Logone and Mono Basins of West Africa.

A joint hydro-meteorological investigation by the World Meteorological Organization in the drainage area of the Nile above the Sudan is collecting data that will be essential to any later, more detailed planning for that part of the basin. Other hydrological work is in progress under the United Nations Educational, Scientific and Cultural Organization in the Upper Paraguay Basin, and a larger study is taking shape in the Plata Basin. The Economic Commission for Europe has established a body to deal with regional water resources and pollution control problems. All of these have in common the assembly of basic facts and understandings that will assist in later development decisions.

During the same period the international agreements affecting river development have increased in several critical areas. The Rhine Treaty of 1963 has added regulation of water pollution among five nations to the control of navigation on the waters of that basin. Treaties, chiefly relating to pollution abatement, are in effect for the Drava, Lake Constance, Lake Geneva and Moselle drainage areas. Canada and the United States of America operate in accordance with a new joint programme of development for the Columbia Basin. The grounds for co-operation in navigation and transport were established in the Niger Basin in 1964 with the assistance of the United Nations.

The Indus waters treaty brought a legal and engineering solution to a vexing problem created by the partition of the subcontinent. Yet, while it divides the waters of the Indus Basin to the satisfaction of India and Pakistan, it avoids integrated construction and operation.

In these international ventures, in addition to the regional economic commissions referred to above, two United Nations financing agencies play dominant roles. At the preliminary investigation and reconnaissance stages, the United Nations Development Programme (UNDP) is highly influential in funding and shaping the character of the survey work. Where completed projects run into serious problems of coping with their secondary impacts in the ecology and human organization of adjacent areas, the UNDP provides essential assistance.

In implementing the construction and operation of major projects, the International Bank for Reconstruction and Development frequently assists through its studies of particular projects or of national economic development programmes, and through provision of loans for constructions. Whereas many projects are financed through government borrowing in the bond market or through bilateral loans and grants, the Bank affects the process of economic and financial evaluation in a powerful way by virtue of the standards it sets.

In general, national administrative capabilities for dealing with river problems are increasing, and the international machinery to facilitate both national and international basin studies is being strengthened. A co-ordinating committee of the United Nations organizations meets annually, and while the Department of Economic and Social Affairs provides the Secretariat for those meetings, there is as yet no special office with the full duties recommended by the Panel.

As indicate, the annexes to the report have been changed in this edition to reflect the new developments. The body of the report remains the same except for minor editorial changes.

REFERENCES

The writer wishes to acknowledge the help he has received from a number of experts within and outside the United Nations Secretariat who have shared with him their current appraisal of the 1958 report.

(1) See, for example, reports on *Major deficiencies in hydrologic data in Africa*, Geneva, WMO and Economic Commission for Africa, 1966, and on *Multiple-purpose river basin development*, Bangkok, ECAFE, 1955, 1956, 1957 and 1960.

(2) United Nations. *A case study of the comprehensive development of the Kitakami River Basin.* ECAFE flood control series. Sales No.: 62.II.F.7.

(3) John A. King, Jr. *Economic development projects and their appraisal: cases and principles from the experience of the World Bank.* Baltimore, Johns Hopkins Press, 1967.

(4) *Water and choice in the Colorado Basin: an example of alternatives in water management.* Washington, D.C., National Academy of Sciences, 1968.

(5) See the annual reports of the Committee for Co-ordination of Investigations of the Lower Mekong River. Bangkok.

(6) A. A. Mitaishvili. *Economic indices and advantages of inland water transport of the USSR, its place in the single transport system and conformity with plans and tasks of the national economy.* United Nations Symposium on Inland Water Transport. Leningrad, 1968.

(7) *A unified national program for managing flood losses.* Washington, D.C., 89th Congress, 2nd Session, House document No. 465, 1966.

(8) R. H. Lowe-McConnell (editor). *Man-made lakes.* New York, Academic Press, 1966.

(9) *The Volta River project: report of the Preparatory Commission.* London, HMSO, 1956.

(10) President's Science Advisory Committee. *Restoring the quality of our environment.* Washington, D.C., Government Printing Office, 1965. See also *Waste management and control*, Washington, D.C., National Academy of Sciences, 1966.

(11) Ludwik A. Teclaff. *The river basin in history and law.* The Hague, Nijhoff, 1967.

(12) International Law Association. Report of the fifty-second conference held at Helsinki, 1967, pp. 484-5. See also *Legal problems relating to the utilization and use of international rivers.* (A/5409, 15 April 1963).

(13) United Nations. *Hydrologic networks and methods.* Bangkok, WHO and ECAFE. Sales No.: 60.II.F.2.

(14) *An Agroclimatology survey of a semiarid area in Africa South of the Sahara: FAO/UNESCO/WMO interagency project.* Geneva, WMO, 1967.

(15) United Nations. *Large-scale ground-water development.* Sales No.: 60.II.B.3.

(16) Bernd H. Dieterich and John M. Henderson. *Urban water supply conditions and needs in seventy-five developing countries.* Geneva, WHO, 1963.

(17) *Development of natural resources: implementation of a five-year survey programme. Report of the Secretary-General.* (E/4302, 1967).

(18) Arthur Maass and others. *Design of water-resource systems.* Cambridge, Mass., Harvard University Press, 1962.

(19) United Nations. *Manual of standards and criteria for planning water resources projects.* ECAFE water resources series. Sales No.: 64.II.F.12.

(20) United Nations. *Water desalination in developing countries.* Sales No.: 64.II.B.5.

(21) Special Commission on Weather Modification. *Weather and climate modification.* Washington, D.C., National Science Foundation, 1966. See also a report of the same title by a committee of the United States National Academy of Sciences, 1966, and World Health Organization.

CONTENTS

ANNEXES

MAPS

EXPLANATORY NOTES

The following abbreviations have been used in the report:

ECAFE	Economic Commission for Asia and the Far East
FAO	Food and Agriculture Organization of the United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
WHO	World Health Organization
WMO	World Meteorological Organization
BTU	British Thermal Units
gpd	gallons per day
mgd	millions of gallons per day
ppm	parts per million

Reference to "gallons" indicates United States gallons, and to "dollars" United States dollars, unless otherwise indicated.

Chapter I

SCOPE AND PURPOSES OF RIVER BASIN DEVELOPMENT

THE CHALLENGE

Making optimum use of the water resources of continents is a task which long has engaged human effort and which in recent decades has often taken the form of integrated river basin development. The Panel interprets "integrated river basin development" as meaning the orderly marshalling of water resources of river basins of multiple purposes to promote human welfare. As new techniques for the use of water have evolved and as human needs have increased, the management of water for augmenting food and water supplies, for transport and for energy production has become more complex and more urgent. Opportunities for promoting further fruitful economic and social growth in the river basins of the world — both large and small — are great.

From the experience that has accumulated through development of numerous areas — the Damodar, Nile, Rhone, Tennessee and Volga, to name only a few — it is now possible to distinguish certain lessons that have been learned, and to outline in broad terms the character of work which seems essential to productive use of river basin development as a tool of social action. It is also possible to define the more troublesome problems of an economic, social and administrative character that will be involved in carrying out new river basin programmes.

The need for integrated river basin development arises from the relationship between the availability of water and its possible uses in the various sectors of a drainage area. It is now widely recognized that individual water projects — whether single or multipurpose — cannot as a rule be undertaken with optimum benefit for the people affected before there is at least the broad outlines of a plan for the entire drainage area. Integrated river basin development with the aim stated involves the co-ordinated and harmonious development of the various works in relation to all the reasonable possibilities of the basin. These may include irrigation and drainage, electric power production, navigation, flood control, watershed treatment, industrial and domestic uses of water, recreation and wildlife conservation.

Engineering characteristics of the various hydraulic structures to be established should be determined on the basis of a careful analysis of the agricultural, industrial and domestic needs and possibilities.

The construction and the subsequent operation of the engineering works involve economic and social problems. These problems bring with them a need for integration reaching beyond, and different in character from, the integration needed in the design of engineering systems. The success of a river basin development scheme will depend, in large measure, upon how effectively they are faced and solved. To these problems the Panel has necessarily given close attention.

In regions where economic development is already well advanced, a river basin may lose some of its cohesion as an economic entity because the boundaries of what may be considered an economic unit do not coincide with the physical limits of the basin area. The situation is often different in less developed areas where, because of the very lack of economic development, water projects may have a more dominating influence. When the works are extended to the physical boundaries of a river basin, there will be a tendency for these boundaries to coincide with those of an economic unit.

When part of the benefits from a development — such as part of the electric power or even part of the water — are to be exported outside the basin, the study must be extended to include the effects of the proposed export. A special case may arise where the development is mainly intended to supply needs outside the basin area; consideration of such projects enters only incidentally into the framework of the present study.

Regional development cannot be considered as an end in itself but rather as a contribution to general progress carrying the approval of the government of the entire country. Sometimes, it is necessary to make a choice between several basins or to establish an order of priority imposed by the need to take one step at a time. In the case of large basins it may also be desirable to choose a subbasin or a division of a subbasin as a development unit.

It is evident that the influence of any river basin development on the rest of the economy is likely to be considerable. Moreover, the investment needs of any development scheme are closely linked to the needs of the whole economy. The Panel is well aware of the problems of the relation of river development schemes to the economy as a whole but considers that they would lead beyond its terms of reference and its competence. Consequently, they are only touched upon in this report to the extent that they are directly relevant to problems of intergrated river basin development as it has been defined.

Early hydraulic works and some lessons of history

While evidence of development of water resources by human effort has been found in very early civilizations, notably in Asia and in the Mediterranean region, such development generally centred upon one immediate use, with other uses incidental. Often man has in a sense imitated nature by transporting water long distances to supplement local water supplies, just as rivers like the Amu Darya, Euphrates and Indus carry surplus water from high rainfall areas to arid lands. In many cases, a single purpose predominated. Thus, in some basins, benefits to agriculture stood out above any other use of the precious water. The whole of society was dependent upon irrigation. Irrigation techniques, including regulation of the flow of water in canals, were developed at a very early period to a remarkable degree.

Use of water for mechanical power by means of water-wheels to lift water for irrigation also dates from at least 3,000 years ago. At a later date, power was transmitted to mills of various kinds. With limited materials and techniques at hand, characteristically each unit was small, serving only local needs for water, flour or oil. In Iran, large groups of water-mills were incorporated in the headwaters of extensive irrigation systems. Water-mills were prominent in the economy of Europe during and after the Middle Ages and were instrumental in bringing on the early stages of industrial development.

Improvement of rivers for navigation began in China at an ancient period and apparently was one of the centripetal forces in the old Chinese empires. At a later date, the Romans improved many waterways and interconnected certain rivers in their lower reaches.

For thousand of years dikes have been constructed in China as a method of preventing disastrous floods. Dikes were also used by the Romans — in the Po valley, for instance. In France, in the Lowlands and in the English fens, comprehensive systems of dikes, canals and sluices came into existence at an early date. Knowledge of these techniques gradually spread over wide areas. Roman civilization left aqueducts in several parts of the world as reminders of the basic importance of water in maintaining urban life.

The building of dams for the storage of water was well known in early times, but such reservoirs generally were limited in size and scope, and designed chiefly to store water for use in periods of drought. For example, the thousands of "tanks" built in Ceylon in ancient times were a link between irrigation and a variety of domestic and ritual uses of water.

With the beginning of the industrial revolution water needs for irrigation, water-power, navigation, flood control and water supply experienced a sharp increase. New techniques made it possible for engineers to undertake larger and more spectacular works, such as huge irrigation dams in India and canal systems in Europe. Need for industrial water began to appear, and for standards of water purity for human use. While the needs multiplied and new projects were undertaken, the prevailing pattern remained one of building single projects to serve single purposes. There were exceptions, of course. Some navigation works also reduced flood levels; many irrigation canals also supplied domestic water; water-wheels were operated on certain canals. But multiple purposes generally were not served by a single project. Multiple-purpose use of water in single, large projects on a wide scale is a relatively recent development stemming from technological innovations. These will be described in the next section.

The Panel makes these passing references to the history of water use because it believes they point to some lessons which have relevance to river basin development today.

First, some of the works of the ancient world were abandoned by reason of changes in human need and technology not anticipated when the projects were built. Thus, the Roman aqueduct at Nimes, France, fell into disrepair, after only about a century's use, on account of population shifts that reduced a prosperous town to a village. When Nimes again needed water it found a better supply nearer by.

Secondly, many of the ancient water systems were abandoned and stand as archaeological monuments today as a result of human failure to sustain a social system which would permit maintenance of the works. There is strong evidence that some early irrigation systems fell into ruin not basically because of silting or soil deterioration, but because economic distress, wars and political unrest prevented the proper operation and repair of upstream terraces, canals, ditches and dams. It is as true today as it was 3,000 years ago that the most expertly designed water projects will deteriorate rapidly unless skilfully maintained.

Thirdly, in a few cases systems were abandoned in the wake of catastrophes which were apparently beyond the technology of earlier times to cope with, and which caused heavy damage exceeding the power of the society to repair effectively. There is always a possibility that a rare flood or an earthquake may breach levees or dams or canals in such fashion that only a great, concerted effort can place them in operation again. Such an event may thus wipe out the product of centuries of slow construction.

Origin of the concept of multipurpose development

The idea of multipurpose development has a double origin: the first technical, the second non-technical. On the technical level the search for ways to make water serve two or three different purposes at the same time began at an early date. This is not surprising since, as will appear, the essential techniques involved are the same for the different purposes. For a long time, however, engineers tended to restrict projects to works designed to meet only limited purposes, a tendency which has not entirely disappeared.

In spite of this resistance, the task of apportioning among different purposes the total volume of waters available upstream of a dam has been undertaken on various occasions. Either a smaller expense was involved in construction of a single work instead of two or more separate ones, or the number of sites for economic construction of dams was limited.

New factors of engineering technique have led, since the beginning of this century, to increased adoption of these combined solutions. Particularly important has been the addition of one particular purpose: production of hydroelectric energy. This improvement has tended to lower costs of production of electricity below the prices which consumers had been accustomed to pay. The possibility of a "rent" from electricity induced dam constructors — irrespective of the main purpose each of them was trying to achieve — to add to the main aspects of their projects the greatest possible production of kilowatt-hours. Proceeds from electricity sales would substantially reduce the cost charged to the main purpose, and in favourable circumstances might offset this cost completely. This prospect provided the impetus for the plans of development of the Rhone River, where the total costs for navigation and flood control works were to be repaid by electricity sales. After more than twenty years of operation, this original aim does not seem unduly optimistic.

The non-technical origin of the concept is more complex. On the one hand there has been a growing awareness that natural resources in general, and water resources in particular, are limited. The United Nations Scientific Conference on the Conservation and Utilization of Resources, in 1949, emphasized this point to the participants from many countries present at the discussions.

On the other hand, the magnitude of the works undertaken during the first decades of this century, and the large amounts of capital they required, called them to the attention not only of engineers but of statesmen, financiers, geographers, economists and lawyers. It was in the discussions taking place within these continuously enlarging circles that progress was made in moving from the idea of a combination of various purposes to the idea of not neglecting *a priori* any one of them, even when it might appear to some people as secondary.

In the elaboration of this concept, as in most creations of the human mind, one can discover an element which escapes both logic and technique and which to a degree transcends both. The part played by this element, which might almost be termed mystical, has not been negligible.

The discussions that went on within the circles referred to led first to a more complete enumeration of the purposes, to include such new elements as fisheries, wildlife preservation, recreation and the like. Once formulated, each new purpose could be more or less identified with an entitlement to rights, and each new purpose found the support of vigorous advocates. In the absence of any established prior rights the advocates of various purposes met on an equal footing to present their claims. As in every case of competing claims, conflicts arose, and their existence evidenced the necessity for a higher authority which would have a conciliatority and arbitrating function.

A river is a living entity providing a source of wealth which ought to be shared equitably, as a legacy among its beneficiaries. When by development the potential riches of a river have been realized and apportioned among the people, it may be said that the initial river, wild and often destructive, has disappeared; but it lives again as a new domesticated river bringing only beneficent results.

Technical considerations

The purpose of river basin development, viewed in its hydraulic aspect, is to improve the distribution and utilization of surface water. This report is mainly devoted to the problems of carrying out development schemes of this kind under the best possible conditions. It is concerned more specifically with particular administrative, economic and social aspects of these problems, rather than with their technical aspects. In this section, however, mention must be made of some technical considerations governing the utilization of surface waters after a brief discussion of basic physical factors governing hydraulic development.

Basic physical factors

In the light of the above review, it is clear that man's efforts to control water usually take the form of changing its distribution in time and place. The water thus transferred may in some cases be withdrawn from points, in place or time, at which it was useless or even harmful. The flow of water from a river basin into the sea can thus be reduced without adverse effects. It has already been reduced to virtually nothing in the case of certain rivers at certain seasons of the year, when all the available water is used for irrigation. In the extreme case, it may be expected that some rivers will no longer discharge any water into the sea. This is already true, in some instances — for example in the case of the Jordan River, which flows into an inland sea. If an inland sea is incorporated in the basin of the river which flows into it, it may be said that, for the whole basin so defined, water replenishment and water loss in the river are in equilibrium.

Transfers of water may also be made from one river basin to another, either by artificial rain-making or by means of appropriate civil engineering works, supplemented, if necessary, by pumping installations. Theoretically, transfer of water from river basins with abundant supply to other basins deficient in water, and the irrigation of arid regions, could, if practised on an increasing scale, lead to a stage at which there would no longer be a single river discharging into the sea. The only way to increase the supply of fresh water then would be to extract salt from sea water.[1]

[1] Cf. annex VI, "Saline and brackish water conversion".

Though not all so far-reaching in its scope as this, work carried out by man is capable of altering climatic conditions and in particular the rainfall in certain areas of the globe. A decrease in the discharge of rivers could conceivably bring about a new equilibrium corresponding to a general drop in the level of the sea, but this influence will, for a long time, be more than offset by the slow melting of the ice deposits accumulated in the polar regions, owing to the present warming of the earth.

Dams and canals

The fundamental element in modifying the distribution of water is the dam, which stores water in its natural movement towards the sea. To be useful a dam generally must have a gate or other control devices which can regulate the flow according to a desired schedule. Over many centuries the dam and the gate have been the basically simple means of changing the distribution of water in time.

Distribution of water in space, in ancient periods as well as today, characteristically has been controlled by canals. A canal, to be effective, must have a channel with a slope capable of carrying water to the desired destination, and for moving it long distances the water must enter at a level notably higher than the place where it is to be used. Here, also, a dam generally is essential to lift the water to the required elevation. Human or animal power until recent times, and pumps, have been able to elevate water sufficiently to supply only small canals. The dam has been the common means of obtaining needed water levels.

The dam, the gate and the canal, then, have been the essential works. They have been supplemented by aqueducts and tunnels, which permit transport of water without following the natural terrain and which, while often small, have carried precious water for the maintenance of cities.

In most significant multipurpose use some kind of dam is involved. The construction of a storage dam of large capacity requires a favourable site and a substantial investment. It may also cost a considerable loss of water annually, for, in addition to seepage losses, evaporation losses from reservoirs, particularly in arid regions, may be a substantial part of the total water flow for the year.

Because of the importance of an effective link among different water uses, it is sometimes naively contended that the construction of one dam should make it possible to satisfy all of the needs in the area of the dam. In rebutting the idea, engineers have sometimes gone too far in the other direction and have failed to recognize all the possibilities and advantages of water management for multiple purposes. When the problem is examined further, it is found that there are many cases where multiple uses are satisfactorily met but also some cases of clear conflict in use.

A storage dam used both to produce hydro-electric power and to maintain navigation downstream may be operated so as to release water during the hours when the sales value of the kilowatt-hour is greatest and thus may cause distress to the navigator, at least in the immediate vicinity. Similarly, an apparent conflict may arise between efforts to maintain storage space behind dams in order to reduce great and unpredictable floods, and to store water for release in the dry season. The desire to keep the reservoir empty in readiness for a major flood may seem to work against accumulating the maximum storage in preparation for the dry period. These aims may be in opposition, but they may be reconciled by enlargement of the total reservoir capacity, or by limiting the amount of water stored during rainy seasons, thus permitting regulation seasonally or annually without increasing the uncertainty of results. In a general way it is necessary to reconcile two opposing purposes through a regulating schedule which recognizes the need in each case for some fraction of the reservoir capacity. Conflicts are primarly in respect of operation rather than construction.

Consumptive and non-consumptive uses

In considering broad possibilities for water use, it is important to distinguish between consumptive and non-consumptive uses, the former being those in which the water is wholly or largely used up. A large part of irrigation use is consumptive, but even here part of the water spread over the land may rejoin the stream as drainage. While the use of water in cities returns most of the water to the stream, it is in the form of sewage and waste, which may need to be treated before it can be used again.

The passage of water through generating turbines is a non-consumptive use in the sense that the physical quantity is undiminished. At the same time, the water is "used" in the sense that it is no longer available at the upstream level. Navigation also is non-consumptive when boats may circulate on stable water surfaces such as the ponds in a canalized system. If, on the other hand, navigation requires a minimum flow to maintain depths in a natural stream channel, the water is in effect used at the point of discharge.

Consumptive uses are exclusively for one purpose or another: water consumed by irrigation on one bank cannot be used for any purpose on the other bank. Consumption being a matter of degree, however, multiple use of a watercourse is sometimes possible and sometimes impossible in a particular case. Choices must occasionally be made between several uses or between conditions of use.

Developing part of a basin only

Reference has already been made to development of a subbasin or part of a river basin. This often happens in the case of large basins such as the Mississippi. Thus, the Tennessee, a tributary of the Ohio, was selected for intensive work. The Kama, a tributary of the Volga, also represents a highly developed subbasin. In any subbasin it is necessary to consider the possible effects of the proposed development upon the rest of the basin.

Development of storage facilities upstream will always affect the lower part of the river — in most cases advantageously, because such development will usually lead to a reduction of extremes, either of flood or of low-water stages. This is particularly clear in the case of tributaries. It must be kept in mind, however, that insufficient development of the upper portion may later make more difficult a desirable development of the lower part. As an example, it can be imagined what would have happened if, in construction of dams on the upper Tennessee, these had been of small capacity at sites which were suitable for dams of large capacity. Although the relationship is not so obvious, work done downstream may have an effect upstream. Thus, in developing the lower part of a river, it may be necessary to take care not to do anything that would later on make that part more difficult to render navigable, with consequent disadvantage for communication with parts upstream.

New technical possibilities

Even though the types of waterworks used today are little different from those used in antiquity, progress in technology now permits, and increasingly will permit, a growing expansion in water management. Progress to date has been chiefly in the field of engineering.

Improvements in earth-moving equipment, such as heavy excavators, dump trucks, dredges and transportation pipelines, have made possible the construction of great earth dams and canals in much less time than formerly even where tens of thousands of workers might have been employed. The science of soil mechanics permits the building of earth structures of increasingly greater heights without danger of failure. Today, the volume of earth moved in a major construction project far exceeds the masses moved only ten years ago. Likewise, methods of blasting and moving rock have advanced notably.

Most water-use structures are built in part of concrete and have benefited from successive improvements in making, delivering and reinforcing concrete. Use of steel has made it possible to bear heavier weights and, in particular, to construct large conduits; because of this the lead pipe of Roman times has been abandoned, and aqueducts are now used only in special situations. More spectacular is the use of concrete for huge gravity or arch type dams: dimensions of such dams are constantly increasing and their limits are more in the domain of finance than of engineering. Foundation materials which once would have been considered unsafe now can be strengthened by grouting.

New techniques for lock construction open up opportunities for navigation connexions with high lakes and reservoirs, perhaps combining locks with emergency flood spillways. Here, as in other respects, some of the traditional technical limits to water management are being extended.

Substitution of steel for wood has changed the basic dimensions of gates. Only one hundred years ago it would have been difficult to design a movable gate to close off a watercourse between two masonry abutments as much as ten metres apart, but today there is practically no limit. Large single gates can be closed against pressures of more than 100 metres of water, and special mechanisms can stop the flow of water in pipes up to 2,000 metres in height. This opens up new possibilities for water diversion.

It is less than 150 years since the first industrial turbine was mounted, and progress in hydraulics and metallurgy has since made possible steady improvement in energy generation. Pumps capable of lifting water to a considerable height have removed the need to rely solely upon gravity distribution systems for irrigation, while at the same time they make effective use of large blocks of low-price power.

The importance of the transformation of water-power into electric power has already been noted. The first dynamo was constructed eighty-five years ago, and the first transmission line carried electricity a bare ten kilometres sixty-five years ago. Although line losses are not negligible, and transmission facilities are expensive, it is now possible to transport electricity for distances in excess of 1,000 kilometres. Important new developments are not far distant. Progress in automation opens new fields, as in remote-control hydropower plants, water supply, irrigation and drainage systems. New hopes have arisen in the practical possibility of desalting sea or brackish water, in reducing evaporation from lakes and reservoirs, and even — in favourable circumstances — of controlling rainfall by proper seeding of clouds.

While the progress which has been realized in the past few decades has probably flowed largely from improvements in the use of metals, in a broader sense all of the sciences have contributed in various ways to the advancement of water management by the engineer. To cite only a few instances, better understanding of strengths of materials now permits more and more audacious designs; hydraulic models and electronic computers assure the safety of new devices; chemistry and biology offer deeper understanding of the factors affecting water quality.

From the point of view of technology, is is now possible to expand the programmes of water use to a level which could not have been foreseen a few decades ago. Man has the techniques to modify the geography of the world by storing and transporting water on a wide scale.

Opportunities for river basin development

More than three quarters of the land surface of the globe is susceptible to integrated river basin development such as has been described (see table 1). The remaining areas lack the combination of water and land that would make integrated development technically feasible. In the regions which are open to such projects, only a few streams have been regulated and used to a point approaching full development. Indeed, the limits are not so much the volume of flood waters that flows unused to the sea or the energy of rushing streams that remains unharnessed, as they are the economic, and in some cases, the political ones. In a number of basins where heavy additional investment seems warranted on economic grounds, the political barriers to such action are still formidable.

Physical aspects

Approximately a quarter of the land drainage area may be eliminated from consideration as being too cold or too dry for intensive development. Wherever permanent ice conditions prevail, the opportunities for economic development are so limited as to make river development relatively unimportant. The Union of Soviet Socialist Republics has made highly significant advances in using cold lands, but for the most part icy areas do not lend themselves to elaborate water utilization. This category includes Antarctica, Greenland and parts of the northern margins of Eurasia and North America.

Likewise, wherever the potential evapotranspiration consistently exceeds precipitation, the stream flows are so small and ephemeral that large-scale water storage is impracticable. This category includes expanses of desert in central Asia and the Middle East, central and western Australia, the Sahara of northern Africa, the Kalahari of southern Africa, and the western coast of South America. The sparse supplies in certain of the dry areas are so salty that there is little prospect for using them unless economic means of desalination are perfected. Some of the very cold areas also are dry deserts (see map 1).

TABLE 1. LAND AREAS IN RELATION TO RIVER BASIN DEVELOPMENT

Type of land area	*Estimated area (thousands of square kilometres)*
Total, world land area	144,485
Areas not suited to river basin development:[a]	
Antarctica and Greenland	13,671
Extremely arid lands	5,984
TOTAL	19,655
Areas possibly suited to river basin development[a]	124,830

[a] In the estimates of land possibly suited to river basin development, only land in ice-cap areas and in extremely dry deserts is excluded. There are, however, large basins lying wholly within the permafrost regions, in contrast to basins draining through such regions, which are unlikely to receive intensive development. There are also wide expanses of dry lands that will support only scattered development. If these are excluded, the total area susceptible to river basin development is more nearly 100 million to 110 million square kilometres.

Certain of these very cold or very dry areas are traversed by streams originating elsewhere, which carry water across their wastes from warmer and wetter drainages; such areas are susceptible to management. Thus, the Yenisey and the Mackenzie flow northward from lands where power generation and navigation are feasible, through lower reaches where frost and cold preclude significant agricultural use. Several of the great irrigation streams of the world — the Amu Darya, Colorado, Indus, Nile and Tigris-Euphrates — bring life-giving water to desert lands that otherwise would be barren. Other parts of the dry areas, as in the Negeb, may be susceptible to intensive development of the sparse water resources on a small scale.

Along the ocean coasts and the borders of certain dry interior drainages are numerous streams which flow from such such small areas that integrated development in the sense that it is used here is highly unlikely. These include the short streams that drain flat coastal areas along the south Atlantic coast of the United States of America and the eastern coast of South America, as well as the smaller streams in parts of the Mediterranean and Pacific basins. There are exceptions: where there are heavy water surpluses and relatively steep slopes, as along the Philippine and Japanese coasts, smaller streams may lend themselves to integrated development. There is also the possibility of managing a number of smaller basins as part of an integrated system. The Scottish Highlands hydroelectric power scheme is a case of such planning for a network of streams with power as the major benefit.

TABLE 2. AGGREGATE SIZE OF RIVER BASINS OF THE WORLD

Size of basin	*Number of basins*	*Estimated area (thousands of square kilometres)*
More than 1 million square kilometers[a]	19	45,719
100,000 to 1 million square kilometres	78	28,438
Less than 100,000 square kilometres[b]	(?)	50,673
TOTAL[c]	(?)	124,830

Sources: estimates of drainage basin areas are taken from various reports, including the following: M. I. Lvovich, *Elementary vodnogo rezhima rek zemnogo shara* (Moscow); H. P. Kosack, "Länge und Einzugsbereiche der grossen Ströme der Erde", *Geographisches Taschenbuch*, 1956–1957 (Wiesbaden). Where these were not sufficient or where there was major disagreement, the areas were estimated from equal-area maps in the Department of Geography, University of Chicago.

[a] Amur, Amazon, Congo, Ganges-Bramaputra, Lake Chad, Lena, Mackenzie, Mississippi, Niger, Nile, Ob, Orange, Orinoco, Plata, St. Lawrence, Volga, Yenisey, Yangtze-kiang, Zambezi.

[b] Including large arid and cold areas.

[c] Excluding very dry areas, Antarctica and Greenland.

Within the land areas that have sufficient heat and water for basin development, the major possibilities lie within a relatively few basins. If the drainage areas are classified according to their size it becomes apparent that about 60 per cent of the land area suitable for development is drained by eighty-five streams. (See table 2 and map 1.) The nineteen rivers with a drainage area of more than 1 million square kilometres together account for 40 per cent of the potential developed area. This is not to discount the value of lesser rivers such as the Flumendosa or the Ishikari, whose management is complex and of basic importance to the regions affected. However, in terms of area and of volume of water, the great opportunities arise in the few larger basins, some of them like the Amazon, the Mississippi and the Ob, so large that for certain planning purposes their subbasins can be developed with a large degree of independence.

Economic aspects

With given physical characteristics, it is the economic and social conditions which determine whether and to what extent a river basin can be developed. Its development will depend, that is to say, upon such vital considerations as the potential market for the crops or the power produced, taking into account the unit costs of irrigated land and power; the amount of in-

TABLE 3. RIVER BASINS OF FROM 100,000 TO 1,000,000 SQUARE KILOMETRES

Stream	*Approximate area*	*Stream*	*Approximate area*
Albany	600,000[a]	Narmada (Narbada)	400,000[a]
Amu Darya	465,000	Negro	150,000
Awash	400,000	Nelson-Saskatchewan	960,400
Cauvery	130,000[a]	Neva	281,925
Chao Phraya, Mae-nam	160,080	Oder	118,600
Churchill (Missinipi)	400,000[a]	Ogowe	300,000
Colorado	590,000	Okovanggo	785,000
Columbia	772,000	Pechora	327,000
Cuanza	149,000	Pei-Ho (Hai)	210,120
Danube	817,000	Red	120,000
Dnepr (Dnieper)	503,000	Rhine	224,400
Don	422,000	Rhone	99,000
Elbe	145,800	Rio Grande	220,020
Essequibo	120,000	Rio Parnaiba	200,000[a]
Euphrates-Tigris	765,000	Rufiji	178,000
Fraser	221,700	Ruvuma	145,000
Gambia	182,000	Sabi	130,000
Godavari	350,300	Sacramento	153,000
Hamilton	119,600[a]	Salween	325,000
Hsi Chiang (Si Kiang)	601,600[b]	San Francisco	700,000
Huai	166,110	Senegal	441,000
Hwang Ho	980,000	Severnaya Dvina	411,000
Ili	300,000[a]	Syr Darya	454,000
Indus	960,000	Tapti	115,000[a]
Irrawaddy	431,000	Tocantins	980,000
Juba	196,000	Ural	219,900
Kistna	308,660	Vistula (Wisla; Weichsel)	198,500
Koksoak	130,000[a]	Volta	300,000[a]
Kunene (Cunene)	137,000	Yalu	100,000[a]
Kura	188,000	Yukon	855,000
Kuskokwim	230,000[a]	*Permafrost basins*	
Lake Rudolf	500,000	Anadyr	300,000[a]
Liao	170,000[a]	Dubawnt-Thelon	500,000[a]
Limpopo	440,000	Indigirka	396,000
Loire	120,500	Khatanga	400,000[a]
Magdalena	266,000	Kolyma	533,000
Mahanadi	132,000	Olenek	390,000
Maroni	100,000	Yana	271,550
Mekong	810,000		
Mobile	109,557	TOTAL, including permafrost basins, and basins of interior drainage	28,437,838
Murray-Darling	956,516		

Source: Compiled by J. R. Shaeffer, Department of Geography, University of Chicago.

[a] Estimated by J. R. Shaeffer.

[b] Including extensive delta area.

vestment involved and the competing claims upon available investment funds; and the availability of people and organizations to plan, carry out and subsequently exploit and maintain the necessary works.

Only a few small streams in the world can be considered fully developed in terms of making full use of falling water or fully regulating the flow regimen to meet human needs. The Tennessee perhaps comes as close to full regulation of flow as any large sub-basin and yet it still has a major flood problem at one city and has not been regulated in a number of tributary drainages. Among the smaller sub-basins, the Ruhr has been more intensively managed than any other European stream, but notwithstanding its re-use of water several times for industrial purposes it still is amenable to further development. Probably the lesser drainages in arid regions of water shortage, such as the Salt River in Arizona, for example, where the available flow is largely utilized for irrigation and power, are the ones which may be considered most fully developed in a physical sense.

The decision to make the investment and undertake the work necessary to realize plans for a river basin development will of course be reached on the basis of an appraisal of the expected benefits in relation to the outlays. Such an appraisal involves a considerable element of judgement, not only because, as in all investments, the benefit will be made manifest in a future which cannot be known with certainty, but also because of the complexity of interrelationships and the lack of much of the statistical data needed to put quantitative values on certain of the interrelated factors.

It is of great importance that the tools and methods of economic analysis for this purpose be refined and improved so as to provide as many quantitative tests as possible of the judgements on which decisions to invest in a plan must finally be made. To this end the study and analysis of experience already acquired in a wide variety of conditions should yield useful results in making it possible to assess more rapidly and with greater certainty, in economic and social terms, the opportunities for integrated river basin development.

The physical as well as the economic and social conditions that affect the costs of any given river basin development vary greatly in different situations. There is no doubt, however, that integrated development of a river basin of any considerable size involves large-scale investment costs.

Political issues

While a high proportion of the world's great basins are international (map 2), only a few of these are now undergoing major development programmes. This is not accidental. International streams offer special problems, discussed further in chapter IV, which may delay both the planning and the construction of regulation works. For the present, international boundaries crossing river basins are in many areas obstacles rather than aids to river development. Even within a country there also may be political barriers. Disputes over jurisdiction and ownership such as those over rights of bordering states to the waters of the Delaware River, may hold up river plans for years or decades.[2] Even where there are no such disputes, lack of suitable agencies to draw up plans and carry out the needed works in co-operation with citizen groups may effectively limit new programmes.

So long as the present rate of world population increase continues there will be heavy pressure in many regions for the expansion of cultivated acreage through drainage and irrigation. It also seems probable that even with anticipated expansion of atomic energy production there will be need for large investment in hydroelectric power installations to meet growing energy consumption. Rapid industrialization will place greater demands upon water supply and threaten streams with a greater volume of waste. Only drastic changes in production technology or in population growth may change this prospect for increasing concern with water resources.

To fail to take steps now to deal effectively with these needs would seem not cautious but reckless. We know that river development programmes take a long time to plan and carry out. Once completed they endure for decades or centuries. Delay in improving the basic methods of study threatens the soundness of projects which may be undertaken in later years, and would be false economy. If it is assumed that need for irrigated land and hydroelectric power will continue in the future, that capital investment may be enlarged, and that new administrative means may be perfected to deal with the planning and operation of river programmes, it appears that the rate of expenditure may increase and that some of the great international streams may become, instead of lines of irritation, unifying networks of co-operative effort.

* * *

Account being taken, on the one hand, of the physical possibilities throughout the world for integrated river basin development, and on the other hand of the increasing pressure upon the world's natural resources, the Panel is convinced that in the next few decades many such developments will become economically attractive. In the light of what is known of the volume of investment which has gone into some of the more important river basin development schemes in recent years, and assuming that only the more economically promising areas are developed, the Panel ventures the suggestion that, in terms of present prices, the equivalent of several hundred thousands of millions of dollars will go into such developments in the next forty to fifty years. While this would represent an appreciable increase in the world's stock of capital assets, it would seem to imply neither a rate of investment disproportionate to that required for social overhead in other fields nor an improbably great increase in the world average rate of saving.

[2] A Delaware River Basin Compact was concluded in 1961 between the co-basin states of Delaware, New Jersey and New York and the Commonwealth of Pennsylvania and the United States of America providing for the establishment of the Delaware River Basin Commission to ensure co-ordinated and integrated development and use of water resources for multiple purposes including water supply, pollution control, flood protection, watershed management, recreation, hydroelectric power and other water withdrawals and diversions within the entire Delaware Basin.

Chapter II

MAJOR ASPECTS OF INTEGRATED RIVER BASIN DEVELOPMENT

Each plan for developing a river basin must of course be tailored to the physical environment and the social and economic needs of the area it is intended to serve. It is possible, however, to outline a generally applicable procedure for the preparation of such plans, as a means of suggesting the range and complexity of the problems with which Governments may be expected to deal. The Panel discusses the major aspects of river basin development in terms of procedure because it wishes to illustrate their importance as concretely as possible without proposing a precise but somewhat arbitrary set of steps to be taken.

In general, the procedure here outlined should make it easier to set up a national programme for integrated basin development, and to carry it out. Four broad stages are indicated, from the inception of the river basin development programme to its completion: (1) preliminary investigation and organization; (2) a general reconnaissance including formulation of a preliminary plan of development; (3) initial phase of implementation, including an actual start on small-scale projects and preparation of *avant-projets* [1] for the major structures; and (4) finally, construction and operation of the major structures. The special problems of the development of international rivers are discussed in chapter IV. The Panel is aware of the fact that some Governments will find short cuts essential to reaching decisions and taking action. In certain cases aspects not mentioned or not stressed here may prove of major importance under the special circumstances of a particular case.

PRELIMINARY INVESTIGATION AND ORGANIZATION

However the proposal for truly integrated development of a particular river basin may originate, the responsible authorities may wish to be briefed on the nature of the problems raised by such a programme before they are involved in any expenditure and before the population is led to entertain hopes and expectations that may not be realized. It is therefore common practice to instruct a small party of experienced survey specialists to make a preliminary investigation and report on the possibilities of water resource development and use, and also to outline the further inquiries that will be needed in order to draw up a definite development programme. The Composition of the investigating team will obviously depend upon the task it is given.

Data which are already available, no matter how scanty, should be put to use. Also, in almost every country there is an agency or agencies responsible for collecting data with regard to each river basin or for promoting or defending specific interests in the area. It is a wise policy to bring representatives from these agencies together and collect the data they may have before the broad lines of the report are decided upon. Similarly, inhabitants of the area have experience and knowledge about the behaviour of the river under the influence of climate and weather extremes, or about soils and other natural resources, which may be of value in the absence of more scientific observation and research. Sometimes useful information about extremes of rainfall and stream flow can be obtained through the recollections of the older inhabitants. Tree-ring measurement is also a helpful tool in filling gaps in weather data. Investigations should not be confined geographically to the specific river basin under review. Geological and climatological information, for example, may be inferred from data collected at stations at some distance from the river basin, provided adequate discretion is used.

A broad distinction can be made between basins whose areas are sparsely inhabited and whose underground and surface resources have not yet been exploited intensively and basins with long established and concentrated population. In the first category, there is much greater freedom in locating structures to be built and in deciding how the benefits shall be distributed. Physical conditions are determinative. In the second category, physical conditions are still important but it is also necessary to consider the existing economic pattern, the communities with their long-established political, cultural and economic centres, and the rights and interests of the local inhabitants. The problem here is one of harmony between the development and utilization of resources — existing and potential — and the needs and requirements of the population inhabiting the area.

Often, the idea that "something should be done" arises out of general public concern following natural disasters or catastrophes such as prolonged droughts or serious floods. It should be recognized that any attempt at river basin development means using general re-

[1] Preliminary economic and technical reports.

sources for a geographically restricted area. Often a "master idea" has been lying in the files or in the minds of a small circle of experts without any realistic possibility of its being executed until the need for improvement was felt in a dramatic way. The 1916 and 1953 floods had this effect in the Netherlands. Similarly, the Bengal famine in 1943 and the 1944 flood precipitated the Damodar Valley development in India. The need for developing the area may also be felt outside the river basin. Lack of power or fresh water in large cities or need for more agricultural production and an expansion of the available farming area, or need to settle people in relatively underpopulated areas within a national framework may stimulate the desire to accelerate development.

The preliminary investigation should lead to (*a*) a broad idea of what kind of basin development programme seems technically possible; (*b*) an outline of the main requirements and objectives of the project from the viewpoint of the people already living in, or eventually to be settled in, the area in question; and (*c*) a listing of the questions and problems which must be investigated before an over-all plan of development can be drawn up. It should also contain a provisional estimate of the expenditure involved in making this further investigation.

On the basis of the preliminary investigation, it should be possible for the Government concerned to reach a decision to proceed with a more detailed survey of existing conditions and potential development. The Panel believes that this first decision, which too often is qualified or vague, should be clear-cut and effective. In countries where a variety of developmental areas exist — and even among the smaller countries this is the rule — experience shows that this decision can best be made at the central executive level. In this way it is easier to ensure that money will be available for making the reconnaissance and that an organ of the Government — or organs — already existing or one to be established will have the necessary authority.

There are a number of possible administrative arrangements. (1) All major agencies dealing in a general way with aspects of development of a specific river basin may agree to co-operate by making staff and data available for the reconnaissance, the results being integrated (*a*) by one agency in consultation with others; or (*b*) by a working party with members drawn from various agencies. (2) Or, all data may be assembled in a co-ordinating agency created especially to prepare a programme of integrated development, which may be (*a*) set up for a specific area, or (*b*) set up for the country in general.

It should be noted that solution (1*a*) comes close to (2*b*), when a special planning department or an agency of the Government is entrusted with many of the tasks needed to draw up a programme. Rijkswaterstaat in the Netherlands and the Central Engineering Authority in Pakistan are examples. However, there is serious danger that if existing agencies are used the staff will have these new responsibilities superimposed on their existing work, and will devote to their new obligations only whatever time and energy are left from their regular responsibilities. Moreover, the working party seems to be too loose a body to stretch beyond the first stages of survey. In the Panel's view the most practical alternatives are a country-wide agency with full responsibility for the work, or a body entrusted with the over-all development of one specific area. Establishment of such a body for one specific area can hardly come about without special legislation, and sometimes there is a long struggle before it can function. Therefore, in countries with a great variety of river basin potentials — for example, Brazil, the Soviet Union and the United States of America — it seems that the establishment of specific corporations or authorities before the reconnaissance has been completed is a poor substitute at this stage for a well equipped central organ for general studies. Countries dominated by one or two important river basins — Egypt, Iraq and Thailand for instance — may, however, greatly benefit from early establishment of an integrated river basin agency. In these cases, there is more hope for united action by the whole nation. The responsible agency, however it may be constituted, is referred to in this report as the "river basin authority". If a country does not have enough experts to carry out the reconnaissance surveys, this difficulty can be overcome either by hiring foreign experts or by securing international technical assistance.

Reconnaissance of existing conditions

Bringing together the great variety of data which are necessary to determine whether a programme of development is technically and economically feasible and what it shall be is an undertaking of great magnitude. The agency responsible for carrying out these activities should be allowed to do so objectively and in a scientific manner, without pressures of politics or publicity. Wide publicity as to the local investigations at the reconnaissance stage has only too often done more harm than good. At a later stage such publicity is essential in order to secure co-operation and participation by all elements of the public.

The studies which are discussed below and which are required to reach a responsible decision are not exhaustive, nor does the order indicate priority in timing or importance. Conditions vary greatly from case to case, both in respect of objectives, and in natural conditions and human settlements in the area concerned, and it is these conditions which determine priority as to time and emphasis.[2]

The task of the reconnaissance group may conveniently bc characterized as follows: a careful evaluation of the human or socio-economic factors in the area, their present state, their trends, and of the corresponding needs and requirements; a detailed study of development potentials offered by water and other natural resources; and preparation of a preliminary general programme of development.

[2] Annex I contains suggestions for the organization of a basic survey.

Socio-economic factors

Integrated river development is a tool for social change, supporting economic growth and bettering living conditions not only materially but also culturally and spiritually. This is the ultimate justification for the enormous efforts a development requires at the national and international levels. Thus, one of the most important tasks of the reconnaissance group is to arrive at a determination of the main needs and requirements of the population living within the area of the basin. The survey should include, not necessarily in quantitative terms, analyses of the following factors:

The various deficiencies, and the dangers and damage incurred to health, to personal and industrial properties and to public works as a result of drought, floods, saline soil or lack of drainage;

The pattern of human settlement and distribution of human activities, together with present use of water and land, including the main centres of population, as well as traffic and transportation facilities;

The flow of goods within the area as well as its imports and exports, and the main trends of migration within it and to or from the outside. These movements of goods and population may throw much light on the need for improvement in the economic, social, educational and health domains, for example.

The study group will often suggest dividing the basin area into subregions for development purposes. A variety of circumstances may justify considering such a subdivision. The programme may be easier to develop, explain and carry out if it is divided into manageable pieces. The interests of the people upstream and downstream, in an urban centre and on the land, of farmers on the plain and herdsmen in the hills, will differ. The criteria for defining a subregion should be ecological rather than political. Once they have been defined, the concept can be used to elaborate on possibilities of separate or consecutive treatment.

Study of development potential of water and other natural resources

The reconnaissance group should acquire a knowledge of all major geophysical conditions which may affect the development of the river basin. This, however, presupposes a systematic gathering and analysis of voluminous data, work which in some circumstances may require a number of years. Therefore, it is expected that initially the group will centre its more detailed study on those features which may help in meeting the needs and requirements discussed in the preceding section, particularly the solution of deficiencies, dangers and damage due to water resource conditions. Meanwhile, surveys of a broader nature would be pursued, the result of which might open possibilities not previously recognized in the domain of hydroelectricity, for example, and in development of land and mineral resources. Geological surveys and topographic mapping should be carried on to the extent required for the particular programme.

One of the most important evaluations to make is the adequacy of water supply in view of requirements for the whole broad range of water uses (for livestock, households, industry, navigation, power, sanitation, irrigation). In determining the annual water cycle it is essential to know not only the usual or average conditions but also the recurrent or random variations in the relation between supply and demand which create medium-term and long-term disequilibria. Storage facilities may have to be included in the plan for the purpose of extending the period over which there is equilibrium between supply and need, Storage which changes the incidence of surplus supply may also reduce danger of floods.

The yearly cycle of addition and depletion of water supply is closely connected with seasonal variations in rainfall, temperature (evaporation) and plant absorption. The available water supplies must in turn be related to water needs, as a total and also seasonally. Some uses (for industry, households, sanitation and navigation) show little seasonal variation. Water requirements for power development also may show little seasonal variation, but the need for power to pump irrigation water introduces a seasonal factor.

On low-lying flat lands or in marshes, there may be a need for drainage pumps. In this case, data on short-period maxima — twenty-four to seventy-two hours — of rainfall and run-off are more important than any other data as a basis for maintaining a water balance. Actual conditions vary so much from river basin to river basin, and from place to place within a basin, that detailed water budget sheets have to be set up for each significant area or subarea. Without an appraisal of monthly or biweekly changes in the supply of, and demand for, water, not even a provisional estimate can be made of expected benefits.

The extent of water deficiencies or surpluses depends of course largely upon water and soil management. Drought and flood are frequently not predictable, nor can all those that are foreseeable be eliminated by technical and managerial means. However, with the benefit of adequate meteorological and topographical data, it should be possible to determine the inadequacies of the current situation and to assess the likelihood of realizing sizable improvements.

Preliminary over-all plan of development

It is on the basis of a comparison of needs and requirements, on the one hand, with the corresponding physical possibilities of water resource development, on the other, that the reconnaissance group will develop a preliminary over-all plan. The principal aim of this plan is to outline in general terms the possible alternative water projects and to ensure that, whatever priority and timing may be chosen for each individually, proper co-ordination or integration of water development schemes and of water uses will be maintained.

It may soon appear to the reconnaissance group that there are certain varied projects which might be carried out at specific locations. At this stage, it should not try to reach any conclusion as to the most desirable or most effective solution. It should only list and objectively describe the various development possibilities. The history of large water projects is studded with examples of long delays originating in too early a choice by the planning agency. For example, at least seven basically different plans were drawn up in the course of a century to empolder the Zuider Zee before one proved suitable, and the Hashiro Lagoon plan in Japan went through at least six variations.

When the draft is made public, independent planning bureaux and engineers will make their own analyses and bring up alternative recommendations. This is wholesome when the reconnaissance plans have not been frozen, but it could otherwise be frustrating to the agency or the Government responsible for persuading a parliament or executive to approve a plan of development. The most practical procedure appears to be a broad coverage of the feasible alternatives in the first analysis. This shows even to laymen that further study is necessary and leaves the reconnaissance group in a position to take full advantage of any suggestions which it receives.

The alternatives should be presented in such a way that at least a broad comparison can be made between them, as to their respective costs, the expected effect on the development of the human and natural resources of the basin, the degree to which water supply and requirements in general, by season and by subarea, are being brought into equilibrium, and last but not least, in what way the alternative solutions affect conflicts of interest between various uses of water, between subareas and between occupational groups.

Generally it will be found that real or alleged conflicts of interest, even of minor importance, have a profound influence on lawmakers. This is quite understandable and legitimate. A planning group can most effectively help people to understand the implications of various possible solutions by underlining the degree to which some conflicts of interest are inevitable or by indicating the cost of safeguarding all special interests. For example, a dam at one spot may flood only agricultural land while a few added metres of height or a slight difference in location may seal the fate of a village, a temple, or a church. In general, individual interests should yield to the collective social interest, subject to the payment of fair compensation in accordance with prevailing law. Local attitudes and values must, however, be taken into account in determining such details. The Panel believes it will be helpful, even at this early stage, to make clear the effect of the several possible schemes on local special interests and the cost and sacrifices which would be involved in avoiding such effects.

The aim of the reconnaissance group in shaping an over-all plan is to obtain prompt decisions as to needed steps of implementation. Unfortunately, but perhaps naturally, at this point many programmes suffer extended delays, with a resulting dissipation of the hopes and enthusiasm of the people of the area, not to mention the members of the reconnaissance group. In securing action looking towards succeeding steps, much may depend upon the way in which the planning team presents its findings to the responsible authorities.

In general, a practical description in laymen's terms of the prevailing situation will serve to open the readers' minds to consideration of the prospective programmes of action. The water control structures themselves will present the lesser likelihood of opposition. People will generally accept, even if they do not understand, the engineers' conception of a programme of engineering works if limited to the larger aspects, but to make clear what improved water control may do for farming, industry and transportation is another matter. Most difficult of all will be to portray the interlocking and indivisible primary and secondary effects of a comprehensive development programme. Most of the water control structures do not yield automatic results but rather open up opportunities for new initiative and investment. The general attitude is both to underestimate the far-reaching potential of benefits to be expected and the often huge secondary investments, as well as the need to educate, train and organize the inhabitants of the area, all of which are essential to realize the benefit potential.

The over-all programme will, in the beginning, have to be of a tentative character. Efforts from outside the designing body will no doubt be made to render the programme rigid and definite, in the interest of easier presentation to the public, or for budget convenience, or for other reasons. Flexibility of a tentative programme is to be desired over the rigidity of a definite proposal at this stage. None the less, an attempt should be made to delineate the whole programme in broad outline. Constructive imagination, aided by experience with similar developments, will have to come into play in visualizing the future shaping of things.

To some people, taking any action indicated in the outline would come too soon. Others will be disappointed that the authorization to proceed with the over-all plan entails further studies and does not provide immediate relief from danger or risk. From the national point of view, the urgency to alleviate inequities or to increase production may well lead Governments to immediate action. In order to satisfy these needs, the reconnaissance should specifically aim at delineating such immediate action as can be taken to alleviate or improve the situation without interfering with the whole plan. If it is found that such action is possible, it is highly advisable to include the request for authorization and appropriation for such early action in the reconnaissance report.

Initial implementation

When a decision is reached at the appropriate government level instructing the river basin authority to go ahead with the over-all plan, three parallel and simultaneous courses of action will normally be indicated. First, systematic studies must proceed in order to supplement the data gathered during the reconnaissance stage, thus permitting final plans to be drawn up. Secondly, the authority will wish to make an actual and prompt start on small projects susceptible of immediate execution and on *avant-projets* for the major water projects which have high priority. Finally, there is the important task, often overlooked, of deciding policies and measures in anticipation of the widespread changes in the economic and social domain which inevitably result from major improvements in water resource development and disposal. Following these three courses of action is by no means all that the authority will be doing at this stage. For one thing, since the stages are not consecutive, there will be much overlapping. In this stage, for example, there must be a beginning on the problem of financing, which is discussed at length in connexion with the next stage of development. But the activities listed are the major ones which are specifically characteristic of the first stage of implementation.

Supplementary studies

There are hardly any data mentioned in the discussion of the reconnaissance survey that do not need substantiation, often in a detailed and time-consuming way. It is assumed, for example, that throughout the period of reconnaissance reliable data on climate and stream flow have been assembled. Together with the general data, available from historic records in and around the area, there must be the basis for further detailed calculations. In sparsely settled and far-off sections of a country, the problem of evaluating short series of climatic data, especially rainfall, is most difficult. If the series is short and there is no safe way to extend the data, calculations must be based on an assumption of more adverse vagaries of the weather than might be called for on the basis of more adequate data. Inevitably, this will entail more expensive structures than might otherwise be necessary. The risk of underestimating floods and droughts, however, is generally too great to be taken without a substantial safety factor. In this connexion the Panel urgently advises Governments to intensify the study of relevant components of the weather in their own territories and to co-operate through the World Meteorological Organization in exchanging weather data and information on methodology of observation and evaluation. Soil surveys, and in many cases agricultural experiments with various crops, crop rotations, fertilizers and levels of water use also take considerable time and should be started at the earliest possible date.

Small-scale water projects of local interest susceptible of immediate execution

As noted earlier, the report of the reconnaissance group should specify any water projects and other projects of local interest, requiring relatively small outlays, that could be rapidly assigned and executed without waiting for the implementation of the major works included in the over-all plan.

As noted in the Secretary-General's report,[3] the execution of small-scale engineering projects, for example on tributaries of the main river,

> "may serve not only to improve the economic and social conditions of local communities but also to contribute to the general scheme. It would help to stabilize the water flow and allow a more widespread and systematic collection of the data needed to determine the practicability of various technical measures for the control, development and use of the water resources in the river basin as a whole".

Whereas the execution of large projects is often hampered by scarcity of finance, foreign exchange and technical and skilled manpower, small projects are less subject to such limitations. Their construction schedules can be made to accommodate availabilities of local labour, equipment and materials. Quick local returns in increased production will encourage local contributions of labour and indigenous materials by the prospective beneficiaries.

Local projects especially can stimulate development in those parts of the programme that need earliest completion. Among other things they should speed up improvement in control of erosion and local floods in the watershed. The sooner conditions in the watershed are improved, the longer will be the useful life of the main engineering works on the stream. Where erosion and silting are serious problems it may be essential to start local projects to keep the soil in place in order to justify the main engineering works.

River basin authorities, can make a significant contribution to programmes that involve many local projects by standardizing the design of basic elements of such items as micro-hydroelectric units and irrigation structures. By this means it will not only be possible to speed up construction but there should also be substantial savings in costs and reductions in maintenance and operating expenses, as well as a higher degree of structural safety and reliability.

Local projects, if properly controlled and planned, will also be conducive to a better utilization of the major facilities when they are completed. The full utilization of large newly developed supplies of irrigation water and power by the user normally requires a long period of time, and the educational effects of easily implemented local projects will represent a most welcome help to the administration of any river basin development project.

Some local projects may require substantial modification when physically incorporated into the over-all work. For example, a local project may draw its supplies of water or power from a temporary source which will later be replaced. Irrigation development furnishes probably the greatest number of examples of a switchover from temporary supplies to permanent supplies. This is because irrigation development, even involving only a limited acreage, takes a considerable time, and only a relatively limited water supply will be required to satisfy the needs of the first few years. In such cases it may be economically more favourable in the early years to obtain the necessary irrigation water from ground water by tube wells, by pumping from a

[3] See *Official Records of the Economic and Social Council, Twenty-first Session, Annexes*, agenda item 7, document E/2827, para. 71.

stream or by erection of temporary diversion or intake structures on small watercourses, even though in the final stage of the development the major storage dam will supply irrigation water to the entire area. The irrigation distribution system should, where possible, be built in such a way that the switchover from the temporary supply can be carried out without major changes in the irrigation system itself. In addition, drainage corridors should be demarcated at the outset.

There are limitations, however, to what can be done in the way of local water projects. Proposals for such projects should be scrutinized with the greatest care. Nothing may be more permanent than a "temporary" structure. If immediate relief is necessary engineers should try their utmost to devise means whereby the local project will fit into the over-all programme of development.

Avant-projets *for individual major water projects*

Determination of priorities for individual major water projects is sometimes made on hydrological grounds (river training should generally start in the lower reaches, watershed protection at the higher parts of the catchment), sometimes on economic grounds (the work that gives fastest relief from hazards or which gives greatest return, without being dependent upon completion of the whole scheme), sometimes on engineering grounds (paving the way for more difficult waterworks, or being easier to start because of closeness to existing road connexions). An *avant-projet* should include relevant engineering data, requirements for experts and for skilled and unskilled labour, for materials (indicating which are of local, domestic or foreign origin), and for equipment and machinery (domestic and imported), and the overall cost in domestic and foreign currencies. It also should specify the expected returns in various fields. Where possible, an *avant-projet* should of course, take into account future benefits from additional waterworks.

It will often pay to contract for the preparation of an *avant-projet* by a consulting engineering firm, provided the river basin authority has set the terms of reference adequately. In this way the river basin authority will at the same time relieve its own engineering staff of much tedious work and get the benefit of the perspective of a fresh look at the over-all job to be done.

Each of the major projects must be studied not only from its technical aspects but also in respect of its economic and financial consequences, including not only the revenue producing facilities (power and irrigation) but also the general overhead services (such as flood control and roads) and secondary features (such as recreation and wildlife). Failure to scrutinize carefully the implications of each of those projects may easily lead to an underestimation of costs or an overstatement of benefits.

Policies and socio-economic measures needed in anticipation of economic and social changes

Major improvements in the water economy will result in widespread changes in the economic and social conditions of an area. Much can be done to shape and channel those changes so as to effect improvement in agricultural and forestry practices, exploitation of fisheries and mining resources and development of industries.

A more productive land use pattern must be developed, based upon the results obtained in the soil surveys and agricultural experiments. Experience has shown the great difficulty in persuading farmers to change their agricultural practices and adopt improved tools, techniques, and farm management systems. Deeply embedded practices, based upon a history of recurrent droughts or floods, will change but slowly unless there is an effective educational programme. Pilot schemes and demonstration farms should be developed wherever feasible in order to show what new possibilities may arise once the waterworks come into operation. Failure to do so has cost nations large sums in forgone benefits from large projects. It has also led agricultural services to give wrong advice on future land use, which has in turn added to the problems of securing farmer acceptance of new and better ways of tilling farms.

In countries with private land ownership, land tenure conditions may require careful study and the development of new public policies. Who will own and who will dispose of the new lands to be developed and on what terms? How are new settlers to be selected and organized? What will be their obligations, and what facilities will be made available to them? What system of payments will be imposed upon people who benefit under the scheme? How will possible damages be assessed and paid for? Knowledge of the reconnaissance report will have aroused the interest and activity of land speculators. Appropriate legislation, possibly giving the right of expropriation at pre-development price levels, or imposing improvement taxes or capital gains taxes, will be needed. Therefore, a survey of real estate holdings and prevailing land values is necessary at an early stage.

Land tenure conditions and property rights on water vary from country to country, in accordance with needs and traditions, and it is neither necessary nor desirable that there should be uniformity on this score. There is one extreme, however, which the Panel views with concern, where vested private interests in water supply are protected by law to such a degree that the private owners of water rights, even though offered compensation, may obstruct the execution of a project. It seems obvious that no water development programme can be carried out for the general good under such circumstances, and where they exist a precondition for a successful water development programme is a revision of the law dealing with water rights.

Some occupations are bound to lose ground. For example, cultivation of lands formerly used for grazing will reduce pastoral opportunities. What new possibilities are to be opened up to groups which are adversely affected, and to the young whose labour becomes available? To what degree do educational and training facilities have to be reconsidered? To convert herdsmen to farmers, for example, involves a wide variety of measures. The availability of more electric energy and the improvement of transportation and communications will have widespread effects on all branches of economic activity in the area. Technological, economic and sociological surveys may be needed in order to plan adequately the site of new industries, new markets and even new villages and towns. In specific cases there will be other problems to be considered. This is the time to draft an outline of policies and measures to deal with these.

Increased economic activity in turn requires a wide variety of new services, both private and public. In some cases, as in a depressed or under-developed pocket in a generally highly developed country, much can be expected from the unorganized inflow of people, skills, capital and initiative from surrounding areas, but this is an exceptional situation. In the typical case such services will not be adequately provided without well directed information, technical guidance and assistance, and credit facilities. Among the services which must be provided, educational and health services rank high. Agricultural and vocational training for the new environment also becomes highly important. Very often new as well as old health hazards have to be met. Malaria, bilharzia and other diseases which are related to changes in the water economy of a region have in the past often seriously jeopardized developmental schemes.

Objections will be raised to various parts of the programme; they will have to be anticipated and measures to meet them must be thought out in advance. One of the most common and understandable objections is that a project seems to discriminate in favour of or against a limited group of citizens. Sometimes this trouble can be overcome by making a direct link between benefits and burdens accruing out of the programme; sometimes a measure may in principle be desirable for the whole country although it would at first be applied only in one area. In many cases, potential objections can be overcome by active citizen participation from within the area. A consideration of possible objections may suggest desirable modifications of the projects.

To be put into operation, the set of policies and measures thus outlined may sometimes require legislation or measures to be taken by authorities outside the specific river basin. Foresight makes it possible to ascertain that no unexpected obstacles will arise out of lack of co-ordination.

Finally, as more detailed data are analysed and further studies of the future development are being made, the over-all plan outlined by the reconnaissance survey group will need revision. Changes in the design or timing of one part of the programme may have an important impact on other parts, and new information may suggest engineering revisions or economic revaluations. It is important that programme revisions reflect the results of consultation with all parties concerned.

Particular care should be taken by the river basin authorities to maintain close contact with organizations responsible for general problems of economic and social development, agricultural and industrial development, education and health, and for fiscal and monetary policies. The need for such collaboration is obvious where parts of the programme, such as roads or schools, are to be carried out by the national organizations responsible for these sectors. In the case of a regional authority vested with large executive powers, the need for close and current contact with national organizations is no less necessary if conflicts and overlapping activities are to be avoided.

Construction and operation

When the *avant-projets* for the major water projects have been completed, a new phase begins, dominated by the need to secure decisions at the appropriate government level concerning the execution and financing of the plan and the final implementation of the various steps by the river basin authority and other organizations. A host of practical problems now arise, among which only the most important are discussed in the following paragraphs.

Governmental approval and decisions

Governmental institutions and procedures vary so much from country to country that it would be difficult to suggest the steps or procedures for securing required approval and decisions. Experienced administrators will have intimate knowledge of the workings of their own government institutions. However, there are a few points of such general importance as to warrant discussion here.

Broadly speaking, there are two ways of obtaining parliamentary approval where such approval is necessary. One is to request allocation of the first year's expenditure; the other is to submit the plan as a whole and request approval for the total expenditure. The first method involves smaller initial appropriations and may provoke relatively little opposition. Its weakness, however, is that each year's expenditure will have to be separately approved, and the project may fail of completion if the parliament should change its mind. The Panel believes it is desirable, wherever possible, to secure approval of the full programme at the outset, and recommends submission to the parliament of the whole programme, with all its financial and other implications, in order to secure not only approval by the parliament but also its endorsement by public opinion and the support of other government departments. Once a large project has been undertaken with the consent of a firm majority, the chances are better that the nation will bring it to completion even in times of scarcity of funds or in case other more spectacular projects are presented.

Under the governmental systems which prevail in a number of countries, the legislature approves only an over-all budget figure and leaves to executive authorities the formulation of programmes and selection of projects within the total amount. Under such circumstances river basin authorities, acting within the established framework of executive controls, will make final decisions on programmes and projects. In other countries an autonomous or semi-autonomous corporation is empowered to proceed with a river development programme and to finance the programme by borrowing, use of revenues from projects already in existence, or in other ways. In the latter case there may be substantial assurance of carrying the programme through to completion without need for parliamentary approval beyond that called for in creating the corporation.

Where construction is partly financed with funds from the International Bank for Reconstruction and Development, the loan agreement with the Bank customarily includes a requirement that the Government will provide sufficient funds to carry out the programme according to schedule and will, if necessary, make available such additional funds as are needed for expenditures and works which are not to be channelled through the borrowing agency. The required ratification of the loan agreement or guarantee, or both, by the parliament adds to the status of this undertaking. In actual experience, over the past ten years, this kind of solemn undertaking has greatly helped authorities in charge of river basin development to carry on the work.

The assurance of uninterrupted financial support is of great importance for a river basin development because of the indivisibility of a large long-term programme in a small geographical area, tying up a huge amount of investment resources over a long period. In case of interruption of the programme, the added interest cost would completely change the financial calculations upon which the development was predicated. Moreover, delays beget discouragement and lack of interest, and invite the collapse of the programme.

The changing role and status of the river basin authority

When the over-all programme has received full governmental approval, it may be necessary to change the functions and legal status of the basin authority. Until this point the authority has been mainly a programming body, collecting data and formulating plans; now, although it retains its former duties as regards work preparatory to carrying on further phases of the plan, the authority becomes an executive body. New types of decisions must be made, new activities undertaken, and new staff employed.

Unless execution of the programme has been delegated to central executive agencies, or parliament has itself made the decisions, the river basin authority will now have to decide on the timing of the various parts of the work, and determine the need for personnel, machinery, equipment and funds for a number of years ahead. It will also need to correlate the timing of accessory operations (by other government departments) and of private investment and activities. Whereas, in the planning stages, engineers, economists and sociologists were the most important and most numerous personnel, they must be supplemented by a construction staff, a purchasing organization, finance and accounting staff, lawyers and other administrative personnel.

The period of conversion from purely planning functions to one of broad executive responsibility is usually a good time to reconsider the organization of the authority. Even if a regional authority or corporation with wide powers has been set up previously, now is the time for a thorough reconsideration of its management, staff composition and powers to assure its capacity to carry on the new executive functions.

Engineering management

The river basin authority will have large engineering responsibilities and must of course equip itself to discharge them satisfactorily. Detailed engineering designs, generally made under the direct supervision of the executive staff, will have to be prepared as a basis for the project's execution. Even if important parts of the work are to be done by contractors, it is nevertheless the duty of the executive staff to prepare the detailed description and blueprints of these before calling for bids. In some countries it has proved helpful to employ an independent supervising engineer to check upon the quality as well as the amount of work performed, and to compare the cost with the estimates. In many cases, employing a supervising engineer with much international experience assures a country in an effective and relatively inexpensive way the benefit of the latest and best techniques. Needless to say, the independence of the supervising engineer towards the contractors should be absolute.

The execution of the major programme should be under as strong and unified a command as practicable in the administrative situation. In any event the planning function should be thoroughly unified. Nothing is more frustrating than divided leadership during the phase of implementation.

The early dispatch of orders for machinery, equipment, tools and materials is especially important in areas far from the centres of industrial production. Moreover, special attention should be paid to the adequacy of the spare parts reserve, and the way machinery and spare parts are stored and protected. Experience has shown that one of the most common bottlenecks in large-scale construction projects arises out of the inadequacy of arrangements for the supply, maintenance and storage of equipment and spare parts. In a number of cases technical assistance experts have been requested to assist in organizing maintenance services and supply stores.

Labour problems

It is necessary at an early stage to review the expected labour problems in detail and to frame a labour policy which is practical in the light of local conditions. In some cases difficulties in labour supply may either necessitate increased mechanization or changes in the timing of projects.

Shortage of labour of various categories — unskilled, semi-skilled and skilled — is a frequent problem in underdeveloped countries. Training courses held near the project site are helpful but of themselves do not always solve the problem. In some countries, moreover, experience has shown that most workers leave the project after receiving training in order to obtain better jobs in other parts of the country. The projects must be made sufficiently attractive to draw and hold the necessary workers. In some cases labour problems may be greatly lessened by setting up, at an early stage, an organized settlement near the site of the projects, enabling the workers to move in with their families. This, however, will be practical, in most cases, only if the programme also provides for the establishment of small towns or villages on a permanent basis.

Employment of a large number of workers and the creation of new payrolls may provoke a sudden rise in the purchasing power of the local population, and in its demand for goods, especially consumer goods. Local shortages of goods and rapid price increases are problems which must be faced.

Readaptation problems

As indicated earlier, almost every large water project disturbs the existing situation in such a way that some people or some groups will suffer from the change. The residents in a reservoir area are an obvious example. If a newly constructed dam floods agricultural land, not only should people be paid for the land, but if land is scarce and resettlement is difficult, they should also have first preference as settlers on new land to be developed. The opposition of special-interest groups may include an effort to postpone the execution of the programme. If an existing occupation is doomed to a decline in importance, special institutions for vocational training of young people for other jobs, and retraining of adults, may be necessary.

The best remedy against this eventuality, the Panel believes, is to taking careful cognizance of the human and social problems involved, and to make clear the costs and risks involved in a delay.

Utilization of new assets

The fate of most of the great water control projects of ancient times teaches a lesson which must not be ignored: adequate maintenance of a project is just as important as proper construction. Projects which are not well maintained not only deteriorate to a point where they lose their usefulness, but they can become an added burden on the State and a danger to the local population. There are many cases where water control structures have failed because of inadequate maintenance, causing large loss of life and property. The Panel recommends that river basin authorities consider their responsibility for water control structures as continuing until these are placed in trained, capable and responsible hands for maintenance and operation.

Preparations for future utilization of the new assets must be made at an early date. This is often a more difficult and a more extensive job than construction of the major projects themselves, and may involve many different tasks in a wide variety of fields. It begins with the use of the marketable products, such as water and power; this in turn will involve the organization of agriculture to absorb the water; and later it may involve the establishment of facilities for processing and marketing agricultural products, for training the settlers, and for supplying the necessary credit. Such problems will not be strangers to the river basin authority if, as mentioned earlier, they have been the subject of intensive study prior to adoption of the development programme. Solutions will have been incorporated in the programme.

The delegation, under conditions which safeguard the programme's objectives, of specific tasks to other suitable bodies wherever available, such as village and town councils, producers' organizations, industrial federations and co-operatives, is good practice and frequently essential. In general, the more tasks the authority has safely delegated, and the larger the group of supporting agencies and institutions, the easier it will be for the authority to accomplish its objectives. Unfortunately, in less developed countries effective local bodies are too few; consequently, many tasks may have to be handled by the authority itself, which it would delegate if it could. Consequently, the authority may have to organize and finance the economic and social transformation of the area required for utilization of the new assets. These myriad problems must be solved within a given time in order that the large investments in the programme will yield the expected return. Such a responsibility is a challenge to the wisdom and ability of even the ablest and best staffed of agencies.

Chapter III

SOME SPECIFIC PROBLEMS ENCOUNTERED IN RIVER BASIN DEVELOPMENT

In carrying out river basin programmes of the character described in chapter I, at least five economic, social and administrative problems persistently arise. Even where the basic data are adequate and there has been time for the necessary surveys, these questions may be expected to complicate national and international action. What are the true costs of the proposed work and the benefits therefrom? How best may it be financed? How should it be organized and administered? What role do citizens and citizen groups properly play? What is the place for small pojects, primarily local in effect?

Answers to these questions may differ from country to country but the questions are everywhere important. To recognize and study them carefully is a matter of urgent concern for two reasons. First, while there is a wide range of experience in dealing with these basic questions of economics and social organization, the results have not been thoughtfully assessed for the benefit of countries which are entering into new river basin development. The sooner the lessons of recent experiments can be shared and improvements devised, the greater is the likelihood of effective use of resources in future programmes.

Secondly, it is difficult to appraise and compare the desirability of particular river programmes as long as fundamental differences in aims and methods are not clear. Standards of economic justification and of financial feasibility vary according to national conditions. The Panel does not suggest that all countries should adopt identical standards. It does believe that countries should be aware of the differences in their approach and should have systematic ways of assessing the results.

Economic evaluation

Even though a plan for a river basin development is feasible from an engineering and physical point of view, it will not be put into effect unless it is judged to be economically feasible as well. The word "judged" is used advisedly in this connexion, since the means for arriving at a completely objective measurement of the economic benefits of the plan in relation to its estimated costs are lacking. Both the complexity of the interrelationships of the various component elements and the lack of essential statistics on many aspects make it inevitable that a judgement in some degree arbitrary will enter into the decision whether or not to carry out a plan, and in what fashion. It is essential that information relevant to establishing the economic viability of a scheme should be assembled as completely as possible, but it is evident that deficiencies of data will vary considerably in different situations. There is no simple rule by which to determine at what stage these deficiencies are too glaring to permit venturing large investments. Each situation must be treated on its own merits. Nevertheless, if all the factors which need to be taken into account are recognized and carefully considered, it will generally be possible to arrive at a reasonable and defensible decision whether or not to proceed beyond a preliminary stage.

An economic evaluation is different from a financial or commercial one. The financial evaluation, as that term is used here, is concerned with the ability of a project to repay with interest the financial obligations incurred in its construction. It is conceivable that a project which failed to pass the broader tests of economic feasibility could be financially feasible (if, for instance, it were necessary to borrow only a part of its cost) and an economic project could be commercially not feasible (because the benefits to be provided were not saleable, as in the case of flood control, to take one example). A commercial evaluation which is concerned with profitability from the point of view of private business is too narrow a test for the programme as a whole, though private enterprise may often be involved in large sectors.

The basis considered here is evaluation from an over-all economic and social point of view. Ideally, such an evaluation should include consideration of the economic impact in every area of the economy. The effects on transportation and communication are relevant, as are also its effects on diversification of the local economy, on use of idle resources such as labour and land, and on new investment opportunities—matters likely to be of particular importance in less developed areas.

In reviewing these crucial economic aspects of the problem of river basin development, the Panel examines first the nature of the benefits which such a development must be expected to yield; secondly, the types of expenditure involved and some of the problems relating to them; thirdly, the question of the time factor in relation to the costs and benefits; and lastly, the procedures which may be employed for reaching decisions in the light of what may be known of these various elements, including some account of methods, such as the cost-benefit ratio, currently employed in some countries.

Nature of benefits

It is difficult to measure in money terms the benefits of a river basin programme, partly because some of the benefits tend to be so widely diffused that they cannot be measured with the techniques that have thus far been evolved, and partly because statistical data are generally inadequate. While some of the more direct physical benefits — such as the number of kilowatt-hours of electricity produced and the area of land irrigated — which are the ultimately significant benefits, are much less easy to identify. Yet it is precisely the dynamic effects of a river basin programme in improving the lot of both the local community most immediately affected and the wider area within reach of its influences which provide its final justification.

All the relevant benefits and effects should be taken into account, more or less explicity, in making decisions concerning river basin programmes. Some will be measurable with reasonable accuracy, others will be subject only to approximation, and still others — including some of great importance — must rest largely on judgements which cannot readily be substantiated. Integrated action results in technological and managerial improvements, which are reflected in the benefits accruing from river basin programmes.

It may be said in general that integrated development improves both the quantity and the quality of water supply. In arid and waterless regions it serves to raise the rate of consumption of water by human beings and domestic animals to a level promoting better health and growth. The supply of water to those regions makes it possible to transfer the labour force occupied in the conveyance of water to other occupations. The improved water supply may also make it possible to establish new industries and to raise industrial output and labour productivity as well as to reduce annual costs of production.

The increased utilization of water resources for irrigation made possible by the integrated programme promotes a sharp rise in the productivity of agriculture and the introduction of more valuable and profitable crops such as vegetables, cotton, rice and fruit. Crop yields are not only significantly increased but are also far less variable since they are no longer dependent exclusively upon the amount of rainfall during the growing period. The net annual income from each hectare under various crops, given normal operating conditions, often increases several times. In many instances, the economic gain from a cubic metre of water used in agriculture leads to giving irrigation preference over the other purposes served by a controlled reservoir régime.

In addition to averting recurring flood damage, flood control or drainage projects in the integrated programme also make available additional land for reliable cultivation and may lead to a considerable net increase in income.

The integrated utilization of water resources for power generation is characterized by a much lower operating cost than that involved in thermal generation; the advantages may be particularly noticeable in the saving of foreign exchange hitherto used to import fuels or a saving of current expenditure otherwise required in extracting and handling fuel, although fixed annual costs, which may also include foreign exchange outlays (interest and depreciation), are likely to be much higher for hydro-power.

With regard to water transport, the most important positive effect of river works is the deepening and widening of channels, permitting use of larger and more economical vessels and increasing the freight-carrying capacity of the fleet using the waterway. At the same time expenditure for dredging decreases sharply. The straightening and improvement of channels, in conjunction with control of river flow, also conduce to higher speeds and lower fuels costs. Benefits are usually measured by the savings in transportation costs in the use of the river after improvement or by comparison with costs for other means of transport. While an adverse comparison with the latter should be computed as a negative factor, the improvement of navigation facilities carries with it many indirect benefits, such as extending the radius of markets and making it possible to open up new land for cultivation or exploitation of timber and mineral resources.

Fishing interests may play a considerable part in the problem of multiple-purpose river works. The damming of rivers and raising of water levels may adversely affect migratory fish by disturbing their spawning grounds. These losses, however, may be offset by an important increase in the catch of local fish due to enlarged new reservoirs and to improvement in the conditions for fish growth. The catch of fish in reservoirs may be many times that in rivers under natural conditions.

It is much more complex to estimate other possible benefits such as arise from pollution abatement, recreation, wildlife conservation, salinity control, silt control measures and perhaps afforestation in sparsely forested regions. Gauging more accurately the direct effects on production increase in some of these cases must be attempted.

The benefits discussed above may be classified in various ways depending on the type of analysis. The effort to estimate them closely has led to distinction between direct and indirect benefits. Benefits directly attributable to the project itself, such as obtaining electric power, may be relatively easy to measure, though difficult to add together in a meaningful way; such benefits are frequently compared with the costs and efforts necessary to make them possible, in which case there should be a correspondence between total benefits and total costs.

The main difficulty is in calculating indirect benefits and secondary effects, which may be particularly important in establishing priorities among various projects of the same kind or among investments of a different nature. The realization of benefits resulting indirectly from the utilization of a project, such as those brought about through installation and operation of power-using equipment, entails additional, often considerable, investment and other costs. Utilization of previously unexploited land and reduction of disguised unemployment may bring new services of considerable value without a social cost. Indirect benefits also include some which sound judgement may show to be real but which are impossible to assess in monetary terms. Typical of the latter are those relating to welfare, such as saving human lives through flood control, making electricity available to rural populations, suppressing malaria through river discharge control, preventing air pollution and improving sanitary conditions — the latter two characteristic of changed conditions due to installation of hydro-power stations, as compared with thermal stations.

One aspect which is gaining importance in countries where shortage of foreign exchange is a factor limiting economic progress is the saving of foreign currency which may be achieved by substituting for imports articles produced domestically or substitutes that satisfy the same needs. It may be in the interest of the country's economy to use the foreign exchange thus released for purchasing other capital goods, raw materials or consumer goods. A similar aim in river basin planning may be to diversify production of exports, thereby giving the economy greater stability.

Another important example of secondary effects is the creation of new investment opportunities as a result both of the new physical facilities provided by the integrated river basin programme and the disbursements for wages, materials and equipment leading to additional income, savings and demand for consumer goods. A study of the multiplying effects of the original investment would be valuable, but it seems unlikely that in the near future it will be possible to work out a reliable and practical method of evaluating in monetary terms the secondary effects of the initial investment in river works and — even more unlikely — evaluating the effects of a permanent increase in income. It should be remembered that the multiplying effects of the initial investment also apply to investments of a different nature which may compete for capital funds.

Types of capital expenditure

Even the prospective outlays necessary to construct and maintain the works and activities planned for any specific river basin programme can generally be estimated only approximately. There are several reasons for this. Construction work will normally extend over several years, and estimates of total investment costs made at the beginning will necessarily involve large elements of conjecture. Every river basin presents some unique features which make estimates of construction and related costs difficult. In less developed areas, in particular, lack of data, limited supporting economic activities, and shortage of suitable labour are among the problems likely to be encountered. Finally, the success of an integrated river basin programme may depend in large measure on collateral investments in training, housing and transport facilities, which do not lend themselves to close estimates.

There are five main types of capital outlays involved in the execution of an integrated river basin programme — the investment in the main river works, compensation payments, the contingency reserve, overhead investments and secondary investments.

An approximate estimate of the main construction and installation costs is made by applying estimated unit costs to the volume of the respective components of construction as first calculated. Such units as cubic metres of structure (earth fill, concrete), or, for excavation, of soil or rock, are employed. Among the variables in estimating the capital costs of the proposed multipurpose river works are their size and components, the degree of mechanization of the construction work, conditions of the site and the availability of local manpower and facilities.

In the final estimate, the volume of work is computed from detailed blueprints and specifications and the cost from studies of prevailing price and wage levels and from actual bids and quotations of equipment suppliers. The investment costs of the river works are broken down into separate estimates for materials, transport, operation of construction machinery, wages and interest during the construction period. In countries short of foreign exchange the total is also subdivided into local and foreign expenditure. A construction schedule is prepared, and from this estimates are made of expenditures by years or shorter periods.

Compensation payments made to persons whose property is flooded or who are otherwise adversely affected must be added to the cost of structures, equipment and site preparation. The cost of transferring villages or industries out of areas to be submerged must be included. These expenditures may vary widely, according to local conditions. It may happen that when villages and industries are transferred, the occasion is used to reconstruct them according to a higher standard of housing or productivity. In such cases the expenditure usually exceeds what is necessary for their mere re-establishment. If the excess cost cannot be levied on the beneficiaries, and if there is no general government programme to which such costs may be charged, the river basin authority will have to bear the whole cost, but, for purposes of economic evaluation, only the expenditure necessary for the restoration of the former level of housing or production should be considered. Other compensation payments may be required for land taken from its owners for roads, bridges and other facilities to be replaced or eliminated.

The provision in the estimates for a contingency reserve is of considerable importance, owing first of all to uncertainty as to the level of prices on which costs will be based. From the moment preliminary surveys and studies are made to the time when each undertaking can be considered as ready to be put into operation is a fairly lengthy period. Logically, the initial estimate is revised according to changes in the level of prices in the course of the planning and construction stages. In a country where prices are relatively stable, the logical course is to take the level prevailing at the time of making the estimate. Where changes appear to be imminent it may be advisable either to anticipate a rise in the detailed estimates according to the rate of increase for previous years or on some other reasonable basis. Lack of caution on this point might not only result in erroneous conclusions on investment requirements but also cause financial difficulties at a later date.

There are reasons for having an ample contingency reserve so as to cover emergencies other than general price increases, especially where lack of basic data and of technical and adminstrative experience or other factors complicate the estimating process. Even in developed countries costs of many projects have exceeded estimates by large margins, after adjustment to reflect general price and wage increases. Construction of the project itself may induce a rise in the cost of labour in the area or in costs of certain materials. There are many other sources of error connected with the technical aspects, such as errors in estimating the excavation required for the foundations of dams; such an estimate depends largely on the accuracy of the preliminary surveys. Experience in general leads to the conclusion that an ample margin for unforeseen contingencies is essential.

The overhead investments required in the project area include those for roads and other forms of transportation, schools, hospitals, research stations and pilot plants, vocational training centres and similar public services. Such investments are normally provided by the central or local governments. In countries where this is not the case or where the Government does not provide investments to the extent necessary for the successful operation of the multipurpose programme, the additional requirements for such facilities have to be charged to the capital outlay of the programme. The largest item in this category is likely to be transportation, which may require more than all other overhead investments combined.

Secondary investments are those required in agriculture, industry, mining and other fields, to utilize the water and power to be supplied by the river works. Such investments may be necessary for irrigation lines in the fields, for mobile farm equipment, for silos and refrigeration facilities, for power lines and for industrial buildings and machinery. The total of such secondary investments may exceed by a wide margin the capital costs of the river works, especially if a number of large industries are to be established.

In developed private enterprise economies no special provision is usually made for such secondary investments. It is expected that they will be provided on the local level or by private capital flowing into the project area. In less developed countries, however, there is usually no certainty that such secondary investments will be forthcoming nor do such countries provide for them through central planning. The prospects that these secondary investments will be made can, therefore, be evaluated only by a judgement based on local conditions and a knowledge of public and private commitments. A well-founded judgement on this question is of crucial importance because failure to make such investments, or even delay in making them, may mean that the primary investment in the river works will be fruitless.

Annual costs and benefits

When the amount of required capital expenditure is determined, it becomes possible to estimate the annual costs. Of two projects the one with higher initial investment may be the more economical if its longer life or lower operating cost results in lower costs on an annual basis. After the total capital and operating costs have been calculated on an annual basis, an estimate of the benefits can be set against the total yearly cost. The calculation involves two principal steps, determining the productive or service life of the investment (separate estimates are usually made for each physical component — generators, transformers and the like) and converting all costs and benefits to an annual basis.

The depreciation charge is intended to ensure that the value of the goods and services used in the project is returned to the national economy through the growth of income before the project wears out, or loses its value by obsolescence. It follows that estimates of the annual cost of a project should include an item equal to the depreciation of each of its parts in accordance with the life expectancy estimated for them, based on the cost less the so-called salvage value of the respective items.

In principle, the rate of depreciation should be based on the period of usefulness of the project, taking into account that this period is not equal for all its components. However, some hydraulic projects, like dams, may be of indefinite life, and it could be argued that for this reason no depreciation should be charged to them. On the other hand, the longer the period involved, the more uncertainty there is as to the effectiveness of the project for the purposes for which it was built, and the greater the possibility of its destruction or obsolescence. In consequence, it is customary to use a fixed period in determining a depreciation charge on facilities of indefinite life.

For purposes of economic evaluation interest must be added to the annual costs even in cases where the project is constructed with regular budget funds, and without recourse to borrowing. From the economic point of view, a given investment means a freezing of resources which might otherwise be used for meeting other needs or for other productive activities. If their use for such ends is postponed, because of investment in the project, there exists a social sacrifice, the value of which is expressed by means of the interest charge.

Due to the long-term capital requirements of multipurpose projects, the interest rate which is employed often becomes decisive in the evaluations.[1] The basis for fixing the rates used varies among countries. In most countries the same rate of interest is charged for all types of investments in river works. In Japan, however,

[1] An investment repayable over fifty years in equal annual payments (combining both principal and interest) would if the rate of interest is 2 per cent, require a total payment of interest amounting to 59 per cent of the investment. At 4 per cent interest, the total amount of interest would be 133 per cent of the investment; at 6 per cent interest, it would be 217 per cent; at 8 per cent, it would be 309 per cent, and at 10 per cent, it would be 494 per cent.

different rates are applied for flood control, power and agriculture. In the United States of America only investments in river works allocated to irrigation are exempt from an interest burden in project evaluation. In the Soviet Union no interest is charged or computed on project investments.

No international data have as yet been collected on the interest and deprecation rates which are applied by river basin authorities or on the underlying bases for establishing such rates. There is also no satisfactory international information on actual experience with such rates.

In addition to depreciation and interest charges, annual costs must include the average operating and maintenance costs of the project, including administrative costs. These include costs of materials and supplies, labour, repairs, minor additions and replacements and all other costs incurred to maintain the project in sound operating condition for a maximum economic life.

Estimating the annual benefits is not a simpler matter than estimating the annual costs. It is necessary to determine the prospective rate of charges for the various commodities and services produced by the project and to apply these rates to the estimated units of output that will be sold. Even the estimates of physical output are not free from the possibility of serious error. It may be difficult, for example, to determine hydroelectric output in the absence of long-term hydrological data. Markets for the products of the project may not develop as anticipated; and various other contingencies affecting the estimates may occur.

Other tests of economic feasibility which are discussed below, such as the cost-benefit ratio and even the overall economic evaluation, are also applied on the basis of annual averages. Since they include not only direct investment costs but also consideration of indirect and secondary economic consequences, they are far more difficult to apply and necessarily involve wider margins of error.

Criteria of economic efficiency

While political and strategic considerations may have a decisive effect, the basis for reaching a decision should ordinarily be the assessment of the economic factors. The economic evaluation is necessary in any case, if for no other reason than to show the price to be paid for deviation from the most economic solution.

An economic evaluation serves at least four purposes: (*a*) to determine whether a particular river basin programme is feasible or advisable in the light of overall national development programmes and considerations of national economic interest; (*b*) to determine the relative economy of variants in the programme in the planning and later stages; (*c*) to make a choice among a number of river basin programmes; (*d*) to assign responsibility for repayment of the whole or parts of the investment to the ultimate users of the new facilities.

The choice of type of evaluation is to a large extent influenced both by the specific need to be met and by local conditions. There are various measurements and ratios, none of which, however, can serve as an automatic substitute for judgement. All involve some arbitrary elements, and each encounters difficulties of measurement.[2]

The cost-benefit calculation is perhaps the best known and is often applied for lack of more refined yardsticks. As traditionally used in the United States, it requires that for a project to be justified from the economic standpoint, on an annual basis its estimated total direct benefits should exceed the estimate of its total direct costs, and that an equivalent benefit should be impossible to achieve at a lower cost. This is formulation of an ideal; in practice, the ratio has various shortcomings on both the cost and benefit sides. No absolute value can be given to what may be called "economically justified", and the value of 1.00 for the cost-benefit ratio has only the resemblance of a yardstick. In any case, the ratio must be supplemented with considerations not entering into the calculations.

Further shortcomings of the cost-benefit method are: (1) lack of comparability of the benefits that are added together (for example, for irrigation the estimated net increase in farm income is used, whereas for industrial and municipal water supplies and for power the value or selling price is employed); and (2) failure to give recognition to the possibly wider impact of river works on the economy which, in many cases, is a most important aspect.

Where total investment in an integrated river basin development is considered a national effort to achieve a national purpose, more elaborate yardsticks, such as input-output analyses, become more applicable. But even such methods give no answer in themselves for a single project or programme.

An interesting method used in the Soviet Union is based on a comparison between alternative costs. In this case, theoretical annual cost savings are divided by the additional capital investment involved in the alternative method, and the quotient is expressed by the number of years of repayment (without interest on capital).

Whatever the method or refinement used, the figures or ratios, when uniformly applied, are more useful as a basis of selection among a number of parallel projects or programmes than as a means of justifying any one of them. They make it easier to sort the better projects from the mediocre or too expensive ones. Only in a few countries, however, are local situations (for example, with regard to the relation between irrigation, power and flood control effects) sufficiently alike to allow for an easy comparison. None the less, the choice of priorities among different river basins, in particular, may be the easiest part of economic evaluation.

Similarly difficult questions are also inherent in the problem of allocating joint costs in multipurpose projects. This is, however, of considerable moment for the solution of a number of important problems, including the planning of projects, evaluation of the economic efficiency of the project as a whole and of

[2] See annex III.

its various branches, comparison and choice among alternative technical schemes and justification on the principal variables. Cost allocations are no less important for the correct evaluation of economic indices — costs of production and others — in operating the multipurpose facilities as well as in providing a basis for rate-making and other purposes.

Various methods of cost allocation are in use, and each of them has advantages and disadvantages. Usually each cost element that can be identified with a single use or purpose will be charged to that use or purpose — a generator to power, and a lock to navigation. A dam, however, is an example of a multipurpose structure for which the allocation of costs is difficult if it produces more than one important benefit.

One method allocates costs for multipurpose construction in proportion to the benefits gained from each component of the project. In this case costs are directly linked with their effects in comparable monetary units. This method, however, requires the evaluation of secondary benefits by means of intricate calculations, including consecutive gradual approximation. Until the final designs have been approved, there are numerous alternative possibilities, and this complicates the calculations still more.

Another method, "the justifiable alternative expenditure method", determines the differences between the specific costs for each purpose of multipurpose projects (or the benefits, if less) and the possible costs of single-purpose alternative projects, and allocates the joint costs in proportion to these remainders. The hydropower element, for example, is calculated in terms of what it would cost to produce the power in a single-purpose power plant. The difficulty often is to find a reasonable method of arriving at cost estimates of hypothetical single-purpose projects (for example, the benefit from flood control). The method has, however, been used for cost allocation and to show whether integrated development has advantages over isolated single-purpose projects.

All these methods of evaluation and cost allocation have their limitations, pitfalls and short-comings. There is no accepted single formula or method. The belief is even held by some that no formula can be devised which would be generally acceptable. The area of disagreement as to method of evaluation is particularly wide with regard to secondary benefits, involving as they do various social aspects and unmeasurable factors.

The Panel feels it cannot deal at length with the numerous methods which have been developed for allocation of costs and evaluation of river basin programmes or recommend any specific one. However, since Governments are continually faced with the need to make judgements on the comparative merits of a variety of development programmes, and in view of the fact that no careful study on an international scale has been made, it urges more international comparisons of methods in present use. Especially in areas where resources are scarce and interest rates are high, there is a great need for refinement of methods of evaluation.

PROBLEMS OF FINANCING

Problems raised by the financing of river basin development are in many respects similar to those encountered in other projects of a comparable size. Certain features of these problems, however, are either unique to river basin development or deserve particular attention. This section deals with some of these and is primarily concerned with cases in which investments are carried out mainly by government agencies.

In the space allotted it is possible to cover only some of the most important aspects of public investment, but in this connexion it should be noted that private investment often plays an important role. In some countries, for example, mixed corporations of public and private ownership are used. Private individuals or concerns naturally often have to make secondary investments, and some development projects are carried out entirely by private interests. In order to facilitate such private investment it may sometimes be indispensable to ease government credit policy or to introduce stimuli of another nature.

Financing of the main river basin works

In regard to the manner of financing basic investments, there are two major questions: (*a*) the role played by the central and local authorities,[3] and (*b*) the utilization of public credit.

The proportion of the contribution of both the central and local authorities depends to a great extent upon the type of fiscal and political organization in the respective countries. Where a high degree of fiscal centralization exists and, consequently, the local revenues represent but a small percentage of the total public income, it is natural that the central authorities should carry all, or the largest part, of the investment. Where the local revenues are of importance, however, other circumstances should be borne in mind, such as whether the effects of the project are limited to one region, without influencing greatly the national economy as a whole, or whether, on the contrary, they will have notable repercussions.

Likewise, the area and population of the region covered by the project should be considered in relation to the area and population of the whole country, and the question of whether the realization of the project meets objectives of national policy or more limited ones of local progress should be taken into account. If, for example, the aim is to facilitate relocation in the area of an excess of population from other regions, or of displaced persons, it is evident that there exists an objective for national policy which places upon the central authorities the responsibility of carrying the burden of the basic investment. On the other hand, a river basin often consists of not one but two or more administrative subdivisions, and in that case the proportion of the contribution of each of them towards such part of the

[3] In countries which have a federal form of government, the functions and powers of state authorities should of course be taken into account.

disbursements as the central Government may not cover should be studied.

The variety of circumstances renders it impossible to make general rules on this aspect. However, in principle, it may be affirmed that local public organizations should contribute to the basic investments.

As regards the second point, the advisability of having recourse to loans depends on the nature of the disbursements and the general conditions prevailing in the public sector. Use of public credit is, barring any objection from the point of view of economic policy, justified for a self-supporting project, inasmuch as the strain that its repayment throws upon the treasury is compensated by the sums that will be received from the beneficiaries of the project. In projects other than self-financing ones, what must be particularly studied is whether or not their direct benefit will have a sufficient effect on public revenues to allow the Government to bear the fiscal burden of the loan. In some cases it is possible to foresee a growth of the indirect revenues — when, for example, the project creates new investment opportunities or when an influx of population into the area is likely to result in a general increase in the value of the land and, in consequence, in real estate taxes.

When considering the advisability of seeking a foreign loan, the following are among the principal points to be studied:

(*a*) Availability of domestic capital;

(*b*) The extent to which realization of the project requires disbursements in foreign currency (construction equipment, remuneration of foreign technicians and engineers, imported materials and machinery);

(*c*) Whatever increase is likely, during the period of construction, in the demand for foreign goods and services resulting from the increased income generated by investments in the project;

(*d*) The cost of foreign financing compared to the cost of financing with domestic funds;

(*e*) The country's capacity for foreign payments and the foreseeable variations in such capacity, taking into account the effect of the project on foreign exchange income and expenditure in the future.

It may be helpful to mention the policy of the International Bank for Reconstruction and Development in studying development projects. The Bank first of all examines the economic justification, without losing sight of the indirect and intangible benefits. It attaches primary importance to a study of the country's foreign payment capacity and to the effects that carrying out the project may have upon it; it also takes into consideration any possible increase in exports as well as substitutions for imports. The general principle that governs the Bank's policy is whether a given project may or may not generate an effective improvement in the standard of living of the population.

The Bank generally limits its loans to the direct foreign exchange requirements of the project, financed as indicated in (*b*) above. In a few cases it also has taken account of the demand for certain categories of foreign goods as mentioned in (*c*) above. In accordance with the Bank's Articles of Agreement, only under exceptional circumstances does it make loans for the local currency financing of projects.

Apart from internal and foreign loans and ordinary taxation, various forms of revenues, compulsory savings and special taxes have also been used to secure financing for river development projects.

In some cases such sources of financing have been assigned to special revolving funds. For example, when the Reclamation Fund was created in the United States of America (1902), it was arranged that it would absorb the revenue from the sale of public land and, later (1920), the Oil Leasing Act directed that 52.2 per cent of all funds collected through this Act should be allotted to it.

It may be useful to note some other special financing systems even if they may not all refer specifically to the integrated development of river basins and some may be used for other undertakings as well as water projects.

The Bank for Economic Development in Brazil and the National Electricity Commission in Mexico are allocated funds from obligatory savings systems and special taxes covering the entire country, with a view to facilitating certain development programmes considered of interest for the national economy as a whole. In Brazil, taxpayers, besides paying their income tax, must subscribe a sum equivalent to a certain percentage of such income tax in bonds of the Bank with a relatively short maturity period. As this continues year after year, the Bank's financial capacity increases progressively. In Mexico, the National Electricity Commission is allocated for its electric development plan funds from a special tax on consumption of electricity, equivalent to a percentage of what the users of the service pay monthly.

The projected integral development plan of the Cauca River Basin in Colombia (CVC) affords an example of regional planning where the proprietors of the area which is expected to be directly or indirectly benefited start contributing to the financing of the project before it is actually carried out, by paying a 4 per thousand tax on the property value of the land and buildings.

In these cases of national or regional programmes, the possibility of specifically allotting revenue from such financing systems to these programmes makes it easier to obtain loans and, consequently, to carry out the projects speedily. Transfer of existing assets to development bodies or corporations, as in the case of the CVC in Colombia, may also serve as a guarantee for securing such loans.

Problems and systems of financing in the Soviet Union have a different nature. The financing bodies (banks) there have a subordinate function. After approval by the authorities of the projects and estimates for hydrotechnical works, the financing bodies have to provide funds within the time limits fixed by the State. The constructing organization has to present certain reports to the financing bodies for purposes of control.

Reimbursement of public investments

Integral development of river basins implies expenditures of a varied nature. Some are generally considered as expenditures of the public budget (agricultural extension services, schools, sanitation plants), the burden of which falls on all taxpayers of the country or of an administrative division, being distributed through the general tax system. It is accepted that they cover a function of the State itself and that all citizens should contribute towards their fulfilment.

A problem arises, however, when government funds are invested in such a way as to benefit primarily a particular group, as is often the case with a river basin. It can be summed up as follows: public resources are limited, and particularly so in less developed countries. In these circumstances, should the State require reimbursement, and to what extent, for the funds it invests in objectives that chiefly increase the economic capacity of a particular group? Should that extent be such as to allow the funds recovered to be allocated to other undertakings or to repay the loans the State secured for the investment?

It would seem natural to demand from those most directly benefited a total or partial payment of the funds in order to be able to apply them to other projects. How large a proportion is to be paid back by the direct beneficiaries would of course vary from case to case.

One essential aspect is that related to the economic situation of the area and in particular of the groups benefited if they are easily identifiable. Sectors already enjoying a relatively better standard of living than that of the population as a whole should not benefit from the effect of a public investment without making adequate reimbursement. On the other hand, if the economic level of the group which receives the benefit has been very low, reimbursement should be restricted to a minimum.

In the case of irrigation, drainage and flood control, particular attention should be given to the distribution of property in the area and to the system of land tenure. Some countries have set a maximum area for agricultural properties in land irrigated by public projects. Generally speaking, the owners of land, even if a large part of it is not under cultivation, should share proportionately to the size of their properties in compensating the State for the benefit they receive.

Some projects — such as electric plants — are suited by their nature to producing a permanent revenue. This revenue should be sufficient not only to cover their operating expenses but also to build up reserves for replacement of equipment and facilities when these wear out. The reserve fund may even contribute to the cost of works for other purposes.

To determine to what degree the cost of a project should be refunded to the public organizations which build it, through fees, special assessments or new regional taxes, many circumstances have to be taken into account, among them type of project, nature of its effects, extent of the benefits, economic conditions in the area, size of the disbursement in respect to the public budget, and source of the funds used. A set of principles should emerge from these considerations that may constitute the policy concerning public investments in river basin development projects.

Mention should be made of the practice adopted in some countries of setting aside payments made by beneficiaries towards amortization of capital or interest in a separate fund which is devoted to new investments of the same type. This practice involves creating a revolving fund to finance renewals and new works, or permitting administrators of a project to use such funds for expansion or for complementary works. When the river basin development programme requires sizable investment over a long period, this method, which has been fruitfully used in respect to electrical power supply services, has the advantage of guaranteeing a continuous flow of funds to the development in question. Adequate financial reporting and some degree of policy control will help to ensure that investment of these funds will be consistent with general fiscal and monetary policies.

Whatever the systems adopted, in all river basin development analysis it is highly desirable to state as accurately as possible which investments are reimbursable and which are not, so as to know the amount of the burden to be supported by the ordinary State budget and to avoid making plans on the basis that projects may pay for themselves, only to find later that this is not so. The possibilities of error will be much smaller if, in analysing the financial feasibility of the projects, only the direct and tangible benefits are estimated, regardless of whether the economic justification study takes into account benefits of a wider nature.

Methods of reimbursement

Reimbursement from the beneficiaries for the cost of projects is secured in various ways, sometimes in the form of direct control of the improved assets by the State, which buys them before improvement and sells them afterwards. Another way is to levy special taxes on the increased value of the assets (predominantly used in agriculture) or fees for the services rendered (more suitable for those enjoying industrial benefits).

In certain circumstances the authorities may decide not only that the State must be paid by beneficiaries for the cost of the project but also that all or part of the revenue in excess of such cost should adhere to it. A method occasionally used in cases of irrigation or drainage projects is to expropriate the land affected. Such land is purchased at its standing value, but, once the project is in operation, it is sold at its new market value, preference being given to its former owners. It can readily be understood that this method is applicable only in regions where the system of private property prevails, where the land is sparsely populated and where irrigation or drainage works may result in a substantial increase in the marketable value of land.

In relation to plans for changes in land tenure, in Colombia and in the Thal area in Pakistan, the cost of projects carried out in regions where latifundia commonly exist may be refunded not in money but in land, which may be sold to other persons, thus enabling the property to be divided into smaller holdings. The State may then recover the cost in accordance with the instalments and terms set for the buyers. This system is usually combined with the fixing of the maximum area that each property holding may have within the region benefited.

Assessments on the increased value of properties may cover both direct and indirect benefits from a given project. For example, when irrigation schemes are carried out, unirrigated properties adjacent to irrigated land will probably increase in value as a consequence of the influx of population into the area and its correspondingly greater economic activity. In such cases a general property tax may be devised to pay for the indirect benefits, and complementary special assessments may be imposed on the direct beneficiaries.

When an increase in land value is the basis for assessment, payments should come out of the increase in yearly income, so that the total contribution, which normally does not exceed the cost of the undertaking, may be spread over a relatively long period.

The method of charging a fee for the use of a service appears to be most advisable in connexion with the supply of electric power and also of irrigation water, where consumption is measurable. On the other hand, it does not lend itself to projects for flood control where, if it is planned to collect at least part of the cost, it is more advisable to have a special assessment. Improvements in navigation are frequently considered as non-reimbursable, but a toll has been recommended for vessels navigating rivers in some basins, and a charge for use of port facilities is common. A fee is often charged for the use of drinking water.

Fees charged for services normally cover expenses for operation and maintenance, which are calculated separately from the amounts set aside to reimburse the cost of the project. In some cases expenditures of this nature can be estimated fairly easily (furnishing of electric power, irrigation water) and can be charged to the users of the service by setting certain rates. In others, especially when the prime objective of a project is to prevent damage to persons and property, as happens with measures for flood control, the State often carries the operation and maintenance costs of the works.

Repayment capacity and liquidity

In cases where a Government, public authority or an association of landowners has borrowed funds for the execution of a project, the period of repayment is generally shorter than the period of depreciation of the main works and the duration of the benefits. Also, farmers and other users of facilities such as power will reap the full benefit only years after completion of the project. These circumstances may create serious difficulties for the borrowing agency. For that reason, in setting up the financing scheme, sufficient provision should be made for additional financing, or repayment to the central treasury may be deferred in order to overcome a cash deficit in the period before full fruition.

When ascertaining the repayment capacity of the ultimate users of new facilities, it should be kept in mind that a project should be sufficiently profitable and attractive to the users of land, water and power to enable the beneficiaries to make all scheduled payments and at the same time achieve a noticeable improvement in their standard of living.

Fees or assessments levied by public authorities must take cognizance of additional obligations (land development loans, housing, agricultural or co-operative credit). If loans are contemplated, some agency should be made responsible for collating all debts with regard to the financial position of the ultimate user. A longer amortization period may reduce the burden of too heavy annual payments. On the other hand, especially in countries where the long-term capital market is not well developed, the amortization period should not exceed, for example, twenty years. It is a useful check on the amount that the beneficiary can or cannot be expected to repay.

There are many cases where, although it was at first expected to secure reimbursement of the capital cost within a set period, it was later decided to extend the period, to introduce changes in interest charges or even to give up the idea of reimbursement altogether. This is sometimes due to social and political considerations, but it may also be the consequence of errors in the estimates of benefits, which turned out to be smaller or to take longer to come to fruition than anticipated. Conversely, inflationary conditions prevalent in many countries have often reduced the real burden of reimbursement by the beneficiaries even below that which had previously been determined to be fair. The possible emergence of such situations must be carefully considered in working out reimbursement policies.

Organization and administration

The way in which any task is organized and administered depends upon how the particular responsibilities involved can be most efficiently discharged. In the case of a river basin programme, these will typically include planning the programme, constructing the necessary works — which will probably include one or more structures of great size and cost — operating the project and co-ordinating the activities of outside groups, both private and public, when they impinge upon the execution of the programme. These activities must be fitted into the framework of existing government undertakings in the same or related fields, and conducted in such a way as to win wide participation and support. To carry out these functions will require the use of a variety of administrative and technical tools and the assistance of experts in many fields. All these elements must become parts of a single unified programme. It is apparent that the responsibilities are not such as to be easily discharged.

Many development schemes have as yet made little progress because of the inability of the responsible authorities to carry them out. Because of poor organizational planning, there are cases in which river basin authorities have not even been able to make effective use of the technical assistance that has been provided to them. A river basin programme, because it is so complex and because it does not fit neatly into the general governmental framework, requires an especially imaginative approach to its organizational problems — all the more in its critical early stages.

Need for unified planning and administration

The type of organization of any river basin authority must be determined not only in the light of the particular range of its activities but also on the technological basis of its programme and the economic interdependence among the various parts of the river basin and between the river basin area as a whole and other areas. Thus, if the irrigation phase of its programme depends upon a multiple-purpose reservoir, a form of organization may be suggested different from that proposed if irrigation depends on underground water or the free flow of a river.

If a river basin programme is to be integrated in more than name, it will require unified planning and administration. One essential therefore is to provide an organizational framework under which such unified planning and administration can be carried on. A second essential is continuity in the planning, construction and operating phases. While it is not necessary that the planning agency should build or operate a project, it is important that planning, construction and operation should be regarded as a continuous process and that all the staff engaged in these various functions should be under common control. In the Soviet Union the largest integrated schemes (for example, on the Volga and Dnepr Rivers) are usually designed and carried out by the Power Ministry; each integrated scheme is implemented by a single construction authority. Less important integrated schemes, such as those in Middle Asia and the Caucasus, are often carried out co-operatively by the Power Ministry of the Soviet Union and the Ministry of Water Management of the republic concerned. The planning and control of large power plants and integrated programmes are handled by the State Planning Commission, and of the others, by the planning commissions of the respective republics.

There is certainly no single correct way to organize and administer a river basin programme. The plan of organization must in each case be fitted into the general governmental structure and into the cultural patterns and political traditions of the countries and regions that are involved. Whatever the form, however, the requirements of unity of control and continuity of administration must be observed if waste of natural, capital and human resources is to be avoided.

Because the activities of a river basin authority cover a broad front and represent a relatively new approach to water resource development, it is especially important that the programme should have from its inception the help of gifted people in top executive positions. Ability to view the programme with comprehensive vision, executive drive and sensitivity to social needs will all be required for a good start.

The scope of the powers to be conferred upon the river basin authority is a basic question, and upon the way it is decided may depend the form of the organization as well. As a minimum this body should have adequate authority to ensure the unified development of the river itself through construction of dams, locks, canals and other water-use structures. Beyond this, however, are many related activities. Distribution of the power produced, use of the water for irrigation purposes, encouragement of new industry, land inprovement programmes to increase agricultural productivity and reduce erosion and silting, and operation of wharves, barges and other transportation facilities are examples of activities which are intimately related to a programme for the development of the river itself. It is apparent that the more extensive the powers conferred upon the river basin authority, the greater will be the peripheral problems that will be raised in reconciling the programme within the basin with national programmes in the same fields.

Form of organization

The form to be given to the river basin authority is a problem that must be faced early in the programme. While it is essential to maintain the integrated character of the programme, this can be done in more than one way. Administrative solutions vary from those in which the departmental set-up is preserved and the programme is conducted within one of the regular departments or ministries of the government to the case in which a new and largely autonomous regional agency, perhaps corporate in form, is created. The Tennessee Valley Authority (TVA) and Damodar Valley Authority are examples of the latter type, combining various functions ordinarily exercised by specialized government departments concerned, exclusively or partly, with the development of a river basin. Thus, TVA has responsibility within the Tennessee Valley in the fields of navigation, flood control, power, agriculture and other resources. The Hokkaido Development Corporation is an example of a strong interdepartmental set-up with planning and executive duties. La Compagnie nationale du Rhône is an example of a mixed corporation which combines features of both types.

Each of these forms of organization has its advantages and disadvantages. In general, the departmental set-up makes it more difficult to secure unified direction of the various parts of the programme. The regular government departments are frequently burdened with procedures too inelastic to meet the needs of a new and complex activity, and the key department executives may be so busy with their other work as to be unable to give the requisite time and emphasis to one specific river basin programme. However, a department operates within a stable government framework. It has large resources of staff and facilities which may be utilized in the programme, and existing or readily expanded administrative machinery which facilitates tying in the river basin programme with national programmes in agriculture, health, irrigation, education and other fields. A regional agency, on the other hand, has the advantage that it can focus all of its attention and resources on the discharge of its single responsibility. Being a new agency, it is more likely to be given freedom from the restrictive administrative procedures that handicap the start of new programmes and activities by regular departments. It is also more likely than a department to be given certain fiscal freedom, such as the right to borrow and to use its revenues for construction and operation. However, it must create new arrangements for collaborating with existing departments and with regional and local organizations and citizen groups. It must recruit new staff, and — in a country of limited resources — its success in attracting staff may be at the expense of other programmes and other areas of the country.

Whether a departmental type of organization or an autonomous regional agency is created, a particular effort should be made to avoid the weaknesses and to build upon the strengths which have been discussed above. For example, if a departmental type is adopted, it should be granted as much financial autonomy and administrative freedom as possible. Similarly, a regional agency can be assigned a programme so defined as to minimize jurisdictional rivalries with the regular departments and to obtain many of the advantages normally associated with the departmental arrangement.

Specific problems

Because a river basin programme provides for intensive development within a limited area, there are special reasons for placing the centre of administration within the basin or as close to it as conditions permit, and for assigning a maximum degree of authority to the local officials who will be working with the people of the area in many different fields of activity. In giving power to an administration there must be limits in terms of policy considerations, size of financial commitments and perhaps other criteria, but a good test of the effectiveness of a river basin authority is the degree to which it may safely delegate authority down the line. A system of broad delegation must be accompanied by effective liaison between central and field offices, so that everyone who has authority to make a decision will have a solid foundation in an understanding of the objectives and procedures of the organization.

Staffing a large new organization is a difficult problem even in highly developed countries and all the more so where the resources of trained technical personnel are limited. Establishing training schools at an early stage may be a useful expedient. If domestic training facilities are lacking, it may be possible to provide training opportunities abroad. There should be no hesitation in employing foreign specialists where necessary in order to secure adequate staff. Arrangements with foreign specialists commonly provide that it will be part of their responsibilities to train local people who may succeed them.

A unified river basin programme will require that all the specialist groups see the programme in the same perspective and fit their work into a common endeavour. If the goal is to make the most effective possible use of the river basin's resources, the river basin authority must be alert to prevent distortion of the programme by professional rivalries among the specialist groups — irrigation *versus* navigation, or power *versus* flood control. For this more is required than a means for arbitration of disputes, or even central direction of all activities according to the programme requirements. There must be a common vision and a common purpose.

A perplexing problem of organization is whether to consider the continuing planning function within a river basin authority as one to be discharged by a special planning staff or whether the head of each of the major administrative units or divisions should be responsible for planning within his own sphere of activity, a concept sometimes referred to as "planning in action". In making this choice, again much may depend upon the qualifications of key personnel. The Panel believes that in most circumstances it is unwise to divorce planning from the execution of programme activities. Some of the advantages of a central planning unit can be realized by installing planning specialists as advisers in the offices of the division heads.

The problem of organization and administration is never a static one but changes constantly within any agency as its programme develops, as key staff members leave and are replaced by others with different capacities, and as changes take place in related fields of activity carried on by other agencies. Adjustment to changing requirements will be especially important in the case of a river basin authority which is evolving from a planning organization to one which includes responsibilities of construction and operation as well. Organizational arrangements which may be essential at one stage may not be appropriate at another. The assumption of important construction and operating responsibilities will require a thorough overhaul of the whole agency to ensure that it is adequately organized and staffed for the discharge of its new functions.

The TVA case is illustrative. Here four different systems of internal administration have been employed. In the first few months of its existence, the chairman of the three-man board, by vote of the board, exercised the powers of a chief administrative officer, subject to policy guidance by the whole board. This system proved unsatisfactory after a few months, and the administrative powers were then divided among the board members, each having administrative control over activities within his special range of competence, subject to over-all board control. After this system was in operation for a few years, a co-ordinator was appointed to correlate staff activities. From this expedient there evolved the present system under which all staff direction is exercised by a general manager, the board confining itself to policy making and general guidance, and approval of important transactions and plans. This is not to say that the administrative arrangements now employed should have been adopted from the beginning. During the starting period there may have been great advantages to the initial administrative arrangements, and, despite internal board friction during the early years, this was a period of considerable achievement. A system similar to the one presently used in TVA is now employed for the Zuider Zee works in the Netherlands.

Even in highly developed countries no perfect solution has been found for the problems of organization and administration inherent in integrated river basin programmes. There is no comprehensive evaluation of the administrative techniques which have been developed in various countries for handling such programmes, and each country has developed its own administrative framework for such programmes on an empirical basis. The Panel believes there should be a continuing effort to exchange information on experience in this field and to appraise the usefulness of these varied techniques for more general application.

Citizen participation and local projects

The interest and support of the great majority of the whole population of every class, urban as well as rural, is important if a river basin development programme is to be adopted and successfully completed. This point does not need to be laboured. What does require emphasis is the special significance of securing the active help of the local citizenry, the farmers, villagers and tradesmen in the various phases of the programme. An integrated river basin development programme will usually include large hydroelectric plants with interconnecting transmission lines, and major flood protection and irrigation works, which will be built and operated by the central authority. It will also include numerous watershed management improvement works, farm irrigation and drainage systems and small-scale industrial enterprises which will not only have value in themselves, but will contribute to the success of the over-all programme. It is here that citizen participation can be of the greatest importance.

Basis for securing citizen participation

Citizen participation involves a two-way movement: from the authorities to the people and from the people to the authorities. On the one hand, it is necessary to obtain the help of the people of the area to put the development plan into operation, at minimum cost, in the shortest possible time, and with maximum benefit. The responsible officials will need the help of the local citizenry at every stage, including planning. Plans must rest on an accurate appraisal of the existing realities and reflect an understanding of the aspirations of those to be affected. Adequate knowledge of the social, economic and physical conditions of a particular river basin can be acquired only by close contact with the people and their problems. History is full of examples of the failure of unrealistic plans made by authorities remote from the problems they sought to deal with. The expert cannot escape from the consequences of his planning as can someone whose planning is divorced from execution. He must ask himself: Who will carry out this plan? Will the people understand it? Will they co-operate? Will they make the plan their own?

Citizen participation involves a parallel flow of information and help from the authorities to the people. The people of the affected area should be advised as early as feasible on the various stages of the programme, the solutions being considered, the promise afforded for improvement in their way of life, the results already obtained, the conflicts of interest that have developed or may develop and the considerations involved in resolving these for the general good.

Unified development of the resources of the river basin must become the common purpose of all the people and all the agencies of the entire area concerned. Only if the people have learned to comprehend the implications of the basin scheme for their well-being will they approach the required tasks with energy and enthusiasm. For it is the people themselves who must rebuild their land, the farmers who must change their land-use patterns and try out new methods of farm management, the workers who must build the dams, and the businessmen who must build and operate factories when the conditions for successful business enterprise have been created. Every co-operative effort will stimulate the interest, enthusiasm and sense of participation that is vital to success. Moreover, each co-operative activity provides a training experience which has educational value for the performance of future tasks and the solution of future problems.

In areas where under-employment is considerable, it will greatly facilitate progress in securing local citizen participation if local labour and other resources can be used to accomplish part of the programme. This is not to suggest creating unnecessary work. On the contrary, nothing will defeat the purpose of the programme more readily than providing any basis for local opinion that the programme is unsound or is being advanced in an unsound way. However, if the plan calls for building roads or levees, digging ditches, or similar simple construction jobs, mobilizing local labour will provide a foundation for a solid co-operative relationship. If these local projects are of immediate benefit, it may be possible to get them done with help which is volunteered in a partnership spirit, an important consideration where capital budgets are strained.

Far more than land and water, the manpower of a river basin is its chief asset, and any development must capitalize on it from the very start. The inhabitants, being the ultimate beneficiaries of the development, should be made to feel that it is not something imposed on them from above, but that the greater the contribution they make, in the shape of local and co-operative effort, the greater will be the measure of the success achieved. Hence, in any development scheme, plans for the progress and welfare of the common people, particularly in the rural areas, must take first precedence, as they are likely to evoke the greatest general interest.

The success of any citizen participation movement will depend to a large extent on the competence, zeal and initiative of the staff employed to work on this phase of the programme. They should, therefore, be selected and trained with care. The staff at the village level should preferably be recruited from rural areas and given an intensive training in special institutes, staffed with instructors who have themselves received special training. The object should be to instil in them a clear idea of what must be done in the villages to improve agriculture, health, communications and rural industry, and above all, to teach them how to help citizens to pool their efforts and resources in order to solve their problems. The staff should be taught to use their hands as well as their common sense, so that they are able to demonstrate, not merely explain, to the villagers how something must be done.

It is familiar doctrine today that research pays good dividends in all schemes and is indispensable where large investments are to be made. Citizen participation involves new concepts and new problems, and the importance of research in this field is all the greater because there is no proven body of special knowledge upon which to draw. Research is needed on the progress being achieved, physical as well as human. Systematic study of the training curricula, of the methods adopted in the field, of the extent to which targets are realized, and of the reasons for failure in any particular development, is essential as a continuing process for the success of a citizen participation programme.

This success might, in turn, be essential for ensuring the citizen participation which is indispensable for carrying out local projects, whether they are concerned with land and water use or with industrialization.

Local land and water use projects

Local land and water use projects may serve not only to enable local leaders and technicians to learn from specialists, but also to enable specialists to learn how to apply their theoretical training to specific local situations. The effectiveness of training can be improved when a local project is used for training not only personnel directly engaged on the project but also groups of specialists brought to the project for the specific purpose of learning practical local operation. Administrations responsible for integrated river basin development should sponsor such field training, or at least stimulate and provide financial means for it. The Damodar Valley may serve as an example. Here, a number of local watershed improvement projects are used for training purposes. The Government of India has established in the upper valley a periodical training centre for soil and water conservation and watershed improvement, using these local projects.

An integrated programme may lend itself to development by steps and, indeed, this may be essential to the success of many river development schemes. It takes a long time to assimilate and make profitable use of new resources. The ground must be prepared for the new large-scale supplies of water and power and for efficient operation of new institutional arrangements. River basin projects cannot be developed at once to their full capacity. Even in highly developed countries an immediate full-scale development of major projects would immobilize large capital investments for a considerable time without sufficient return. Development by steps makes possible the realization of benefits during the construction period. It also provides the time needed for creating a body of consumers and preparing markets. Local projects, even very small ones, could play a predominant role in that type of development by acting as spearheads. This is especially the case in the field of improved watershed management, irrigation and fisheries, and in conversion from one type of rural economy to another, as from grazing to cultivation.

The Rufiji Basin, Tanganyika,[4] provides an interesting example of the potential benefits of development by steps. Preliminary studies are being carried out to define the river and land potential of the area and the technical feasibility, as well as the economic advantages, that can be derived from an integrated river basin development. The project lends itself well to such development, because several large areas, each covering 160,000 to 240,000 hectares, could be developed on tributaries practically independent of each other, and each would contribute to a greater control, at a later date, of the water resources for utilization in the lower reaches. While planning of the over-all project is still in the initial stage, local commercial interests have made a proposal to the Government to develop some 20,000 hectares of land on the lower reaches of one of the main tributaries for growing sugar-cane, and to build a sugar factory for production of 100,000 tons of sugar per year. This project can be carried out without major river improvement measures, as the available water will more or less suffice even during the low-water period. At the same time production of 100,000 tons of sugar will justify extending a railway line to the area, which, by improving transport conditions from this new area to the sea, will in turn make possible the development by the local population of another tributary for the cultivation of rice and other crops. In this way, several new local projects will be created. When these reach a certain size, the increasing need for water will justify construction of storage dams on the tributaries. With the development of irrigation farming in the plains, it will become possible to resettle local tribes from the steep slopes, where they are doing damage to the watershed by wasteful practices which cause erosion. This resettlement, combined with protection of the watershed, will in turn improve the river flow of the tributaries. This example shows how, by providing one local project a chain of development is set in motion which will assist in speeding up the development of the main project.

River basin programmes in newly developed areas often encounter novel problems. Mistakes on a large scale can often be avoided if local projects are set up to test any proposed solutions. Moreover, it is easier to make adjustments or improvements in provisional arrangements when they are on a small scale. Experimental projects are frequently used to obtain information on new production types and methods or new crops. As an example, the first phase of the Gezira scheme in the Sudan can be cited. At the beginning of this century, sufficient evidence was collected in the Sudan to indicate that long-staple cotton could be grown

[4] United Republic of Tanzania.

successfully on irrigated land. As a first step, local experimental projects based on pump-lift irrigation were started on areas not exceeding 4,000 hectares. Only after a long period of production on this scale, and after having obtained good results, was the larger-scale irrigation project implemented. The pilot pump schemes have been incorporated in the main project.

Local experimental projects in agriculture are also often used in areas where the economic value of a new method must be tested, for example, chemical fertilization and seed improvement. Other types of experimental projects may test proposed forms of institutional service or a land tenure system.

The experimental nature of a pilot project should be made clear to the public from the beginning. It is in the nature of experiments that not all prove to be successful, and the public should not be led to doubt the soundness of the major scheme by the failure of an experimental feature of it.

Demonstration projects are also valuable in local phases of river basin programmes. They can be used where new techniques and institutional forms have already proved their worth to the scientists, technicians and administrators, but where they are not yet sufficiently known to the local population and not practised by them. The main objective of a local project is to show the advantages of new crops, new local industries, new improved production methods or institutions. Demonstration farms, such as those used by TVA to secure wide farmer acceptance of new forms of fertilizer and improved farm practices, are a well-known example.

The United Nations and its agencies participate in a number of such local schemes. On the Ganges-Kobadak irrigation project in East Pakistan, which, when fully developed, will cover an area of 800,000 hectares, a local project of about 200 hectares is now demonstrating to some 500 farmers the advantages of irrigation over rain-fed farming.[5] Other demonstration farm groups are being set up in the same area. In addition to this local project, experimental stations have been established for research purposes, and the demonstration farms can utilize their findings. The local schemes will be incorporated later into the main development scheme. This is also the objective of a local project in Aden Protectorate,[6] now under implementation, where the advantages of controlled flood irrigation over wild flooding are demonstrated to the area. On these projects the Food and Agriculture Organization of the United Nations is assisting the Governments in their undertakings.

An interesting type of local project has been introduced fairly recently in a number of countries, in conjunction with community development schemes. In India, these community development projects are now often using subcatchment basins to collect rainfall as a basis for general improvement of production and hence of rural life in the economic, social and cultural fields. Such local projects are started as soil conservation pilot schemes at the headwaters of tributaries and will at a later stage be incorporated into river basin improvement and development schemes. In the Damodar Valley in India the entire watershed, some 23,000 square kilometres, will soon be covered with community development blocks, the task of which will be to carry on comprehensive local improvement projects in the drainage basin. The local projects are handled jointly by the Community Development Department and the National Extension Service, with active participation by the local population.

Local industrial projects

To increase regional productivity and raise standards of living by encouraging the expansion of existing industries and the creation of new ones is an essential part of any integrated river basin programme. The promotion of small-scale industries may be an indispensable part of the development process and is a natural beginning of that process.

A start should be made on the basis of what is already available, plus the additional resources that the water control features of the programme may contribute. One starting point may be found in the existing handicrafts, which are frequently a significant economic activity in underdeveloped areas. Such activities may cover a wide variety of goods and may be either a part-time occupation within a household or the full-time occupation of specialized craftsmen. Ignorance of appropriate techniques, use of primitive equipment, inadequacies of raw material supply and limited markets constitute serious obstacles to the progress of handicrafts and to the contribution that such progress can make to the regional economy. Diversification and improvement of these industries on the basis of a more advanced technology involving the use of mechanical power whenever feasible will permit them to utilize more efficiently the existing raw materials, technical skills and productive facilities.

The service industries and crafts, such as those exercised by blacksmiths, carpenters and tailors, are another starting point. Modernization of these activities would lead to reduction in cost and improvement in quality, thus contributing substantially towards a higher local level of living, as well as introducing to this important sector of the local economy modern equipment and production methods.

A serious obstacle to development is lack of facilities for the maintenance and repair of mechanical and other equipment. Construction activities entailed by local water projects should be an opportunity for establishing local facilities for repair and for training people in their use.

Another stage may consist in the creation of new small-scale industries of a type which may be operated locally with available raw materials. Such industries

[5] The project currently under construction includes a pumping station on the right bank of the Ganges at Bheramara and a system of canals to irrigate lands in the Kushtia and Jessore districts. Another gravity canal taking off on the right bank of the river just below Hardinge Bridge will irrigate polder land in the Khulna district. The total area to receive irrigation benefits is about 800,000 hectares.

[6] People's Republic of Southern Yemen.

might include grain milling, oil pressing, brick and tile making, soap making, cotton ginning, carding and spinning and weaving, also glass making, tanning, lumber milling, timber seasoning and furniture making. Where conditions are suitable, there may be added activities, requiring some outside materials and producing for a wider market, such as fibreboard and building board manufacture, paper making, sugar refining, food canning, alcohol distilling, metal working, production of chemical fertilizers, farm implements and cement, as well as mining and smelting.

For an early start on local industrial projects, it may be necessary to make electric power available before the large sources of hydroelectric power supply provided for in the river basin programme become available. This can be done with small power units. In communities which have never known the benefits of electricity, there is nothing more likely to galvanize local interest and enthusiasm than a demonstration of the uses of electricity for lighting and for operation of simple power tools and equipment, such as power saws. Government assistance may be necessary for a limited period in establishing these local power plants, but there are many cases in which such assistance will be a small price to pay for the benefits realized.

Stimulating local industrial projects may require leadership and assistance by the river basin authority or any other responsible agency. Among the services which can provide such stimulus are research activities, educational and promotional activities, establishment of marketing and credit services and sponsorship of pilot-type units.

Development of a successful programme of citizen participation through local projects may require extensive government assistance. The help needed for such projects may comprise in part extension work, or assistance on administrative problems, or material assistance, or all these. Administrative help is needed on selection of settlers, determination of size of farms, consolidation of holdings, issuance of rights for local industrial and agricultural projects, and many other aspects requiring broad experience and uniformity of policy. Procedures should, if possible, be adapted to the new conditions and should be brought into line with administrative techniques utilized throughout the river basin. Local projects need not only support and assistance, but also a degree of control in order to protect the general public interest. Those administering the programme should, therefore, be endowed with sufficient power to direct these projects toward the established programme objectives.

Chapter IV

CO-OPERATIVE ACTION IN DEVELOPING AN INTERNATIONAL RIVER BASIN

At first glance, integrated development of an international river basin might be expected to present problems similar to those encountered in dealing with national rivers, on the premise that a river basin is a coherent topographic feature and the waters therein should be developed to provide the optimum benefit to the community within the basin, whether or not it comes under a single jurisdiction. Though this concept may be correct in principle, political considerations often make it difficult to apply.

Even in the best of circumstances joint use of international waters can give rise to ill feeling and political tension. Although there may be on all sides a sincere will to co-operate, questions of accuracy of flow measurements and of the justice of water allocations may lead to difficulties. The steady growth in world population and a growing water consciousness have increased the demand for water and, consequently, its value, with every indication that the value will continue to increase. These factors, combined with the usual political differences arising in any international basin, tend to aggravate rather than ease the problem of integrated planning; in this respect it often differs from the planning involved in a national basin under the rule of a single Government.

In a national basin the Government of the country may have both the power and the facilities to deal with social, administrative and economic problems and can pass special legislation to meet a given situation. By wise administration, propaganda, demonstration schemes and other ways and means at its disposal, the national Government can encourage and accelerate progress in a scheme of basin development, all internal differences, disputes and claims being settled by the law of the country.

In the case, however, of a basin falling within the territories of two or more countries, the situation is different. The Governments, on whom it is incumbent to further their countries' interests or at least guard them, themselves become the claimants and disputants. Should they fail to agree, there is no supreme authority automatically available and mutually acceptable to whom they can refer. Moreover, the disputes — some of which may be quite minor — become political issues and often assume an exaggerated significance. It is clear, therefore, that the degree of success in carrying out any project for international basin development will be largely determined by the prevailing political atmosphere and the impact it has on the public will to co-operate.

DIFFICULTIES IN CO-OPERATING

Having regard to the fact that any incentive to co-operate depends on the material and moral benefits derived from such co-operation, it is imperative that the benefits in quantitative and qualitative terms be clearly described as early as possible in the planning of any project and repeatedly stated throughout the process of planning. It is only by such means that the facts can sink into the public mind and engender a co-operative spirit in the international sense. Thus, in framing a plan, the psychological problem will often call for as much attention as that given to physical and economic questions, although the emphasis on each will vary with the circumstances.

In some parts of the world a relatively high standard of co-operation has been built up. Examples in Europe are the Rhine and Danube, where the emphasis is mainly on navigation and hydroelectric power and only to a minor extent on consumption uses. The Soviet Union and some adjacent countries such as Finland, Iran and mainland China are also co-operating in use of some international rivers. On the North American continent, water treaties between the United States of America and Canada[1] and the United States of America and Mexico[2] afford examples of co-operation in the control and utilization of international waters for all purposes but with non-consumptive uses still the predominant feature, though irrigation is by no means unimportant.

But there are regions — particularly those where political changes have occurred since the Second World War and those where several young sovereign States have emerged — where water questions have been brought into sharp focus and bitter disputes prevail today. In the case of Pakistan and India, for example, the original water treaties and arrangements drawn up prior to 1947 and tending towards a global pattern rather than a restricted one, do not cover the new

---

[1] Treaty of 1909 between the United States of America and Great Britain.

[2] Treaties of 1853 and 1944 between the United States of America and Mexico.

situation.[3] Similarly, in other cases, various reasons for disagreement exist, some of which are valid and some distorted and aggravated by questions not concerned with water, such as territorial and boundary disputes.

One source of disputes concerning international river basins is the fact that international boundaries were often drawn without consideration of the requirements for sound water administration. Even when a canal system is located within a single country, uneasy relations may arise between the upstream and downstream executive officers if the division of responsibility for water measurement and other aspects of water management is uncertain and complicated. When the administration of a canal system is not unified, each administrative unit will be tempted to achieve its own goals through its own efforts and works, irrespective of the needs in other areas and of the economies which effective collaboration would make possible. These problems are magnified in the case of international basins and it is important that, in regions where water is a vital economic factor, every facility should be provided for ease of control and co-operation.

Though advances in science and technology have promoted integrated reservoir systems and many other improvements in the means of water control, they have, ironically, contributed their quota to the desire for isolation and independent action. Possibilities for storage and diversion of water are today far wider than they were fifty years ago. A large price may be paid for a scheme which gives independent control of some water resource though such control might be quite unnecessary in an atmosphere of true co-operation.

Another cause for dispute, mentioned above, arises in the terms of some existing agreements which were originally negotiated between certain Powers on behalf of the States they administered, or between one administering Power and a sovereign State. States which have gained their autonomy contend that the agreements in several cases do not apply in the changed circumstances.

Anyone not acquainted with the history of regions in which water disputes have been acute might form the opinion that there had been little law or order in the past where water was concerned. But research shows that vast schemes of development have been carried out in the past century, great programmes for river control — chiefly for single purposes — are in progress, and future water projects are under close and vigorous study. All this has involved negotiations on water matters based, for the most part, on the principles of European law. Moreover, these negotiations were mainly concerned with irrigation supplies, which present problems far more intractable than those for essentially non-consumptive uses such as navigation and hydro-power. Thus, examples of successful past negotiations are by no means lacking, but what is lacking today in many areas is the atmosphere necessary for negotiation.

In spite of the good offices of various impartial agencies, including financial agencies, the atmosphere in many cases is one of mutual distrust and hostility, which obviously retards and often precludes any real progress in co-operation. This is not surprising in view of the numer of States that have only recently started to handle their own affairs in an environment which may still be suffering from the effects of a world war and, therefore, is far from normal. Nevertheless, the situation is one that could have serious repercussions and, in spite of what is being done, calls for further action. Against such a background the problem is not so much one of developing a policy of integrated use, but rather of restoring it and greatly increasing its scope under the new order.

Inadequacy of relevant international law

Though the success of a plan of international basin development in the long run depends on good will and co-operation, it is obvious that many conflicting claims have to be balanced and reconciled. Some of these issues may raise questions of an international nature which are not adequately covered by recognized international law. For many years legal minds have been directing their efforts towards the formulation and systemization of legal principles applicable to users of international rivers, and much attention is being given to such principles at present by the International Law Association and the Institut du droit international.

The International Law Association, at its meeting in August 1956 at Dubrovnik, Yugoslavia, unanimously adopted a statement of principles "as a sound basis upon which to study further the development of rules of international law with respect to international rivers". Acceptance of these or substantially similar principles by the parties to international water disputes might go far to aid adjustment and agreement. The principles are as follows:

"I. An international river is one which flows through or between the territories of two or more States.

"II. A State must exercise its rights over the waters of an international river within its jurisdiction in accordance with the principles stated below.

"III. While each State has sovereign control over the international rivers within its own boundaries, the State must exercise this control with due consideration for its effects upon other riparian States.

"IV. A State is responsible, under international law, for public or private acts producing change in the existing régime of a river to the injury of another State, which it could have prevented by reasonable diligence.

[3] After thirteen years of negotiation with the good offices of the International Bank for Reconstruction and Development (World Bank), the two countries signed the Indus Water Treaty in September 1960 which, as its most important feature, provides for the division of the waters between the two countries. Under the terms of the agreement, all the waters of the so-called eastern rivers, i.e., the Sutlej, Beas and Ravi, shall be available for the unrestricted use of India except as otherwise expressly provided in the Treaty, whereas Pakistan shall receive for its unrestricted use all those waters of the western rivers, the Indus, Jhelum and Chenab, which India is under obligation to let flow under the terms of the Treaty.

"V. In accordance with the general principle stated in No. III above, the States upon an international river should in reaching agreements, and States or tribunals in settling disputes, weigh the benefit to one State against the injury done to another through a particular use of the water. For this purpose, the following factors, among others, should be taken into consideration:

"(*a*) The right of each to a reasonable use of the water;

"(*b*) The extent of the dependence of each State upon the waters of that river;

"(*c*) The comparative social and economic gains accruing to each and to the entire river community;

"(*d*) Pre-existent agreements among the States concerned;

"(*e*) Pre-existent appropriation of water by one State.

"VI. A State which proposes new works (construction, diversion, etc.) or change of previously existing use of water which might affect utilization of the water by another State must first consult with the other State. In case agreement is not reached through such consultation, the States concerned should seek the advice of a technical commission; and if this does not lead to agreement, resort should be had to arbitration.

"VII. Preventable pollution of water in one State which does substantial injury to another State renders the former State responsible for the damage done.

"VIII. So far as possible, riparian States should join with each other to make full utilization of the waters of a river, both from the viewpoint of the river basin as an integrated whole, and from the viewpoint of the widest variety of uses of the water, so as to assure the greatest benefit to all."

Pending establishment of an accepted international code, it is suggested that the Dubrovnik draft statement of principles affords a sound basic philosophy for planning and executing a project for integrated river development in an international river basin. The fifth principle, in particular, should be useful in furnishing a guide for the solution of disputes with respect to the use of such waters, recognizing as it does the pertinence of all equitable and historical circumstances in the resolution of such disputes.[4]

Initial approach

From the foregoing, it is clear that co-operation must be fostered and nurtured if any real progress in international basin development is to be made. The question arises as to what might be the sequence of steps and who is to initiate and promote them.

Different situations will call for different detailed procedures, and much will depend on the prevailing political, social and economic conditions in the countries concerned. In some cases there may be an intense desire to co-operate in bringing about an integrated basin development while in others the feeling may range from a willingness to participate to vigorous opposition to any programme of collaborative action. The only point in common between the two extremes and the cases ranging between them is that in none of them are the countries concerned likely to be able to embark on a programme of integrated development without extraneous help in one form or another.

In view of the global nature of the problem it would appear that only an organization with such an international character as the United Nations can play a really influential role. This does not mean that this international organization would necessarily take an active role in the planning of integrated development of particular river basins; such a step would only be taken upon invitation of all the countries concerned. Nor does it mean that the United Nations should do nothing while awaiting the issuance of such an invitation. In fact, there is much that could be done to lay the foundation for prospective agreement among the interested countries.

The Panel believes that the United Nations has exceptional opportunities and facilities, either directly or through its subsidiary organizations, for gathering the information necessary to make a report on the *status quo* of selected underdeveloped international river basins. This should be a factual statement, which gives an indication of what further steps are called for. It would be the basic report upon which future planning policy might be oriented. For ease of reference and comparison with basic reports on other basins, it should be prepared on strictly standardized lines, using the same terminology and expressing the facts in terms of accepted standard units as well as local units. Such a report need attempt nothing more than a broad outline of the situation based on the information available or easily and quickly procurable. The main headings might be: economy; communications; topography; geology; climate; hydrology. The subheads would have to be decided in conference. The report should be accompanied by a map of the basin prepared on standardized lines and by other maps of the region that are relevant and readily available.

With the basic report available, the next step would be an appraisal of the physical possibilities of the basin. This report would take into account only physical and economic factors. It would appraise in particular the hydroelectric potential and, where necessary, the irrigation potential, as well as water surpluses and deficiencies in the various parts of the basin. The second report should present, both in descriptive and in statistical form, the salient features of any possible development, assuming the basin to be under unified control and without undue regard to present or historical

[4] Since the report of the Panel was first published, the work of several international non-governmental organizations concerned with the general principles of international water resources has progressed considerably. The general rules of international law applicable to the use of waters of an international drainage basin, as adopted by the International Law Association at its fifty-second Conference in Helsinki in 1966, are reproduced in annex VII.

patterns of use of land and water resources. This report, since it would be only a step in the preparation of a preliminary plan of development, should be considered a confidential technical report.

Having obtained information on the *status quo* in all its aspects and a knowledge of the physical possibilities inherent in the basin, the next and third step should be to embark on a preliminary plan of integration, giving full weight to human factors and to existing developments within the basin. The objective should be, of course, the optimum use of sites and water resources. To the extent that this may involve diversion of water from one subbasin to another, or changes in traditional uses, it may be necessary to incorporate provision for compensation or for offsetting benefits. The purpose should be to produce a plan that would provide a reasonable basis for discussion between the countries concerned. Whether their collaboration should be sought during this phase will depend on the circumstances of the case.

Fostering co-operation

For any further progress it is essential that the countries concerned be brought into consultation, for the next step will involve setting up a committee with members from each country presided over by a chairman and the necessary observers from the United Nations. The timing of this step would have to be judged in the light of political and other considerations, since the preliminary plan must now be put on the table for open discussion. The terms of reference of this committee should stress that the discussions imply no commitment of any sort, their object being to determine the areas of agreement and disagreement and to ascertain the reasons for disagreement. Does disagreement spring from economic factors or is it due to political or sociological considerations? If there is a disagreement over the appraisal of the basic facts of the case, joint technical teams might be appointed to attempt to achieve agreement on the factual questions in dispute.

Doubtless, each country will have its own idea of a national development plan determined by its socio-economic needs and by its natural resources (in water, raw materials, labour and capital), and its pattern of development will be governed by these considerations. These national projects will emerge in the course of the discussions, and the degree to which they may overlap or compete with one another will give a fair indication of the real sources of conflict and help to narrow them down. It is most important for the health of future negotiations that the differences in outlook and motive be brought to light, openly discussed and well understood by the parties concerned. The course of those meetings will be determined by the progress made. They will furnish a testing ground and, it is hoped, a prelude to further discussions on a permanent basis.

These preliminary meetings may result in any of the following situations:

(*a*) One or more of the parties decide that they cannot consider the preliminary plan owing to political difficulties. If this is a firm decision, it is obvious that no immediate progress can be made on the over-all plan, and the plan must be shelved "with regret" pending a more propitious time. It should never be dropped entirely. It may be that a part of the plan is salvageable without loss of substantial benefits and that this part does not require the participation of the dissenting parties. If so, this part of the plan could go forward.

(*b*) The parties decide that the plan lacks merit or that it is unsuitable for economic reasons, and therefore not worth pursuing further. This is hardly likely, in view of the way in which the plan has been prepared. Should this occur, however, discussion of an alternative plan should be encouraged.

(*c*) The parties express a desire to co-operate, with a view to implementing the plan in full.

(*d*) The parties agree in broad principle to the plan, subject to many reservations. It is this situation that is likely to arise most frequently.

As regards cases (*c*) and (*d*), measures should be taken towards appointing an *ad hoc* interim committee and, ultimately, a permanent international joint commission agreed to by treaty.

Permanent joint commissions

Two good examples of joint commissions are the International Joint Commission of the United States of America and Canada, agreed to in the treaty of 1909 between the United States of America and Great Britain, and the International Boundary and Water Commission set up by the United States of America and Mexico. In the latter case, a treaty of 1853 made provision for regulation of the waters of the Rio Grande and Colorado rivers for the purpose of navigation only. A later treaty, ratified in 1945, made provision for wider collaboration "considering that the utilization of these waters for other purposes is desirable in the interests of both countries . . . *in order to obtain the most complete and satisfactory utilization theorif*".[5] These joint commissions have international status. They are permanent bodies established to handle water questions that may arise from time to time, and to collaborate closely on all projects that are of concern to the contracting parties. Their activities cover the entire range of water matters: navigation, power, irrigation, flood control, drainage, domestic uses, sanitation, pollution and others.

Though the duties of the commissions just mentioned may not cover as wide a field as that envisaged for true integrated development, they are examples of the kind of organization that eventually should be established. The effectiveness of joint commissions will depend upon the political maturity of the countries concerned. Lessons learned from experience to date should help guide other nations away from wasteful delays and controversies. In the younger States, such commissions would require time to put themselves on a sound basis and

---

[5] Italics supplied.

to gain the confidence of their countries in carrying out their responsible assignment. In the meantime it is probable that an outside agency will be necessary (and even welcomed) in the capacity of co-ordinator, adviser or mediator with a view to keeping the talks alive and steering the discussion along objective lines.

At this stage, effort should be directed towards developing the machinery of co-operation rather than attempting to achieve spectacular results in the field. Thus, the less controversial subjects should be tackled first. For instance, preparation of a scheme for exchange of information and the gathering of basic data would be a logical first step. The mere process of preparing and implementing such a scheme will afford practice in working together and tend to generate an atmosphere of collaboration. Then, in order to arrive at some indication of the extent of surveys necessary and the cost of various works, the technical characteristics of such works and their functions in the general scheme will have to be discussed. This discussion will include at least some of the following: flood control, river training, reservoirs, river gains and losses, silt charge, reclamation in the various aspects required, surface and subsoil conditions, drainage, farm-cropping patterns, irrigation layouts, hydroelectric installations, domestic water supply, fish life, sanitation (especially anti-malarial measures), soil erosion and pollution.

Another subject will be the administrative aspects, involving the operation of the plan and day-to-day working arrangements. Some of the underdeveloped countries involved will be equipped with established and well-trained technical services; others may not be so well off. In some countries, international development will be handicapped by the existence of private rights and concessions. The question of expropriation will have to be considered, at least to the extent necessary to put Governments in a position to negotiate sound working arrangements. The extent to which such concessions should be recognized or others granted is of course a domestic problem for each of the countries concerned, but it is the view of the Panel that international developments are facilitated when all important water resources are nationalized or made subject to public control.

It is apparent that there is a wide range of matters which may be discussed and clarified by joint commissions. Many may be settled in principle if not in practical detail. It is only to be expected that some of the points will be controversial and will stimulate vigorous argument. But in a functioning commission such arguments will be conducted in an atmosphere of co-operation rather than dispute, with a view to arriving at the right answer in the light of integrated planning. The arguments may be recorded in the proceedings of the commission, but they will not form the subject of acrimonious official communication between the Governments.

It is emphasized that the representatives would come together to co-operate in planning, not to settle international disputes. Thus, it might be unwise in some cases to attempt to settle the matter of water allocations as a first step because this question might be influenced by all kinds of other factors, with the result that the atmospere would deteriorate at the outset. The policy should be to sidetrack major disputes and eventually approach them from a different angle so as to avoid, as far as possible, a head-on clash. Should it be of vital importance that a major difference be dealt with promptly, it should be handled by another body under different terms of reference. This is the general practice in settling difficult and controversial problems. Such negotiating or arbitrating commissions are of a temporary nature and are dissolved on completion of the task assigned to them.

The true concept of integrated planning in any major development calls above all for continuity of organized co-operation, and the only way to achieve this is by establishing a permanent joint commission. that is not overloaded with difficult questions to begin with, though it must deal with them eventually. The composition of such a commission and the juncture at which it should be created would be dictated to a large extent by the progress made at preliminary meetings of government representatives. In some circumstances the scope for integrated planning may not justify a permanent commission. At an early stage, the question of finance will come into the picture. The Governments concerned — especially those of the smaller States — may agree in principle to having a permanent commission but raise objections on the grounds of cost. To meet this objection, part of the cost might be covered under the technical assistance programme. Conditions for granting this financial aid would have to be thought out, but it is felt that money spent in nursing these commissions to maturity would be a good investment.

Since joint planning will raise questions of general policy as well as questions in the purely technical sphere, it is only to be expected that the Governments concerned will ask that others besides technical experts be included among the permanent officers when the formation of the commission is under consideration.

If there exists an organization similar to that of the United States-Canadian International Joint Commission, for instance, or the United States-Mexican International Boundary and Water Commission, it will hardly be necessary to create yet another commission on the ground that the existing machinery is not an integration commission in the true sense. In these circumstances the obvious step would be to change the framework and widen the terms of reference of such a well-proved and experienced organization. These commissions not only control waters in accordance with the agreed rules laid down in the articles of the treaty; they also make investigations[6] and take responsibility for the construction of new works. Moreover, they have the right of reciprocal inspection.[7]

---

[6] United States-Mexican Treaty article 6: "The Commission shall study, investigate and prepare plans for the flood control works where and when necessary"; article 7, "The Commission shall study, investigate, and prepare plans for plants for generating hydroelectric energy".

[7] *Ibid.*: "The Commission and its personnel may freely carry out their observations, studies and field work in the territory of either country".

In the case of the Nile Waters Agreement, responsibility for implementing the "working arrangements" does not lie with a commission but simply with the irrigation departments of Egypt and the Sudan. As the Sudan is the upper riparian State and the later organized irrigation consumer historically, most of the clauses in the working arrangements apply to it. In this case, the validity of the existing agreement has been questioned (by the Sudan) for the reason that the agreement was originally negotiated between Great Britain (on behalf of the Sudan) and Egypt. Whatever the situation is today, the Nile Waters Agreement has provided both countries with useful experience in the technique of co-operation in this field, and affords an example of how government technical services can work together in handling a complicated water control matter on a major international river.[8]

The varied circumstances make it impossible to generalize as to the composition of a joint planning commission. The very nature of the problem, however, makes it certain that engineers must play a large part. Indications as to its type and composition, or whether the establishment of a permanent commission is necessary at all, should emerge from the preliminary report. Subsequently, rules of procedure and terms of reference will depend on the outcome of discussions at the preliminary meetings.

Stated simply, the aims of the permanent commission should be to continue the work of the preliminary committee with a view (*a*) to arriving at a comprehensive plan of integration in principle, (*b*) to implementing the components of the plan as circumstances permit, and (*c*) to making such revisions in the plan as may be thought proper from time to time in view of changed circumstances or technological advances. It is obvious that the rate of progress will be slow in most cases and can only accelerate as the commission gains in experience and stature, a process which takes time and cannot be short circuited if the psychological build-up is to be sound. But within limits time should not be the primary consideration. What should be the primary aim is the creation of a sound and effective instrument of co-operation that eventually functions efficiently without outside intervention.

The preparation of the comprehensive plan will naturally raise a great variety of issues, all of which have to be analysed and settled in a spirit of give and take. What must emerge is a plan that exhibits two main features, first, a fair deal for all rather than a good bargain for one, and secondly, obvious benefits, direct and indirect, to all, although the benefits can hardly be equal. In addition, the whole plan — and each phase of it — must be thoroughly understood, not only by the Governments of the countries but by all their peoples. Therefore, the human aspects of the plan must be made clear, for no matter how imposing the engineering works may be, the succes of the enterprise must be measured by its effects in the homes, the fields, the factories, the mines and the offices.

Examples of co-operation

Although examples of co-operation in truly integrated development in the less developed countries are probably few, there are several instances of limited but useful co-operation. Some of these are referred to below.[9]

Nile Basin

There was, and still is, a great measure of co-operation on the Nile,[10] though some controversy has arisen over water allocations since the Sudan has become an autonomous State. The situation on the Nile is peculiar, and a detailed explanation as to how it has arisen is not possible in a few lines. As already mentioned, liaison is effected through the respective irrigation departments. But while the Sudan irrigation department normally operates only within its own frontiers and draws its irrigation supplies from the Blue Nile, the Egyptian department has a strong detachment permanently stationed in the Sudan, whose field of activities covers hydrological and engineering surveys over a great area of the basin, especially the White Nile, including the Lake plateau.

The Sudan is concerned with these studies in so far as the works resulting from them would affect it as, for example, in the case of the projected Jonglei canal for reducing water losses in the Sudd region. Egypt already has a large dam on the White Nile, the operation of which affects both countries and calls for co-operation between them. The latest example of co-operation is the building of the Owen Falls dam at the outlet of Lake Victoria. This is a multipurpose project to generate hydroelectric power for local consumption and store over-year irrigation supplies mainly for the benefit of Egypt. It should be mentioned that a large portion of the Nile Basin has been under a single administrative Power, with the consequence that working arrangements have been greatly facilitated in all fields of river control and especially of survey and investigation. In

[8] After extended negotiations between the Sudan and the United Arab Republic, a new Nile Waters Agreement was concluded between the two countries in 1959. Its key provisions regulate the allocation of benefits to be derived from the development of the river with particular reference to the High Aswan Dam at Sadd El Aali in the United Arab Republic. A significant innovation of the 1959 Agreement, as compared to the 1929 Nile Waters Agreement between Egypt and the United Kingdom, is the institutionalization of its provisions. Part IV of the Treaty provides for the establishment of a Permanent Joint Technical Committee, composed of equal members from each of the two Republics, charged, *inter alia*, with the elaboration of unified development plans, studies and data collection as well as with the supervision and execution of projects approved by the two Governments.

[9] Since the writing of this report a number of international bilateral and multilateral agreements have been concluded between the less developed countries in Africa, Asia and Latin America, arriving at the establishment of more or less institutionalized co-operation in the development and use of jointly shared international water resources. In several instances the United Nations and its affiliated organization have been instrumental in bringing the parties together and in providing data and preliminary feasibility evaluations for joint development programmes. In this regard, mention should be made in particular of the recent arrangements for the Chad, Zambia, Niger, Senegal and Nile Basins in Africa, the Mekong and Indus Basins in Asia and the La Plata Basin in Latin America.

[10] As discussed in the previous section.

the case, however, of the proposed Lake Tsana dam at the head of the Blue Nile, prolonged negotiations have been continually frustrated.

Further important storage works on the Lake plateau are planned, again mainly for the benefit of Egypt, which will have to depend on the co-operation of other countries to allow their construction. At present the countries involved are the United Kingdom and Belgium. In another ten or twenty years, however, the situation may have changed. If the proposed works on the Lake plateau and, in addition, the Jonglei canal can be built, it will be a fine example of progress in at least engineering co-operation. This might lead to similar co-operation all along the Nile, eventually including the Tsana dam.[11]

Gash River

This is a non-perennial stream that rises in Eritrea. A dispute arose in the early 1920s regarding irrigation claims on the Gash in Eritrea and the Sudan. This was satisfactorily settled in a spirit of co-operation between the Governments of the United Kingdom and Italy. One of the clauses of the agreement was that if profits on the sale of cotton in the Sudan scheme exceeded a certain figure, Eritrea would be paid a percentage of this excess.

Shire Basin

On the Shire, a tributary of the Zambezi, there is a multipurpose scheme being carried out for power, flood control and irrigation. This has called for co-operation with the neighbouring Portugese administration of Mozambique. It will also fit in with any plan for integrated development of the Zambezi.

Jordan Basin

In present circumstances, the Jordan can hardly be cited as an example of co-operation. Nevertheless, a measure of co-operation exists among the Arab States in connexion with the waters of the Yarmuk and what will remain of the Jordan. When the region came under the rule of Mandatory Powers, there was a tendency to take a global view of the basin, and the French and British authorities collaborated in plans for hydro-electric and irrigation development. An obvious measure was to use Lake Tiberias as a storage reservoir for both the Jordan and Yarmuk waters, and this was taken for granted by various planners both during and after the Mandatory period. Political conditions now make it unlikely that the lake will be so used, with the result that a natural reservoir site will be lost unless the States can compose their differences.

* * *

International co-operation in all fields is essential to peace and progress, but no one will deny that some fields lend themselves to co-operation less readily than others, and in this category are international river waters, especially in relation to irrigation uses. This point, mentioned earlier, is worth repeating. The allocation of water on an international, interstate or intercommunal river can never be easy either technically or politically. In some places irrigation is fundamental, and almost everywhere in underdeveloped areas it has enormous economic importance. "Historic uses" and "priority of appropriation" have, in many cases, come to have an almost sacred significance, irrespective of the actual benefits derived, or whether the water is being put to the best use. In addition, there are often collateral factors that further accentuate the difficulties of allocation. Shorn of this thorny question of consumptive uses, co-operation becomes far less complex, though seldom a simple problem.

Thus, the magnitude of the obstacles inherent in the whole concept of integrated development of an international river basin is a measure of the fruits to be gained if they can be surmounted and a river can be made into a bond rather than a barrier between peoples. This is a challenge that calls for tackling the problem systematically and persistently. The process will be a long-term one, and some projects may be dropped, to be taken up again at a later date, so that systematic reporting and record keeping are essential to ensure continuity and avoid unnecessary repetition when fresh personnel handle an old question.

As to subsequent procedures in fostering co-operation, progress will depend so much on the attitudes of the nations concerned that no cut and dried formula can be laid down. Once co-operation is properly established, solution of technical problems and implementation of the plan will follow in the course of time, provided the money is available. If the plan and its phasing are sound in conception and timing, the Panel assumes that somehow capital will be found.

[11] A UNDP (Special Fund) project for a Hydrometeorological Survey of the Catchments of Lakes Victoria, Kyoga and Albert became operational in 1966. The five-year survey executed by the World Meteorological Organization in collaboration with the Governments of Kenya, Sudan, Uganda, United Arab Republic and United Republic of Tanzania aims at the collection and analysis of hydrometeorological data of the catchments of the three lakes in order to study the water balance of the Upper Nile.

Chapter V

LINES OF ACTION

The specific problems which enter into river basin development have long been the concern of specialized scientific groups, which have worked across international boundaries. In the nineteenth century international conferences and scientific congresses in such fields as geography, soil science, navigation and engineering dealt with segments of river basin use and development. In recent years the exchange of experience in irrigation and drainage, design of high dams, hydroelectric power development, navigation improvements, and related fields has increased. Conferences have multiplied, and scientists and engineers have come into closer contact through publications and travel.

Within the United Nations and its specialized agencies interest has spread vigorously since the United Nations Scientific Conference on the Conservation and Utilization of Resources focused attention on river basin problems in 1949. At present international collaboration in the development of the world's rivers is more urgent and its importance more clearly recognized than ever before, and the opportunities and obstacles that lie in the direction of international action are more evident.

In the light of recent activities in this field, the Panel suggests in this chapter the major problems of river development that seem to cry for solution and the lines of action which international agencies might be encouraged to follow. What is needed is the pursuit of concrete action by both governmental and non-governmental agencies within a broad framework of United Nations policy. Much of that action hinges on exchange of experience looking to practical solutions of troublesome problems in countries which are emphasizing the effective development of their water resources in the public interest.

Common problems requiring international action

Previous chapters have described a wide array of questions to which the administrator, economist, engineer and agronomist have no definite answers. In those chapters the Panel has suggested various actions to be taken at the national level. Many of the problems which have been considered, however, are common to many countries and lend themselves to international action. But great gaps in knowledge hamper action in the river development field. The steps suggested below are intended to help close those gaps and ensure the fullest application of the resources of studies, materials, people and funds that are at hand.

Suggested steps at the international level may be grouped in five classes:

(1) Improving basic services in hydrology;

(2) Sharpening the tools for analysis and for concrete action in water resource utilization;

(3) Stimulating scientific and technical investigations;

(4) Aiding countries in developing their river basins;

(5) Laying the groundwork for reconciliation of conflicting interests over river basins of an international nature.

Administrative structure

A preliminary word must be said about the administrative problem. The Panel recognizes that allocation of administrative responsibility for carrying out water resource activities at an international level is similar to allocation of such work within a national Government. It differs from national situations chiefly in that it is far more complicated.

Different countries have allocated the work of studying, designing, building and managing river development in different ways, but none has yet arrived at what appears to be a fully satisfactory solution. As indicated in chapters I and II, the physical unity of a river basin lends itself to treatment of water management and related problems in one administrative unit, yet an integrated development raises difficult problems of correlation of policies in widely different fields, such as agriculture, water supply, education, health, forestry, power marketing and transport. Even if a Government were to provide for such a development of each of its major basins by an autonomous authority there would remain the vexing question of how to co-ordinate the separate authorities within the aims of national policies. Moreover, much of the basic work already has been started by agencies of the respective countries having only limited and discrete objectives: precipitation data may be collected by an agency mainly interested in forecasting for aviation, and soil conservation promoted by an agency set up to support farm prices and family-sized farms. As integrated river basin development receives increased emphasis within individual countries it becomes necessary for them either to shift responsibilities from established agencies to new agencies or to co-ordinate the work of the established agencies. In either event some kind of co-ordinating machinery soon becomes necessary.

The same set of choices arises on the international level as the United Nations and its specialized agencies become more concerned with river basin development. No single specialized agency has complete responsibility for water and related problems, though the activities of the United Nations, including those of its regional offices, impinge on river development at many points. Some progress in co-ordination of their diverse activities has been made through the interagency meetings on water resources held regularly during the past four years.[1] Further progress is essential.

The steps suggested by the Panel are intended to further constructive action by the United Nations and its specialized agencies as well as to ensure proper "promotion and co-ordination" by the Economic and Social Council and the Secretary-General of the United Nations.[2]

Improving basic services in hydrology

The systematic recording of basic hydrological data is a long-term task of high importance. Special efforts should be made to obtain adequate records for all river basins that are likely to be developed on an integrated basis. Furthermore, measures should be taken to ensure that more adequate use is made of available meteorological data in connexion with the planning and operation of water structures.

International standardization of hydrological instruments and of survey methods and criteria should be pursued, on lines similar to those long ago introduced in meteorology. It should be possible to look towards a time when data as to volume of water available, hydroelectric power resources, water quality and navigability of streams, to name only a few subjects, will be comparable among different countries. Although there may be special urgency in attaining such comparability within particular international basins, the benefits of standardization will be large everywhere because knowledge of experience in one area will often save time and cost in another similar area.

A survey of the status of hydrological services in the Member nations is being made jointly by the United Nations and the World Meteorological Organization; its findings will point to some clear deficiencies. Without awaiting the final results of that survey a number of major needs may be noted. Methods of quantitative and qualitative estimation of surface- and ground-water discharge should be evaluated, and information on them should be exchanged. Measures looking to prediction of the size of great floods are vital to the efficient design of hydraulic structures. Basic data on the characteristics of river beds are necessary to a prognosis of bank erosion, and stream bed and reservoir silting. Surprisingly little information is available on local moisture and thermal factors as a basis for predicting evaporation and net water losses and surpluses on land surfaces. These deficiencies should be remedied as soon as possible.

Among its other duties, the World Meteorological Organization is responsible for facilitating world-wide co-operation in the establishment of networks of stations that take meteorological observations, for promotion of standardization of such observations and for publication of data and statistics. Some of its data are of great value for river basin studies. However, there is at present no organization with responsibilities in hydrology similar to those of the World Meteorological Organization in meteorology. The Panel believes that it would be highly desirable if, by vote of its member Governments, the World Meteorological Organization were to expand its activities so as to take in hydrology, including study of stream discharges and ground water.

Once this responsibility has been established, the enlarged organization should, among its tasks, take the lead in:

(*a*) Promoting systematic recording of basic hydrological data;

(*b*) Establishing standards for hydrologic measurement and publication of data;

(*c*) Facilitating exchange of experience in the design of hydrologic networks and the conduct of river surveys;

(*d*) Furthering river flood forecasting services.

At the same time, secretariats of the regional economic commissions should be encouraged to make inquiries along the lines of the survey of hydrological data by the Economic Commission for Asia and the Far East and the World Meteorological Organization, or the study of hydroelectric power potential by the Economic Commission for Europe in Europe, and the Economic Commission for Asia and the Far East in the Far East. As indicated earlier, mountains of precipitation and river flow data will be of little value unless personnel are trained to make discriminating use of these. The recent World Meteorological Organization's training seminar on flood forecasting and water balance computation for government experts from the eastern Mediterranean area is an example of a type of service that might well be enlarged in co-operation with the regional economic commissions of the United Nations.

Sharpening the tools for analysis and for concrete action in water resource utilization

Any country's part in planning the joint development of an international basin can only be as effective as its ability to deal with internal problems of water resource utilization within its sector of the basin. However, there is among the nations no uniformity as to their forms of planning and administration, or regulation of local and private interests, and in many nations the administrative structure is only emerging or is still experimental.

Here the United Nations may be of considerable help to its Members. For a number of years the Secretary-General has been calling to the attention of Member Governments the importance of the manifold problems encountered. Various specialized agencies, particularly the Food and Agriculture Organization of the United Nations, the United Nations Educational, Scientific and

[1] Pursuant to resolution 533 (XVIII) of the Economic and Social Council, para. 6 (*a*), 2 August 1954.

[2] Resolution 417 (XIV), para. 1 (*a*), 2 June 1952.

Cultural Organization, the World Health Organization and the World Meteorological Organization, have been of aid in the fields of their special concern. Apart from their technical assistance programmes, to which the Panel refers later, they have made a commendable start on the job of disseminating information, by making exchange of experience easier among nations through publications, and in other ways. This work should be facilitated and expanded.

The Panel is aware that the various organizations of the United Nations family are active in many phases of river basin development. Vigorous interest in land management and the use of water in agriculture and fisheries is maintained by the Food and Agriculture Organization as a part of its operations and training programme. The United Nations Educational, Scientific and Cultural Organization, in its arid zone and humid tropics programmes, is active in making scientific studies and in spreading information. The World Health Organization helps establish standards and provide experience in water quality maintenance and in the provision of health services; the World Meteorological Organization is active in the field of meteorology and — the Panel hopes — soon, also in hydrology. This list of activities is only illustrative.

The regional offices are also active. The Economic Commission for Europe has for a number of years conducted systematic studies of hydro-power development. The Economic Commission for Asia and the Far East has for some time concerned itself with studies and surveys in its area, on flood control, hydro-power development, navigation and other aspects of river basin development. The Economic Commission for Latin America is currently engaged in a survey of water resources and their uses with special emphasis on their multi-purpose aspects.

The Panel believes that much more is urgently needed, both in expansion and in co-ordination of the programmes of all these agencies. There is no focus of interest on integrated river basin development. Continuing encouragement to Member Governments in these highly complicated and long-term matters is at present lacking.

The Panel discussed this state of affairs at length and concluded that nothing less than a special office or unit in the Secretariat of the United Nations can effectively carry out the heavy duties which the Panel believes it is necessary now to assume.

Such a unit would essentially have three interrelated responsibilities in the field of integrated river basin development:

(*a*) Systematic collection and comparison of the most important data, and promotion of a flow of information on world-wide experience through staff studies, the advice of outside experts, and regional and world-wide consultations and conferences;

(*b*) Co-ordination and promotion of the work of the specialized agencies as well as of the regional economic commissions, having regard to their interests and terms of reference;

(*c*) Assistance to the various United Nations agencies in shaping a pattern of concerted action for making technical assistance available to Member Governments in developing river basins.

The Panel cannot list the precise tasks such an office should perform, but it is of the opinion that the unit should concern itself at least with methods, procedures and standards with respect to the following range of problems, working in close co-operation with governmental and non-governmental organizations in the field of water resources:

Evaluating water resources — surface and underground — their exploitability and the conditions (technical and non-technical) under which exploitation could be achieved;

Estimating prospective needs of water users in relation to available supply for entire basins and sub-basins, taking into consideration possibilities for curtailment of wasteful use;

Regulating and guiding national, local and private interests in the use of water resources;

Estimating alternative costs of individual projects considered in relation to, or in combination for, a multi-purpose scheme;

Cost distribution among various purposes of a water project;

Evaluating direct and indirect benefits, economic and social, which may originate from prospective hydraulic works in a project area;

Evaluating direct and indirect costs, and the needs and opportunities for capital investment in a project area;

Organization and administration of river basin programmes.

The Panel recommends that a commensurate strengthening of the efforts of the various specialized agencies and the regional offices accompany the setting up of the proposed unit in the United Nations Secretariat. It commends the regular convening of interagency meetings on this subject and expects that, as the work progresses, these consultations will gain in importance.

Encouraging scientific and technical investigations

Universities, government laboratories and other research institutions play a decisive role in advancing the several frontiers of knowledge encountered in river basin development. In most fields of knowledge there is at least one international agency or organization that concerns itself with research and exchange of scientific information.

Several important scientific and engineering groups periodically bring together workers from many countries to discuss methods, techniques and results affecting important aspects of river management. Chief among them are the World Power Conference, the International Association on Large Dams, the International Navigation Congress, the International Commission on Irrigation and Drainage, the International Association on

Hydraulic Research, and the International Union on Geodetics and Geophysics, especially its Association of Scientific Hydrology, not to mention a number of prominent national organizations.

These international bodies study respective cross-sections of scientific and technical knowledge, with but little overlap. Although some are concerned with several purposes, none can be considered as covering the whole field of multiple-purpose river basin development, even in its scientific aspects, although their work may be of paramount importance in certain problems here considered.

The Panel wishes to reiterate that many technical and scientific aspects of river development still are lacking elaboration. Some elementary questions of how water moves through unsaturated soil, of how it is evaporated, and of how soil finds its way into small watercourses are not fully answered.

The Panel does not recommend any organizational changes affecting research at this time. It believes that steps should be taken to stimulate the exchange of information as to methods and results. New international publications may be needed. The Panel emphasizes that the specialized agencies, and the United Nations Educational, Scientific and Cultural Organization in particular, should pay special attention to ways of stimulating the international flow of information on research methods and results through means that are already in operation or generally authorized.

An international conference of a general nature such as that suggested in resolution 559 (XXI) of the Economic and Social Council does not have high priority at this time in the Panel's thinking. Conferences, no doubt, will in time be desirable, and the United Nations unit should advise on the calling of such conferences according to circumstances.

Aiding countries in developing their river basins

The United Nations and its specialized agencies offer to their Member States more than an opportunity to exchange information. Technical assistance may be obtained under the technical assistance programme of the United Nations, from the Food and Agriculture Organization, the United Nations Eductional, Scientific and Cultural Organization, the World Health Organization and the World Meteorological Organization. Loans may be obtained from the International Bank for Reconstruction and Development.

Technical assistance from these various agencies now includes the following types:

Technical advice and assistance by experts and consultants in organizing and carrying out inspections, surveys and programmes;

Training of individuals, by means of fellowships, training trips and on-the-job training;

Staffing of institutions, training centres and training seminars;

Dissemination of information;

Provision of equipment, apparatus and supplies for experimental laboratories, teaching centres and field surveys.[3]

This activity, widespread at it is, seems, in the Panel's opinion, to fall short of meeting existing and emerging needs in various respects.

First, although there exists a measure of co-ordination of a general nature, the operations of the various specialized agencies in the domain of integrated river basin development are far from integrated. This applies to the timing as well as the scope of the assistance given to various countries, and to over-all national programmes as well as to work in specific river basins. In this respect, however, the Panel noted a few commendable examples of concerted action.

Secondly, there appears to be insufficient co-ordination of action in aiding adjacent countries in various regions. The Panel recognizes the difficulties arising out of limitations both in qualified personnel and in funds.

Thirdly, it appears that the funds at the disposal of the United Nations and its agencies for carrying out this work are far short of needs.

Fourthly, there is frequently a lack of necessary engineering and socio-economic studies, and the resulting gaps in the presentation of projects cause serious delays in their consideration by Governments and may well limit the International Bank for Reconstruction and Development and other lending agencies in their operations.

If an office of the type suggested above were to be established within the United Nations, it could, given adequate staff, probably aid the Member States and the specialized agencies in eliminating the more glaring gaps in knowledge, in expanding technical assistance programmes wherever feasible and in correlating existing programmes and projects to a higher degree. Strong leadership in this field is not only needed in the widely ranging efforts of the United Nations and its specialized agencies but also within nations.

Every year of delay in exercising such leadership means increased dispersion of activities, increased resistance to correcting difficulties and unnecessary delays in much needed concerted study and action.

The Panel has not attempted to cover the problems of providing funds either for the strengthening of technical assistance or for carrying out river basin projects. The latter forms but a part of the much wider problem of general economic development.

The Panel, however, recognizes the financial implications of the need for strengthening certain aspects

[3] See *Official Records of the Economic and Social Council, Twenty-first Session, Annexes*, agenda item 7, document E/2827, annex: "Technical assistance activities of the United Nations organizations in the field of water resources". See also the biennial reports on water resources development in *ibid., Twenty-ninth Session, Special Supplement* (E/3319); *ibid., Thirty-third Session, Special Supplement* (E/3587); *ibid., Thirty-seventh Session, Supplement No. 13* (E/3381); *ibid., Fortieth Session, Supplement No. 3* (E/4138); *ibid., Forty-fourth Session, Supplement No. 3* (E/4447).

of technical assistance by the United Nations and its specialized agencies to provide timely help to Governments in planning and implementing river basin programmes.

Among the activities requiring special attention are hydrologic investigations, mapping, including aerial photography, soil surveys and soil fertility studies, research in the field of water quality improvement and studies of water requirements, sediment control and watershed treatment. Reconnaissance surveys of entire river basins by joint teams of the United Nations and its specialized agencies can also provide valuable help to countries contemplating river basin development projects. Such surveys would, of course, include problems of development of human resources.

Pilot schemes of various types undertaken in various parts of river basins with the help of the United Nations and the specialized agencies could provide valuable information and training facilities needed for the implementation of major projects. Likewise, training programmes should be continued and expanded, and wide dissemination of information on multipurpose programmes envisaged.

Large amounts of money will be needed over a long period for implementing river basin programmes. Integrated river basin development is urgent in many countries because a growing population on limited land leads to the feeling that any sound irrigation project must be undertaken. The urge to immediate action is strong in many depressed areas. Development of hydro-power also has high importance in view of the rapidly expanding demand for electrical energy.

The magnitude of the task ahead, as broadly indicated in chapter I, is large. If substantial progress towards this goal is to be achieved, methods of financing integrated river basin development in countries where capital resources are scarce must be further studied and developed.

Of primary importance in these studies are:

(*a*) A realistic appraisal of physical possibilities;

(*b*) An equally realistic appraisal of the economic, social and political consequences both of action and of failure to act;

(*c*) Development of concrete proposals for action;

(*d*) Provision of adequate funds to carry out worthwhile programmes.

The Panel feels that ill-advised or hasty action could be avoided if a financial programme were devised on an international scale under which adequate assistance for basic surveys and the development of feasible designs were made available to interested countries with the prospect that — where and to the extent necessary — loans also would be forthcoming for later construction work.

Laying the groundwork for reconciliation of conflicting interests over river basins of an international nature

The vital character of current and impending disputes on international streams has been shown in chapter IV where it is pointed out that lack of accepted international law on the uses of these streams present a major obstacle in the settlement of differences, with the result that progress in development is often held up for years, to the detriment not only of the countries concerned but of the economy of the world in general. A number of organizations are now engaged in an effort to clarify and secure general adoption of principles of international law applicable to the development of international river basins. The Panel recommends that the United Nations lend its support and encouragement to this effort to formulate principles as a basis for agreements between countries in order to avoid controversies and settle disputes between them. It also has been demonstrated that the earlier there can be agreement upon basic data and upon general plans the greater the likelihood of reaching an understanding on schedules for regulation and use of the flowing waters. Typically, the most intense friction arises over disputed data or over specific projects which are put forward before there has been discussion of broader aims.

The Panel believes that the United Nations can play a constructive role by offering to any nations that are interested the services of an office or unit which would act to bring together the parties concerned, to resolve fundamental factual questions before disputes have reached the stage of acrimonious political debate. The steps that might be taken by such an office or unit are outlined in this chapter. Their importance is clear. They cannot be taken without the consent of the affected countries, but it would be a mistake to await the independent initiative of all such countries before beginning an exchange of views. If we wait until the problems clamour for settlement, the precious time for data collection and tentative programming will have been forfeited. United Nations leadership is required.

The large international basins[4] that are still largely undeveloped promise a great opportunity for such leadership to promote sound and harmonious programmes.

[4] See map 2.

ANNEXES

Annex I

ORGANIZATION OF BASIC SURVEYS

The integrated development of a river basin covers a wide field, involving a multiplicity of projects, considerable effort and large investment. The success of such a development depends upon a number of favourable factors, including thoughtfully organized surveys and collection of adequate data that are prerequisite to judicious planning and implementation.

Inventory of resources

One of the first steps towards the preparation of an integrated plan for development of a river basin is to make an inventory of its resources. In doing so the authority responsible for the river basin development should make maximum use of the facilities of the existing data-collecting agencies.

In all advanced countries, there are State-run agencies for collecting certain classes of information and data, which are of value in the preparation of sound water and land development programmes. In the less developed countries they are comparatively few and of recent origin. In the case of meteorological data, practically every country in the world has a national meteorological service that is responsible for collecting the data and for co-ordinating the work of other agencies which carry out meteorological observations. In the case of hydrological and other data, there is usually not such complete co-ordination at the national level, and it is consequently more difficult to find out what data are available for any particular project.

In the less developed countries the national meteorological services may have been in existence only a short time, and there may be no national agency at all for collecting hydrological and other data. In the circumstances, the best use should be made of such data as are available, but urgent steps should be taken by Governments to improve their meteorological, hydrological and other services to ensure that more adequate observations will be made and that the data will be collected at national centres.

Some of these deficiencies could possibly be made up by interpelation and intelligent study of data relating to adjoining countries, if they have similar hydrological and climatical conditions. Full advantage should be taken of the United Nations Expanded Programme of Technical Assistance,[a] under which many countries have already received considerable aid in improving their meteorological, hydrological and other services and have been given advice on how to make the best use of available data.

In view of the universal demand for more abundant and more reliable data, coming in the wake of river basin development now being undertaken all over the world, there have come into being commercial agencies which collect data by using terrestrial and aerial survey methods, and which appraise development possibilities. They cover such work as soil survey and classification for irrigation development, land capability surveys of all kinds, vegetation surveys with particular reference to pasture improvement, forest surveys and economic studies on farming systems. They also do photogeological mapping direct from aerial photographs, and carry out economic studies for mineral development, where photo-interpretation, field work and geophysics all interlock. They have built up considerable staff, covering geology, geophysics, agriculture, soil science, plant ecology, agricultural chemistry and economics, and forestry. These private agencies may be helpful where government facilities are not adequate.

In order to make an inventory of resources, it would be necessary to:

(*a*) Appraise the adequacy of the available basic data, such as general-purpose geological and topographic maps, detailed geological, mineralogical and soil surveys, land capability studies, meteorological and hydrological data and records, maps of specific inundated areas under various conditions of rainfall and flooding, census and population trends, and other economic and sociological studies, including studies on the existing developments and their efficiency in the river basin;

(*b*) Determine what additional data are required for the purposes of the inventory;

(*c*) Devise methods, standards, procedures and schedules for acquiring the additional data;

(*d*) Arrange for the acquisition of such basic data as cannot directly be acquired conveniently, expeditiously or economically by the organization responsible for the development, by contracting with established data-collecting agencies, whether run by the State or by private enterprise, in accordance with given specifications and schedules;

(*e*) Establish international relationships for the accumulation, analysis and exchange of essential basic data and records of international rivers;

(*f*) Analyse and organize the data required, and

(*g*) Determine the magnitude, quality, nature and location of the underdeveloped water, land and related resources available for further development.

Assessment of needs

While the inventory of existing resources is being prepared, the agency in charge of the work should proceed:

[a] Technical assistance is currently provided to Governments, at their request, by the United Nations and its related agencies through two main types of programmes. One is the United Nations Development Programme, financed by voluntary contributions from Governments which are Members of the United Nations family of organizations. The second type of assistance operations are commonly known as regular programmes because they are financed from the regular budgets of the organizations concerned. At its twentieth session, in 1965, the General Assembly, acting on the recommendation of the Economic and Social Council, decided to combine the Expanded Programme of Technical Assistance (EPTA) and the Special Fund, established in 1959, in a programme to be known as the United Nations Development Programme.

(*a*) To estimate the required additional agricultural production, which would include not only food for the existing and the prospective increase in population, and raw materials for the existing and proposed industries but also production for export in order to improve or reinforce the balance of trade and to earn foreign exchange;

(*b*) To estimate the water required for ensuring the desired agricultural production;

(*c*) To assess municipal and industrial water requirements;

(*d*) To forecast the requirements of power for various purposes, such as pumping for irrigation, reclamation and drainage, industries and municipal needs;

(*e*) To estimate loss of human and animal life, and agricultural produce, and damage to property, caused by historical floods in the basin, and to determine the maximum tolerable flows at critical points in rivers and waterways, to minimize destruction to life and property by flooding;

(*f*) To appraise the required minimum flows in streams and waterways, and the necessary structural clearances, to support navigation;

(*g*) To determine the minimum flows at critical points in rivers and waterways, necessary to preserve and enhance inland fisheries, and the effects on fisheries of draining ponds;

(*h*) To appraise the need for the provision of recreational opportunities near any water development;

(*i*) To determine the incidence of water-borne diseases and diseases affected by the water régime, their causes and how they may be controlled or eliminated;

(*j*) To appraise the adverse effects of fluctuating levels in rivers, waterways and reservoirs;

(*k*) To determine the additional data which will be needed and the schedule of their collection in order to meet the data requirements in the various phases of planning for comprehensive development, and to estimate the cost of such data collection.

Progressive collection of additional data

The information required for the preparation of a comprehensive development plan may be classified under two principal heads:

I. Physical (including biological and chemical)

II. Socio-economic

Facts relating to the first class are concerned with data that can be observed, measured and recorded. The principal categories are:

1. Climate and hydrology:
   - (*a*) Precipitation, air moisture, wind, temperature etc.
   - (*b*) Evaporation and other meteorological data (including snow cover)
   - (*c*) Surface water
   - (*d*) Ground water
   - (*e*) Soil moisture
   - (*f*) Chemical quality of water
   - (*g*) Sanitary quality of water
2. Topography
3. Cadastral survey
4. Geology
5. Soils
6. Sedimentation
7. Vegetation
8. Fish and wildlife

Information in the second classification relates to socio-economic facts. These also are, in most instances, capable of being observed and measured. They include such items as the following:

1. Over-all basic economic data:
   - (*a*) Population distribution
   - (*b*) Income
   - (*c*) Employment
   - (*d*) Production
2. Functional data relating to:
   - (*a*) Agriculture
   - (*b*) Forestry
   - (*c*) Fishing and trapping
   - (*d*) Manufacturing
   - (*e*) Mining
   - (*f*) Recreation
   - (*g*) Transportation
   - (*h*) Power
   - (*i*) Flood, tornadoes, windstorms and coastal erosion damages
   - (*j*) Water supply and pollution
   - (*k*) Public health

By and large, it may be said that, all over the world, not excluding the most developed countries, there are serious deficiencies in the readily available basic data required for purposes of planning and development. This raises the all-important question of adequacy and how it should be determined. Adequacy is a matter of degree, and the responsible authorities must measure the risks of proceeding with the available data against the needs and the pressure of time. The various agencies in the field that are in a position to supply the different categories of data can advise the users as to the data available, and can help to determine the degree of adequacy. Close co-operation between the planners and the suppliers is necessary at all stages. However, if a fetish is made of collecting complete data before doing anything, much valuable time may be lost. Sometimes, the need for development is so urgent that it is desirable to proceed with the work at the earliest possible moment. It becomes necessary then to draw a distinction between essential and desirable data, and to proceed to collect the essential straight away. Regardless of these expediencies, the process of gathering data must be considered as a long-range programme, the most essential being accumulated first.

The basic data expected at any time will depend upon (*a*) the uses for which the information is sought and the time limit and area involved, and (*b*) the information the data-collecting agencies are able to supply. The first will vary from time to time and from place to place, as needs expand or change. The second will change as the science of resource surveying, interpretation of data, and research unfold. New possibilities are continually being opened up by scientific and technical advances. The adequacy of data collection will therefore need reviewing constantly, in order to meet the needs as conditions change, and to take advantage of opportunities that arise as surveying of resources progresses. Hence, the procedure for meeting deficiencies in information should include the preparation, annually, of advance programmes of resource surveying.

A proper correlation of data compilation and planning activities, will ensure, as far as possible under the circumstances, the necessary basic information at each stage of the river basin development programme. The degree of precision of data required increases as planning progresses from stage to stage. To begin with, the assemblage and evaluation of all available pertinent information will constitute part of the "preliminary investigation" that should go along with the preliminary study of the project. This will provide an inventory of the existing facilities, point out the deficiences to be made up, and identify the requirements of the programme. General coverage of the basin, with a view to collecting, compiling and analysing all the required data, will come next, and constitute a part of the second or the "reconnaissance" stage. This will directly precede the establishment of the feasibility and justification of the projected development, and its subsequent authorization. If and when this is given, the *avant-projet* can be undertaken. This should be based upon the data assembled during the preceding stages, with additional specific coverage for those portions of the basin in which more detailed investigations may be considered advisable. Then comes the stage for the preparation of plans and specifications, for which it may be necessary to undertake some still more detailed investigations, a phase in resource surveying known as "intensive coverage". This will provide the information essential to the correct designing of works, and to efficiency during the construction stage that follows.

Finally, after completion of the works, there will be a continuing analysis of basic information required for sound operation of the entire programme, and maintenance of its constituent projects, in order to achieve the design objectives. This continuing analysis (very important in a multipurpose project) will include, among others, hydrological data, making possible the forecasting of floods and low stages of stream flow, as well as such other information as is needed to ensure the best use of the integrated system of reservoirs and power stations. The operation of such a system involves dispatching water for its most efficient conservation, its optimum use on the land, the greatest protection of life and property, and the best utilization of the hydroelectric power potential. The dispatching of the stored water, and the electric power to meet these requirements is a delicate and complex task, requiring adequate, accurate and timely knowledge of the extent and intensity of storms and snowmelt in relation to the other basin characteristics and of the fluctuating demands on the power load.

Staff organization

The planning department of the development organization should have a strong investigation unit, with a number of divisions, dealing with such important matters as hydrology and sedimentation, geology and soils, social and economic information, surveys and plans, water requirements, power requirements, and such other subjects as may be relevant to the particular development in hand. The unit should be directed by a manager of outstanding ability. He must be able to give general direction and positive co-ordination to a number of highly specialized activities and divergent skills, ranging from economics through sociology to many fields of science and engineering. In the case of major developments, the unit is usually staffed with specialists who are capable of applying the results of basic research to each project. Minor projects, on the other hand, would not be able to support such personnel.

Hydrology division

The duties of the hydrology division would include the accumulation, recording and analysis of data concerning flood hydrology, sedimentation and the quantity and quality of surface- and ground-water supplies, as well as the procurement of instant reports of meteorological conditions, precipitation and river flow at selected points in the basin. It should be responsible for issuing flood warnings to areas likely to be affected. The staff should work in very close collaboration with the national meteorological service, which is normally responsible for collecting and analysing precipitation and other meteorological data and for advising other agencies on how best to use these data. It should also conduct such hydrological research as may be needed, utilizing model experiments, in order to find answers to problems involved in the development of the water and related land resources, to advise the director on the routing of floods and water flow under various conditions, and to ensure that the plans prepared are suited to the conditions revealed by the experiments, and are adapted to the purposes for which they have been designed. It may be said in passing that the availability of personnel trained in hydrology and sedimentation control lags far behind demand, not only in less developed countries but everywhere. More emphasis should be placed on training personnel, both to carry out basic research and to apply its results to specific problems. In general, the curricula of universities should be enlarged to embrace adequate hydrologic training.

A geological staff would be responsible for the collection and study of geological maps and subsurface sections. A principal responsibility is to determine the soundness of foundation conditions. As detailed plans are developed, a need is frequently felt for more intensive study of particular aspects of geological formations by the construction agency. The mapping sections must provide information on workable mineral deposits in the area, which will have a bearing on determining the economic feasibility of the proposed projects. Geological studies should also include investigations for ground-water supply. Data on certain characteristics of soil are required for estimating rates of infiltration and percolation, for determining storage capacities of soils and underlying materials, and for erodibility, under various uses, as well as other properties of soil types and associations.

Social and economic staff

Such a staff is a necessity, to evolve sound plans for any integrated river basin development; it is necessary to know what it is being planned for. What are the needs of the people inhabiting the basin? What levels of population, employment, income and production must the development be designed to serve? What social and economic problems need to be overcome, and what part may the development be expected to play in furthering valid regional objectives? Underlying any sound answer to these questions are certain basic economic and social data, and it is necessary that existing deficiencies in available data be eliminated by including in the planning activities an adequate programme of social and economic analysis. An over-all economic base study of the basin would be necessary in order to (*a*) analyse the over-all population and income potentialities, in the light of the economic and social trends, (*b*) determine the future needs of the regional economy, so that the river basin programmes can intelligently be addressed to them, and, finally (*c*) set forth future economic goals to which all effort in the region can be directed in a co-ordinated way. These goals are for the economy as a whole, as well as for its separate activities: agriculture, forestry, fishing, power, industry and mining. Much of this sort of information is now being gathered by census departments and other government agencies. Some of the deficiencies in data are due to gaps occurring between the periodical census operations. It should be possible to make these up by special study. It would remain to relate the compilation of the necessary social and economic information to the process of river basin planning, in order that such planning may be directed to meeting clearly defined ends.

Water requirements staff

A staff will be needed to undertake a thorough survey of the requirements for water from the basin for agricultural, industrial, commercial and domestic purposes. The reports must give precise location and limits of different kinds of soils, in order to furnish the basis for their intensive classification in relation to the agronomic properties of the land, requirement of water for irrigation of the crops to be raised, and for subsequent land preparation. In deltaic regions, this staff, in collaboration with the hydrology staff, should advise on the processes of delta formation, land use and area zoning. The latter would involve consideration of the best use of land under various conditions of inundation in time, depth and extent. Data will also be needed on the flow, strength and character of the pollution of basin waters by sewage and industrial wastes, and on the physical, chemical, bacteriological and other biological changes in the streams resulting therefrom. Information will be required in connexion with domestic water supply and industrial uses of water, and industrial difficulties in the use of polluted waters. It would also be necessary to obtain pertinent data on fish and wildlife, hatchery opportunities, and effect of stream obstructions on fish propagation. The staff will have to study the requirements of depths of water for navigation in different sizes of streams, as well as of the necessary bridge clearances, both for mechanized craft and country boats.

Survey and planning staff

Professional surveyors and engineers in a survey and planning staff would be responsible for carrying out detailed ground surveys, preparing longitudinal sections and cross-sections of streams, irrigation channels, roadways and drains, contour maps and site plans, and for determining the location, availability (in quantity and quality) and cost (including transportation) of the materials of construction, to enable the design and construction staff to prepare detailed specifications and plans for construction.

* * *

In organizing the basic surveys, stress is to be laid upon the necessity of providing intimate team-work between staff with the principal special skills and those with technical proficiencies required for the purpose of planning integrated river basin development, in such a manner as to secure the utmost co-ordination between them.

Annex II

CORRELATING MEASURES OF LAND IMPROVEMENT IN THE DRAINAGE BASIN WITH ENGINEERING WORKS ON THE STREAM

Land use measures in the drainage area are closely interrelated with engineering works erected on the stream and its tributaries for the control and utilization of river flow. Changes in land use in the watershed will affect substantially the régime of the river and its tributaries, and the movement of sediments, and will have a direct influence on the effectiveness of the major control structures.

The engineering works on the stream will, on the other hand, exert great influence on the agricultural pattern and level of production in the drainage area. This influence will be greatest in the parts commanded or protected by the engineering works, but will in most cases extend over the entire area, as a result of general economic and social development brought about by the river basin project.

Correlating land use policy in the drainage area with the engineering works on the stream and their operation is often a complex and difficult task, especially in the case of a large multipurpose river basin development. In some cases the task is made more difficult by the fact that the influence of watershed treatment on the run-off cannot always be expressed in exact terms. As research in this field progresses, however, uncertainties and controversies are lessened.

Within the United Nations, it is the responsibility of the Food and Agriculture Organization, among the specialized agencies, to carry out watershed treatment studies. This is done through selected experimental and demonstration projects in different areas, as well as by training technicians on the job and in training centres and institutes. The Food and Agriculture Organization is also undertaking the preparation of a handbook on watershed management in collaboration with the United Nations Educational, Scientific and Cultural Organization, the latter dealing with the research aspects of the problem.

Measures for improvement of the river basin

Multipurpose river basin projects sometimes involve competing and conflicting interests; these must be resolved in such a way that the available water is used for the greatest possible benefit of the population of the river basin and the country as a whole. In this respect, the river basin becomes the unit for multipurpose river development planning.

Apart from a few cases where the river régime is so favourable that it does not require major corrections, multipurpose projects can only become effective when the damaging flood peaks are reduced and flood-water, stored during the flood period, is utilized for useful purposes during periods of need. This can be achieved by several methods: (1) by storage reservoirs built in the main river channels; (2) by a large number of reservoirs and flood detention structures on the tributaries; and (3) by improved use of land in the watershed. In many cases, a combination of all three methods will provide the best solution.

Watershed management in the past has not received the attention it deserves. This was due mainly to the fact that water development projects dealt only with individual river sections, where the immediate tasks could be solved by erection of diversion works, power plants and storage reservoirs. Only recently — and even now not sufficiently — has the important role of watershed management in river basin development been recognized.

Whatever happens to the watershed will affect the flow of water and transport of sediment in the lower reaches. Bad cultivation practices, burning and cutting of forests, overgrazing, grass fires will increase the run-off, cause soil erosion, and consequently sediment transport. Good watershed management, on the other hand, will retain more rainfall on the land and improve the river régime by reducing flood peaks and sediment transport.

At the same time, good watershed management will serve the direct purpose of better agricultural production, better forests and grassland, better local water supplies, better income from the land, and consequently higher living standards. In this double benefit lies the great value and importance of watershed management.

As regards the influence of watershed management on the river régime, compared with the value of storage reservoirs in the main valleys, this question has recently been under extensive discussion. Often the issue has developed into a real controversy among engineers and agronomists, and in some countries also between government departments. Supporters of the major starage reservoir solution often emphasize the impossibility of controlling exceptionally heavy floods by watershed management work covering the entire catchment, even if these measures are combined with headwater storage and detention dams. It is now generally accepted that watershed improvement measures can reduce substantially the smaller and medium floods, though they will not have such a decisive influence on exceptionally high ones. In many river basins, the frequently occurring medium floods actually cause more damage to agricultural land.

On the tributaries and in the headwaters flood damage to agricultural land is likewise very high. Watershed management is, therefore, essential for flood protection. Improved land use, especially good forest and grass cover, will in almost all cases also substantially improve spring yields and the low-water discharges of rivers.

But even more important than the discharge-equalizing value of watershed projects is their contribution to sediment control. Except for river bank erosion, almost the entire sediment load carried by main rivers originates in the headwaters. In a great number of major reservoirs, heavy silting creates difficult problems and impairs the economic value of the entire project. Many examples can be cited where the storage space available for useful purposes is rapidly decreasing and, in many cases, no new storage space can be found in the main river channels to replace reservoirs that are swiftly silting up. The heavy silt load causes trouble also in the river channel, on canal headworks. All this makes sediment control a vital issue, which can be solved only by improved watershed management combined with detention and small storage reservoirs on the tributaries. In hilly areas, torrent control works will also have to be included in watershed management measures, and will help to reduce the transport of heavy bedload.

It is also necessary to consider the adverse effect storage reservoirs in the main river have on the river channel. Where natural sediment transport is interrupted by a reservoir, the sediment-free water will cause a degradation of the river bed in the downstream reach, often damaging riverain lands and structures built in the channel.

Watershed improvement measures are, generally speaking, a healthier means of improving the river régime and should, therefore, be applied everywhere where conditions are favourable.

The two measures, storage of flood-water in reservoirs and watershed management, should in any case be co-ordinated. It is important that watershed management measures, including flood and sediment-detaining works in the headwaters, should be started at an early date. These latter should be built, if possible, at key points of the watershed, where sediment transport can best be controlled before the major reservoirs are built. In this case, they would have much more value than if they were built when the reservoirs were already heavily silted.

Role of watershed improvement measures

The feasibility and value of watershed improvement measures will depend largely on conditions of the watershed. Climate, amount and distribution of rainfall, topography, steepness of slopes, erodibility of soils and existing vegetative cover are the major factors on which the success of watershed management will largely depend. Economic activities such as different farming and grazing practices and shifts in cultivation will, of course, also largely influence the state of the watershed.

For river basins in steep mountainous areas, where geological erosion is heavy, there will be little hope that watershed management can contribute substantially to improvement of the river régime. Any measure to retain the soil and water on the slope will be too expensive and therefore not economically feasible. Torrent control works might help to alleviate the evil; their field of application will, however, in general be limited.

In watersheds with favourable topography, where improved land use practices can be easily introduced, where the rainfall distribution is not excessively uneven, and the storm run-off not too heavy, and where improved agriculture and good forest management can yield good economic returns, watershed treatment can play a dominant role.

Equalizing effects of vegetative cover on stream flow

As already mentioned, in most cases watershed management measures can not only bring about a substantial decrease of flood peaks (except with very heavy floods) but also generally increase water discharge during the dry season. There are, however, exceptions to the rule. In areas with low rainfall, with a relatively low run-off coefficient, improved land use may lead, by increasing the vegetation, to a heavier use of water through evapo-transpiration and this, in turn, may cause a water shortage downstream. In some cases, improved vegetative cover in the headwaters may also reduce to an undesirable extent the river flow during the rainy season. This is the case when flood spates in the lowlands are needed for flood irrigation, water spreading and replenishment of the water-table. As an example, wadis in Africa can be cited, whose flood often replenishes well supplies and provides water for certain crops. The reduction of flood spates by water-consuming vegetation in the watershed would, in such a case, lead to a shortage of water for livestock and human consumption in the lower areas.

It might, of course, be more important from an over-all point of view to retain and utilize the water in the headwaters and to compensate the downstream users from other sources. Each case will have to be decided on its own merits.

These examples apply to arid or semi-arid areas, and illustrate some of the considerations relevant to the development of a good watershed management programme. In the monsoon region, watershed management aimed at retarding and reducing run-off has almost always a beneficial effect on the discharge of the main river.

Role of forests

Forests are usually found at higher elevations. Here the slopes are steepest, soils are less stable and more easily eroded unless properly protected, and precipitation occurs in the greatest quantities. Such lands constitute the zones of highest annual water yield. This is due primarily to the greater amount of precipitation, but also the lower average air temperatures are in part contributory. Forest lands are a major source of water that sustains stream flow during non-storm periods. They may also be the source of frequent devastating floods if not properly managed. Precipitation in the form of snow is generally more frequent on forest lands and accumulates to greater depths. This, of course, is due to the generally higher elevations.

Forest lands offer valuable opportunities for effecting changes in the hydrologic characteristics of watersheds. Such changes may be for good or bad. Hydrologic conditions of forest lands may vary over a much greater range than is the case with any other type of land. This great range in hydrologic factors is brought about by variations in forest type, conditions, and form and intensity of use. A forest stand may range from a dense cover with two or three canopy levels to the other extreme of almost complete denudation. The stand may be made up of coniferous or broad-leaved species, deciduous or evergreen, or mixtures of each. The forest may be undisturbed; or it may be grazed at various levels of intensity; or it may be logged by extensive clear-cutting, or patch cutting, or individual tree selection; or it may be burned under varying degrees of intensity and destructiveness. All of these conditions and varying degrees and types of use will effect changes in hydrologic factors that influence watershed behaviour.

The erosion potential might be quite great on forest lands. This applies especially to forested areas along the headwaters of rivers, where slopes are generally steeper than with other types of land, and also because soil development has occured under the protective influence of the forest cover. The maximum protection from erosion is obtained with a dense vegetative cover, with a deep root system fully occupying the soil, and abundant litter and humus covering the mineral soil surface. With other things equal, erosion will vary with the degree of protective covering.

Thus, forests may be changed or used to meet the objectives of watershed management for a specific area. If the objective is to rehabilitate deteriorated lands and thereby decrease flood run-off and erosion, efforts would be made to build up the forest. The necessity of protecting the area from fire and uncontrolled grazing is a first requirement, since these things are incompatible with the development of a dense vegetative cover and a good protective layer of litter. For example, in western United States of America, comparisons of storm run-off and erosion rates from burned and unburned watershed show that storm peaks may be increased fifty to a hundredfold after a watershed has been denuded by fire, and erosion rates increased fifty times during the first year.

If the objective of watershed management is to increase total water yield or the yield during certain seasons, activities aimed at reducing evapo-transpiration losses should be carried on.

The density of forest stands may be reduced by a heavy cut. If soils are relatively non-erosive, 60 to 70 per cent of the basal area may be removed. A study in the Rocky Mountains of the western United States showed that increased water for stream flow was in direct proportion to the residual stand. As an extreme measure, to determine the effect of clear-cutting an entire watershed, such a study was conducted at the Coweeta Hydrologic Laboratory. All woody vegetation, including trees and shrubs, was cut and left where it fell, to protect the soil. With an annual precipitation of about sixty inches, there was an increase in stream flow of seventeen inches the first year after treatment. Althought sprout growth was mowed back each year, the stream flow increase fell off gradually to about eleven inches, where it remained nearly constant for a number of years until the study was terminated. Another watershed was similarly treated, but the sprouts were not cut each year. This watershed showed the same initial increase in yield, but the increase dropped off each year as regrowth of vegetation occurred until it was only about two inches ten years after treatment.

Role of grass cover in equalizing stream flow and controlling erosion

Good management of the vegetal cover of grazing lands, whether these be tall or short grasslands, or various types of shrub and semi-desert scrub associations, may under some conditions reduce the stream flow; under others, increase it. On semi-arid grassland and grazing ranges, one method of improving the plant cover involves the construction of contour furrows or various types of water-spreading devices to keep the sparse rainfall from running to waste down the watercourses and to make it available to the thirsty vegetation. Here, good management may lead to equalizing of stream flow over the season, but it may also reduce it.

Where permanent grassland or temporary pastures occur in a medium- to high-rainfall forest environment, the grass cover may induce a higher run-off than the original forest cover, but the water may be reasonably clean. Improved pasture management of these more humid environments, whether temperate or tropical, generally involves replacement of the tall, matted type of herbage by a shorter, improved herbage which is kept closely grazed. These improved pastures would not have the same water-retaining capacity as the tall dense herbage, with its rotting humus layer, that they replace.

There is some variation in the root depth of different grass species: some extract moisture to a depth of six feet whereas others only penetrate four feet or less. Thus a possible saving of water may be realized by using the shallower rooted species. In areas of low rainfall, the shallower rooted species may not be suited because the moisture available within the shallow root zone may not be enough to sustain the plants during drought periods.

An important item to consider in grassland management is the efficiency of use of water by different grasses. Field-plot observation, in the state of Utah, of the amount of forage produced by pure stands of smooth brome grass, timothy, Kentucky bluegrass, and a mixture of dandelion and sweetsage have shown which grasses commonly used in reseeding are most efficient in water use. Smooth brome grass consumed the most water but also produced the most forage and thus made the most efficient use of the water consumed. Forage yield amounted to 350 pounds an acre for each inch of water consumed. By comparison, timothy consumed 0.79 inches less water, but produced only 135 pounds of forage an acre for each inch of water.

Therefore, although manipulation of grass may not offer much opportunity for increasing water yields, it is important to favour those species that utilize the water most efficiently.

A study in Colorado illustrates how livestock grazing increases run-off and erosion. Run-off and erosion caused by heavy-intensity summer storms were measured from a series of plots for a number of years prior to any treatment of individual plots. No significant difference existed between plots in their reaction. Some of the plots were then subjected to a moderate intensity of grazing — that is, 30 to 40 per cent of the annual herbage production was utilized. Another group of plots was subject to heavy grazing use, 60 to 75 per cent of the current growth being utilized. The remaining plots were left undisturbed.

Following treatment, run-off from the heavily grazed plots increased to three times that from the ungrazed, while run-off from the moderately grazed plots also increased, to about three times that from the ungrazed. Erosion on the moderately grazed plots was not significantly greater than on the ungrazed.

Often there may be a need for supplementary measures, such as contour furrowing or terracing, to break up gully patterns; this should be followed by seeding.

Influence of improved management of cultivated land in the watershed on run-off and sediment transport

Improved cultivation methods and practices on cropped land in the watershed can also contribute substantially to water and sediment control. Apart from steep mountainous areas where geological erosion is going on, it is mainly on badly managed farmlands that erosion causes the heaviest damage. It is on these fields that heavy run-off and sediment transport originate.

Ploughing down the slopes, and leaving no cover during the seasons of concentrated rainfall have been reasons for heavy erosion. It is true that in many instances soils have been put under crops which should have been left under grass or forest cover, but it is equally true that much cropped land could be maintained in good condition if cultivation methods suited to the prevailing conditions were applied.

Ploughing on the contour, strip cropping and use of cover crops are the main methods which have proved effective in reducing and retarding run-off and intercepting and reducing sediment transport. Where, for economic or social reasons, soils on steep slopes have to be kept under crops, these measures might not suffice. Trenching and terracing will have to be applied in order to avoid erosion.

In addition to slopes, the intensity of rainfall and the properties of the soil are the major factors influencing erosion and run-off; but the type of crops grown will also have a great influence on the rate of erosion, and the cropping pattern should be adapted as much as possible to the need for reducing erosion and run-off. It is, however, not only on the heavier slopes that the greatest erosion and the heaviest run-off originate. They occur often on moderately sloping, cultivated uplands, especially if the soils are shallow and, due to their low fertility, neglected. In such cases rain-water flows unchecked in sheets over the slope, concentrating in gulleys and gaining in impetus where slopes become heavier, thus causing damage to lower lands.

The solution in such cases is to increase the productivity of the upland soil to make it more attractive to farmers for improved cultivation. The edges of these flat slopes need special attention, because it is along this line, where the slopes get heavier, that erosion starts; here control measures are needed. In any case a grassed strip along the edge should not be allowed to be ploughed up.

The same applies to certain riverain lands, where, if the bank is not protected, gully erosion can cause great damage, not only to the land but also to the river channel, by increasing the sediment carried into the river bed by heavy concentrated run-off from the banks. This is a clear example of the correlation existing between land use and engineering works on the stream.

The remedy against bank erosion is prohibition of cultivation on a sufficiently wide strip along the bank, which is then protected by permanent vegetative cover.

Irrigation farming will in many cases help to maintain a good vegetative cover by providing the needed soil moisture over the entire vegetative period. On sloping land, however, irrigation should be planned and practised with care in order to avoid erosion caused by concentrated flow from a break in a canal bank or from over-irrigation.

Introduction of measures aimed at reduction of erosion and slowing down of run-off on cultivated land cannot be separated from other improvement measures. Other improvements, better seeds, fertilizers, and many other measures have to be applied in order to assure better yields and better returns to the farmer. Without such improvement there would not be sufficient incentive to justify the effort needed for introduction of conservation measures.

Engineering measures to retard run-off and control erosion

Where land deterioration has progressed too far, biological improvement measures, even when combined with better farming, range and forest management methods, will not be sufficient to check run-off and erosion. In such cases, watershed management has to include engineering measures.

On the land these measures include trenching, terracing, spillways built in terrace banks, gully check, dams, run-off interception canals and small tanks and ponds. All these are integral parts of proper watershed management. To these belong also larger structures such as flood storage and detention dams and gravel detention structures. Water storage and flood detention dams can be utilized for irrigation, and providing water for livestock, for domestic consumption and for fish ponds. In many cases, irrigation water is indispensable for better use of land in the watershed. In the monsoon area, no good second crop can be grown without irrigation, and supplementary irrigation for the main crops is also needed to produce a safe main crop.

As the various types of watershed improvement measures have to be planned on a catchment basis, with a view to optimum utilization of land, water and human resources, these plans for watershed management, based on hydrologic units, have to be co-ordinated with the engineering works on the stream and their methods of operation.

Advantages and disadvantages will have to be balanced, the double objective being improvement in use of land in the watershed and improvement of the river régime and sediment transport to serve the purpose of the major engineering works. This planning work will be a complex task and will need good co-operation in all its aspects. The work should start at an early date and should include cost and benefit appraisal. Experience in many countries has shown that neglect of this important part of river development leads often to great difficulties at later stages, including financing of watershed management and related works.

So far it has been mainly the influence of land use improvement in the watershed on engineering works on the stream that has been discussed. But, just as land use in the watershed will affect engineering works downstream, so will major engineering works influence land use in the areas commanded by them, and also land use in the "upper" watershed itself.

Influence of major engineering works

Effect on land use in the drainage basin

One of the most important objectives of engineering works on streams is to achieve water control in commanded areas for improvement of agricultural land use, which includes not only cultivated land but also forests, grasslands, fisheries and rural settlements. (It may be noted that command can also be achieved by pumping water to higher levels.)

In planning storage reservoirs, flood dikes and flood channels, the losses from submerging land or occupying land for structures should be weighed against gains obtained by providing safety against floods, and by providing irrigation water to large areas from storage reservoirs. In calculating the losses and benefits, consideration should be given to the possibility of using reservoir areas for cropping or for pastures as the water recedes.

In a well-conceived river development project, the benefit will substantially outweigh any losses, but there are often several alternatives, and in deciding, the solutions giving optimum benefit and least damage should be selected. This applies to the selection of flood channels, dike alignments and width between dikes, and height of storage level, where the area of flooding and storage volume can be decided only after comparing cost and benefits of the various — often competing — users.

In building reservoirs, valuable low-lying land can often be protected by dikes. The effect of high-water levels in reservoirs and canals on ground-water — affecting neighbouring agricultural land — has also to be taken into consideration.

In planning flood control works, it must also be borne in mind that the narrowing of flood channels by too closely spaced flood dikes may increase the flood hazard to more valuable land. In addition, flood dikes should not impede the natural drainage of the land they are designed to protect. In cases where the blocking of natural drainage channels cannot be avoided, artificial drainage should be introduced. In many cases this can be achieved only by lifting water by pumping.

Effect on fisheries

On a great many rivers, fisheries are an important economic asset, and it is essential that, when planning and designing engineering works, their interests should be taken into consideration. The possible influence of engineering structures on fish life in the stream will vary according to existing natural conditions and the loocation, type and size of engineering works.

Dams may constitute physical barriers or deterrents to the migration of fish, both upstream and downstream. Their effect will almost always be unfavourable except that they may act as a barrier to harmful fish which otherwise could invade the productive upstream area. Dams may exterminate existing fisheries, but in turn create reservoirs of greater productive capacity, albeit for a different fauna. Altering of the river flow may influence and change the space and size of spawning and nursery grounds. Changed food production zones or their components and the fluctuation of reservoir levels will also affect fish life.

Diversions and conduits (penstocks, turbines, pumps, tunnels, canals) may cause loss of fish. They may carry fish into new habitats and may introduce new types of fish or aquatic organisms into the river.

Soil and water conservation measures may alter aquatic environment by changing the quantity and pattern of run-off and silt. Or they may also produce chemical and temperature changes.

Drainage work may reduce marshes, lakes, lagoons and estuary areas, or change the stream course.

Levees and dikes may change a stream's course and velocity, and depth of water. Dredging operations will alter the stream's bottom and banks.

Pollution control will in general have beneficial effects by reducing deleterious effects of polluted water.

As can be seen from the above, engineering works will affect the migration of aquatic organisms as well as their feeding and growth. Spawning growth and mortality, and the size of stock will also be influenced, as well as the stock composition.

The losses or benefits to fisheries caused by engineering work need to be evaluated in the light of detailed studies and economic appraisal within the framework of the river basin project. These studies should also include possible adaptation of engineering works to the requirements of aquatic life, such as incorporation of fish passes into dams, rakes and electric deterrents, and other measures related to the régime of rivers and reservoirs.

Irrigation development and land use adjustments

The greatest impact exerted by major engineering works on land use is through the supply of irrigation water to large areas. In an arid zone, introduction of irrigation will change the entire land use pattern. Even in many humid areas safer and higher yields can be obtained and new cropping systems, involving double and triple cropping, introduced by providing irrigation water to the land.

Such changes in land use can be of great dimensions in the case of large streams or large storage reservoirs. For multipurpose reservoirs the delivery of water for power, navigation and irrigation will have to be adjusted to meet the requirements of all major users.

Major engineering works can also be used for storage and diversion of water for rural water supplies on the stream, including chains of water points for livestock.

Drainage works

The success of irrigation generally depends largely on f-fective drainage. Drainage becomes often a difficult problem in multipurpose projects, when canals, dikes, highways and railroads interfere with natural drainage conditions. The difficulties can often be reduced if proper attention is given to the problem in the planning of the scheme.

Power and navigation

In multipurpose projects where water supply from the rivers has to be adjusted to power and navigation requirements, and to needs of irrigation, it often becomes necessary to adjust the cropping pattern to the new conditions resulting from the changed hydraulic régime. In addition to economic conditions and climatic considerations, traditions and other social aspects will play a certain role in working out these new agricultural land use patterns.

The possibility of water transport, created by major engineering works in the stream, will also influence the land use pattern by providing cheaper transportation facilities. Likewise, better communications will be created in connexion with large multipurpose projects. Industrial development, stimulated by the engineering works, will produce new markets for more and higher-grade food-stuffs, and this in turn will lead to improved use of land for more diversified crops.

Conclusion

Correlating the often competing interests of various types of land use, and relating them to the requirements for successful technical and economic operation of major engineering works on the stream, are a complex task.

For the correlation of the various land uses, one with another, climatic, hydrologic, soil and agronomic studies combined with social and economic studies will have to be carried out. They are needed for establishing a suitable land use pattern in the watershed and in the lower part of the drainage basin.

The correlation between engineering works on the stream and land use improvement measures will need the co-operation of the administrator, the engineer and the social worker with the group of land and water use specialists. For successful development of a river basin, the closest co-operation among all these is required.

It is important that development plans should be correlated also in time, as it is essential that land use measures in the river basin should be carried out at an early stage in order to provide the needed protection and help to the major engineering works on the stream. On the other hand, certain parts of the major engineering works — generally those bringing quick returns, such as production of hydroelectric power — are often implemented at an early stage, in order to provide funds needed to carry on the rest of the scheme.

Implementation of large river basin development projects by steps is generally dictated also by financial considerations, but gradual development may be even more necessary in order to gain experience and to facilitate adjustment between the various users of river water and — in greater measure — between the various forms of land use in the drainage basin.

Annex III

SOME ILLUSTRATIONS OF ECONOMIC EVALUATION METHODS AND TESTS

Fiscal and financial feasibility

For lack of more refined measuring sticks, Governments frequently rely on simple tests of fiscal and financial feasibility.

The fiscal test is a crude but often useful test, particularly where irrigation benefits are the most important objective of the programme and the Government expects the whole or part of the annual costs to be repaid by farmers (through water rate payments or land revenue tax). In making this test, planning authorities compare costs with assessments to be made on a traditional basis of taxation, taking into account amount of water made available, acreage to be irrigated and crops to be grown. Which part of the annual costs (including an amount for depreciation and interest) has to be repaid in a "feasible" project may depend upon appraisal of indirect benefits or secondary effects and opportunities. Land and water users associations in South America, for example, often are supposed to cover all costs; in some Asian countries, Governments are satisfied with 50 per cent direct coverage.

A financial approach was used in India, for example, in the pre-partition period and retained some importance also after 1947. This approach was expressed in the financial "productivity test" used as the criterion for irrigation projects. The computations showed whether a project was able to earn sufficient revenue to pay a certain minimum return after deducting all working expenses (operation and maintenance) as well as simple interest on the capital cost of construction (plus any arrears of simple interest up to the given year). The interest rate, standard for capital outlay raised directly rather than by borrowing, was 6 per cent from 1921 onwards. Although the Government of India reduced the return considered to be the criterion for productivity from 6 per cent to 3.57 per cent at one point, a subsequent raise left it at 4 per cent. It appears that many projects failed to pass this financial test despite the fact that they might in other ways be economically advantageous.

Following the creation of an independent India, a Planning Commission was established. In tackling a serious food shortage the Commission set out to double the area under irrigation within a period of from fifteen to twenty years. The simple criterion was that "irrigation projects should be undertaken wherever there are facilities for such projects". An accompanying condition was that the project should "add to the food production in the country". This purely physical test relegated the old financial productivity standard to a much lower position in its effect on the determination of project priority.

Standards for formulation of plans in the United States of America

In the United States of America, a statement of policies, standards and procedures for evaluation of water development projects has been prepared by an executive group.[a] In addition to discussing the objectives of planning, planning policies and procedures, and the settings in which plans are prepared, this document makes the following suggestions as to the standards for formulating plans and calculating benefits and costs:

"C. *Standards for formulation of plans*

"1. All plans shall be formulated with due regard to all pertinent benefits and costs, both tangible and intangible. Benefits and costs shall be expressed in comparable quantitative economic terms to the fullest extent possible.

"2. Comprehensive plans shall be formulated initially to include all units and purposes which satisfy these criteria in quantitative economic terms:

"(*a*) Tangible benefits exceed project economic costs;

"(*b*) Each separable unit or purpose provides benefits at least equal to its costs;

"(*c*) The scope of development is such as to provide the maximum net benefits;

"(*d*) There is no more economical means, evaluated on a comparable basis, of accomplishing the same purpose or purposes which would be precluded from development if the plan were undertaken. This limitation refers only to those alternative possibilities that would be physically displaced or economically precluded from development if the project is undertaken.

"3. Net benefits are maximized when the scope of development is extended to the point where the benefits added by the last increment of scale (i.e., an increment of size of a unit, an individual purpose in a multiple-purpose plan or a unit in a comprehensive plan) are equal to the costs of adding that increment of scale. The increments to be considered in this way are the smallest increments on which there is a practical choice of omission from the plan.

"4. Reports or plans shall indicate the scale of development that would result from application of the foregoing criteria considering tangible benefits and project economic costs expressed in comparable terms. This will provide a baseline from which the effect of considering intangibles can be judged.

"5. Reports and plans shall also indicate the extent to which departures from that scale of development are proposed in order to take into account intangibles or other considerations warranting a modification in scale not reflected in the tangible benefits and project economic costs. For example, a higher degree of flood protection, particularly in urban areas, than is feasible on the basis of tangible benefits alone may be justified in consideration of the threat to lives,

[a] United States of America, The President's Water Resources Council, *Policies, Standards, and Procedures in the Formulation, Evaluation, and Review of Plans for Use and Development of Water and Related Land Resources*; 87th Congress, 2nd Session, Senate document No. 97 (Washington, D.C., 1962).

health, and general security posed by larger floods. Also, when long-range water needs are foreseeable only in general terms and where alternative means of meeting the needs are not available and inclusion of additional capacity initially can be accomplished at a significant saving over subsequent enlargement, such considerations may justify the additional cost required. Similarly, long-range power needs, in the light of generally expected economic growth of an area, may justify measures initially to insure later availability of the full power potential.

"D. *Definitions of benefits*

"1. Benefits: Increases or gains, net of associated or induced costs, in the value of goods and services which result from conditions with the project, as compared with conditions without the project. Benefits include tangibles and intangibles and may be classed as primary or secondary.

"2. Tangible benefits: Those benefits that can be expressed in monetary terms based on or derived from actual or simulated market prices for the products or services, or, in the absence of such measures of benefits, the cost of the alternative means that would most likely be utilized to provide equivalent products or services. This latter standard affords a measure of the minimum value of such benefits or services to the users. When costs of alternatives are used as a measure of benefits, the costs should include the interest, taxes, insurance, and other cost elements that would actually be incurred by such alternative means rather than including only costs on a comparable basis to project costs as is required when applying the project formulation criteria under paragraph V-C-2(*d*).

"3. Intangible benefits: Those benefits which, although recognized as having real value in satisfying human needs or desires, are not fully measurable in monetary terms, or are incapable of such expression in formal analysis. Each type of benefit usually has a part which is readily measurable and may have a part which is not measurable or not readily measurable. The significance of this latter part shall be based upon informed judgment.

"4. Primary benefits: The value of goods or services directly resulting from the project, less associated costs incurred in realization of the benefits and any induced costs not included in project costs.

"5. Secondary benefits: The increase in the value of goods and services which indirectly result from the project under conditions expected with the project as compared to those without the project. Such increase shall be net of any economic nonproject costs that need be incurred to realize these secondary benefits.

"E. *Types of primary benefits and standards for their measurement*

"1. Domestic, municipal, and industrial water supply benefits: Improvements in quantity, dependability, quality, and physical convenience of water use. The amount water users should be willing to pay for such improvements in lieu of foregoing them affords an appropriate measure of this value. In practice, however, the measure of the benefit will be approximated by the cost of achieving the same results by the most likely alternative means that would be utilized in the absence of the project. Where such an alternative source is not available or would not be economically feasible, the benefits may be valued on such basis as the value of water to users or the average cost of raw water (for comparable units of dependable yield) from municipal or industrial water supply projects planned or recently constructed in the general region.

"2. Irrigation benefits: The increase in the net income of agricultural production resulting from an increase in the moisture content of the soil through the application of water or reduction in damages from drought.

"3. Water quality control benefits: The net contribution to public health, safety, economy, and effectiveness in use and enjoyment of water for all purposes which are subject to detriment or betterment by virtue of change in water quality. The net contribution may be evaluated in terms of avoidance of adverse effects which would accrue in the absence of water quality control, including such damages and restrictions as preclusion of economic activities, corrosion of fixed and floating plant, loss or downgrading of recreational opportunities, increased municipal and industrial water treatment costs, loss of industrial and agricultural production, impairment of health and welfare, damage to fish and wildlife, siltation, salinity intrusion, and degradation of the esthetics of enjoyment of unpolluted surface waters, or, conversely, in terms of the advantageous effects of water quality control with respect to such items. Effects such as these may be composited roughly into tangible and intangible categories, and used to evaluate water quality control activities. In situations where no adequate means can be devised to evaluate directly the economic effects of water quality improvement, the cost of achieving the same results by the most likely alternative may be used as an approximation of value.

"4. Navigation benefits: The value of the services provided after allowance for the cost of the associated resources required to make the service available. For commodities that would move in the absence of the project, the benefit is measured by the saving as a result of the project in the cost of providing the transportation service. For commodities that will move over the improved waterway but would not move by alternative means, the measure of the benefit is the value of the service to shippers; that is, the maximum cost they should be willing to incur for moving the various units of traffic involved. Navigation improvements may also provide benefits in other forms, such as reduction in losses due to hazardous or inadequate operating conditions and enhancement in land values from the placement of dredged spoil.

"5. Electric power benefits: The value of power to the users is measured by the amount that they should be willing to pay for such power. The usual practice is to measure the benefit in terms of the cost of achieving the same result by the most likely alternative means that would exist in the absence of the project. In the absence of economically feasible alternative means, the value of the power to users may be measured by any savings in production costs, increase in value of product that would result from its use, or its net value to consumers.

"6. Flood control and prevention benefits: Reduction in all forms of damage from inundation (including sedimentation) of property, disruption of business and other activity, hazards to health and security, and loss of life; and increase in the net return from higher use of property made possible as a result of lowering the flood hazard.

"7. Land stabilization benefits: Benefits accruing to landowners and operators and the public resulting from the reduction in the loss of net income, or loss in value of land and improvements, through the prevention of loss or damage by all forms of soil erosion including sheet erosion, gullying, flood plan scouring, streambank cutting, and shore or beach erosion, or, conversely in terms of advantageous effects of land stabilization.

"8. Drainage benefits: The increase in the net income from agricultural lands or increase in land values resulting from higher yields or lower production costs through reduction in the moisture content of the soil (exclusive of excessive moisture due to flooding), and the increase in the value of urban and industrial lands due to improvement in drainage conditions.

"9. Recreation benefits: The value as a result of the project of net increases in the quantity and quality of boating, swimming, camping, picnicking, winter sports, hiking, horseback riding, sightseeing, and similar outdoor activities. (Fishing, hunting, and appreciation and preservation of fish and wildlife are included under para. V-E-10.) In the general absence of market prices, values for specific recreational activities may be derived or estimated on the basis of a simulated market giving weight to all pertinent considerations, including charges that recreationists should be willing to pay and to any actual charges being paid by users for comparable opportunities at other installations or on the basis of justifiable alternative costs. Benefits also include the intangible values of preserving areas of unique natural beauty and scenic, historical, and scientific interest.

"10. Fish and wildlife benefits: The value as a result of the project of net increases in recreational, resource preservation, and commercial aspects of fish and wildlife. In the absence of market prices, the value of sport fishing, hunting, and other specific recreational forms of fish and wildlife may be derived or established in the same manner as prescribed in paragraph V-E-9. Resource preservation includes the intangible value of improvement of habitat and environment for wildlife and the preservation of rare species. Benefits also result from the increase in market value of commercial fish and wildlife less the associated costs.

"11. Other benefits: Justification of the recognition of any other benefits and of the standard used in their measurement shall be set forth in reports. Unless included under one or more of the above categories, reports should show the net economic effects of changes in transportation capability, or changes in productivity of forest, range, mineral, or other resources. A project's contribution toward meeting specific needs for servicing international treaties or for national defense may also be included.

"F. *Definition of costs*

"1. Project economic costs: The value of all goods and services (land, labor, and materials) used in constructing, operating, and maintaining a project or program, interest during construction, and all other identifiable expenses, losses, liabilities, and induced adverse effects connected therewith, whether in goods or services, whether tangible or intangible and whether or not compensation is involved. Project economic costs are the sum of installation costs; operation, maintenance, and replacement costs; and induced costs as defined below.

"2. Installation costs: The value of goods and services necessary for the establishment of the project, including initial project construction; land, easements, rights-of-way, and water rights; capital outlays to relocate facilities or prevent damages; and all other expenditures for investigations and surveys, and designing, planning, and constructing a project after its authorization.

"3. Operation, maintenance, and replacement costs: The value of goods and services needed to operate a constructed project and make repairs and replacements necessary to maintain the project in sound operating condition during its economic life.

"4. Induced costs: All uncompensated adverse effects caused by the construction and operation of a program or project, whether tangible or intangible. These include estimated net increases, if any, in the cost of Government services directly resulting from the project and net adverse effects on the economy such as increased transportation costs. Induced costs may be accounted for either by addition to project economic costs or deduction from primary benefits.

"5. Associated costs: The value of goods and services over and above those included in project costs needed to make the immediate products or services of the project available for use or sale. Associated costs are deducted from the value of goods and services resulting from a project to obtain primary benefits.

"6. Taxes: Allowances in lieu of taxes or taxes foregone will not be included in project economic costs, except as required by law."

The report also suggests ways of setting the time period for analysis, the appropriate discount rate, and the price levels to be used.

Formulae used in the Soviet Union for preliminary measurement of economic effectiveness in multipurpose river schemes

In the Soviet Union the economic effectiveness of hydropower is evaluated by comparing its cost with the estimated cost of thermal power in the area and under the same load conditions. For transportation a similar cost comparison with railway cost is made on an equal ton-mile basis. In agriculture, the annual value of output is compared with operating expenditures. Finally, all the indices thus derived are combined in one formula. These calculations include depreciation but no interest.

The formulae for hydroelectric stations, transportation, irrigation and integrated water resource development are as follows:

Electric power station (interchangeable versions)

1st version: hydroelectric — 2nd version: thermal-electric

based on the following values:

i_1 = investment	i_2 = investment
e_1 = annual expenditure	e_2 = annual expenditure

Taking an equal output as a base, the following two indices are used:

(*a*) Rate of effectiveness:

$$R = 100\frac{e_2 - e_1}{i_1 - i_2}$$

the desirable limits being from 6.6 per cent to 10 per cent and higher;

(*b*) Recovery period:

$$P = \frac{i_1 - i_2}{e_2 - e_1}$$

the desirable limits being from fifteen years to ten years or less.

Transportation

1st version: water-way	2nd version: railway
i_3 = investment	i_4 = investment
e_3 = annual expenditure	e_4 = annual expenditure

on the basis of equal ton-miles

$$R = 100\frac{e_4 - e_3}{i_3 - i_4} \qquad P = \frac{i_3 - i_4}{e_4 - e_3}$$

Irrigation (no interchangeable versions)

C = value of agricultural production

e_5 = operating expenditure

in = income

$$in = C - e_5$$

i_5 = investment

Rate of effectiveness:

$$R = 100\frac{in}{i_5}$$

Integrated water resource development:

(*a*) Rate of effectiveness:

$$R = 100\frac{(e_2 - e_1) + (e_4 - e_3) + in}{(i_1 - i_2) + (i_3 - i_4) + i_5} \text{ (6.6 to 10 per cent)}$$

(*b*) Recovery period:

$$P = \frac{(i_1 - i_2) + (i_3 - i_4) + i_5}{(e_2 - e_1) + (e_4 - e_3) + in} \text{ (15 to 10 years)}$$

Actual recovery periods for integrated hydro-technical systems in the Soviet Union are usually less than the fifteen to ten years indicated above.

Investment is apportioned among the beneficiaries of integrated water resources in two ways: (*a*) a complex one, according to the ratio of additional benefits to public expenditures; (*b*) a simplified one: the cost of individual construction used for a given economic branch is related to it — that is, a navigation lock is charged to navigation and a powerhouse building to energetics. Costs of construction common to all branches, such as dams and storage reservoirs, are charged to the basic component of the entire scheme.

OTHER TOOLS

Various other tools of analysis may be useful for evaluating either all or part of the effects of a programme of integrated river basin development. They include global evaluation measures such as input-output matrices and multiplier effect coefficients, as well as partial evaluation ratios such as the capital-labour ratio and the foreign exchange-investment ratio.

Preparation of significantly detailed input-output matrices is complicated and time consuming. Moreover, matrices only extrapolate existing conditions under given relationships. If it is desired to compute the capital requirements or economic effects of new investments, such matrices are of limited use because changes in technology, markets, income and income distribution, necessarily involved in large-scale investments, are neglected. With the accumulation of more experience, however, matrices may become a useful tool for certain specific purposes.

Similar limitations appear to apply to studies of the multiplying effects of an investment in a river basin. Unless this method can be refined for comparisons of the multiplying effects of a given river basin investment with those of a similar investment for other purposes, it will be of little practical use. Moreover, it should be noted that the multiplying effect of large-scale investments assumed in the computation may not actually materialize, especially in underdeveloped countries.

Partial evaluation coefficients are useful tools in forming an economic judgement of a project, provided the coefficient used is relevant and the underlying statistical data are reliable. Coefficients are to be selected according to the conditions and problems of the area, such as foreign exchange ratios, when foreign exchange is scarce or may become so, or ratios of labour intensity, that is, employment in relation to investment or output, in heavily populated areas.

Whatever the tools employed in economic evaluation of a large-scale river basin project, their usefulness depends chiefly upon the collection of reliable statistical and other economic data.

Annex IV

HEALTH IMPLICATIONS OF WATER-RELATED PARASITIC DISEASES IN WATER DEVELOPMENT SCHEMES[a]

Large-scale water development schemes are increasingly becoming the key to economic and agricultural progress in many of the developing countries. The environmental changes due to the construction of dams and of man-made lakes, to the creation or expansion of irrigation systems or to the draining of swamps and marshes can, however, have far-reaching effects on the health of man and animals in the regions affected. The close relationship between the existence of different types of water bodies and the population size of mosquito, snail and other disease vectors is well established. What is less easily recognized is that man himself often creates the basic conditions for the multiplication of breeding places for vectors of such diseases as malaria, bilharziasis, river blindness (onchocerciasis), distomatosis, paramphistomiasis, and a number of other infections capable of causing disease in man and cattle in endemic proportions. Modern techniques and science offer the means to prevent or at least reduce the dangers of such man-made zoological changes, provided the health factor is recognized and taken into account from the early planning stages of a project and the necessary remedial action integrated in each programme throughout its implementation. It should be appreciated that problems raised by large-scale water development schemes and relating to animal health have many aspects in common with those influencing human health. In most cases, control measures applicable to the human aspect will also bring about good results if applied against vectors or agents of animal diseases.

EPIDEMIOLOGICAL CONSIDERATIONS

Each parasitic infection has its specific mode of transmission by which the infection is spread, and the particular cycle necessary to pass an infection from one man to another — that is, to establish a new infection — varies greatly from one parasite species to another. In all instances, however, it is a highly complicated process, based on the interrelationship between the human host, the parasite and, often, a vector or intermediate host species. Transmission generally requires certain prescribed environmental conditions in order to take place. In this respect, water, either by its mere existence or its specific condition, often plays an important role in the epidemiology of parasitic diseases. Thus, many parasitic infections are, to some extent, water-related diseases.

Before particular diseases and their epidemiology are discussed, brief consideration will be given to the mode of transmission of this group of parasitic infections in general, in order to understand the connexion which exists between the prevalence of these diseases and the presence of water. Three different patterns of water-related transmission can be distinguished:

(1) The parasite is picked up from an infected person by a vector (for instance a mosquito). It then undergoes a period of development in the vector before it can be passed on to another person. In this type of transmission pattern water provides the essential "breeding places" or larval habitats of the vector. The presence or absence of water, or its specific condition, will therefore influence significantly the size of the vector population, and thus affect the transmission potential of the infection. The parasite itself does not exist free in the environment. The principal diseases of man belonging to this category are malaria, filariasis (elephantiasis) an onchocerciasis (river blindness). To some extent perhaps trypanosomiasis (sleeping sickness) could also be included as some species of vector tsetse fly, although not requiring water for breeding purposes, are nevertheless closely dependent on the shelter of evergreen forest associated with river banks and lake edges;

(2) The parasite is discharged by an infected person into the environment (water) from which it has to find and enter a specific intermediate host (usually a snail, a crustacean or a fish). In this secondary host it has to pass through one or more developmental stages before becoming infective to other human beings.

This is a more complex cycle of transmission because the presence of water may be essential *both* for the survival of the parasite and for the life of the intermediate host. The most important parasitic infections following this transmission patterns are schistosomiasis, paragonimiasis (oriental liver fluke), clonorchiasis (Chinese liver fluke), fascioliasis and dracontiasis (Guinea worm);

(3) The third form of transmission is by indirect contact, the parasite is excreted by an infected person into his environment and is picked up there by another person. In the parasitic diseases which follow this pattern of transmission, the parasite (in the form of eggs or larvae) usually has to be deposited for its survival on *moist* soil as the favouring element (e.g. hookworm and other helminthic infections).

In any of these diseases, alterations in the water resources of the environment can have an impact on the interrelationship between man, parasite, vector or intermediate host, that is, on the epidemiology of the infection. A consequence is either an increase or decrease of transmission, thus causing a change in the prevalence of the disease. In the following discussion, emphasis will be placed on the role of water as an influencing factor in the transmission of several of the parasitic infections mentioned above.

DESCRIPTION OF SPECIFIC WATER-RELATED PARASITIC DESEASES

Malaria

Of all water-related parasitic diseases, malaria is probably the most commonly known. Until very recently this infection was highly prevalent in the entire tropical and subtropical belt

[a] From a brochure of the same title published by the Food and Agriculture Organization of the United Nations and the World Health Organization, 1967.

and extended to temperate climates. Wherever the disease is endemic, it is considered to be one of the most serious public health problems.

Owing to its characteristic fever attacks, the infection has been easily recognized since ancient times. The human malaria infection is brought about by four different parasite species of the genus *Plasmodium*; apart from morphological differences, the species differ mainly in regard to life span and the periodicity of the fever attacks they cause.

The most common species, except in Africa, is *P. vivax*. Due to the three days' cycle of fever attacks caused by this species, the infection is also known as tertian malaria. The next in frequency is *P. falciparum*, the infection being also referred to as tropicana or malignant malaria, since the clinical symptoms are more severe than in any of the other malaria infections. *P. malariae* (quarta malaria) and *P. ovale*, which occur only in some parts of Africa, are less widespread.

The malaria parasite is introduced into the human bloodstream as a sporozoite through the bite of an infective mosquito. The parasites develop and multiply, first in the liver and later in the blood stream, where they invade the red blood cells. Some of the parasites develop into sexual forms, called gametocytes, which are eventually taken up by the bite of an *Anopheles* mosquito. In the mosquito, the parasite undergoes various stages of development leading to the formation of sporozoites. These accumulate in the salivary glands and are injected into man during a blood meal.

Malaria infection may be transmitted by about 60 different species of *Anopheles* mosquitoes. All of these are aquatic breeders; however, their preferences for specific types of water vary greatly. A peculiarity of most of the malaria vectors — of which advantage is taken for control — is that they bite humans in or near their houses and rest indoors after a blood meal.

> "Malaria is essentially a chronic disease. It causes, apart from its classic fevers, high infant mortality, stillbirths and abortions; it produces anaemia with enlargement of the spleen, and it predisposes those who suffer from it to other infections. In areas where agricultural production and levels of life are already low, its economic effects are obvious: food supplies are further reduced by the fact that large malarial areas are left untilled, and social and economic development are profoundly retarded." [b]

With modern chemotherapy, malaria infections can be cured radically, and it is also possible to effect prophylactic protection.

In view of the encouraging results obtained in malaria control campaigns with insecticide spraying against the adult vector, a world-wide malaria eradication programme was initiated in 1955, based mainly on indoor spraying with DDT. The aim is to achieve complete interruption of transmission, but not the elimination of the vector species.

However, as long as the infection still exists in some parts of the world, the danger of its being re-introduced in freed areas must be considered, especially in those developing areas where population movements take place, creating, at the same time, new favourable breeding conditions for *Anopheles*.

Schistosomiasis (bilharziasis)

Schistosomiasis ranks among the most important public health problems of the tropics and subtropics, and is recognized as second only to malaria in importance as a parasitic disease. It is estimated that 180 million human beings suffer from the infection which is widely distributed throughout Africa, the eastern Mediterranean and the Far East (mainly China, Japan and the Philippines), parts of Central and South America, and in small foci in South-East Asia.

Human schistosomiasis is caused by at least three species of blood flukes (trematodes), namely, *Schistosoma haematobium* (genito-urinary bilharziasis), *S. mansoni* and *S. japonicum* (intestinal bilharziasis).

Schistosomiasis is a chronic, insidious disease. The initial symptoms in man often pass unrecognized. The clinical manifestations of the advanced stages develop gradually and are frequently attributed to other conditions. They are caused primarily by the deposition of schistosome eggs in the tissues of various organs. In the intestinal forms of the infection (*S. mansoni* and *S. japonicum*) weakness, loss of weight and occasionally dysentery are observed. With increasing intensity or duration of the infection the symptoms become more severe. Eventually liver involvement may occur with enlargement of the organ and portal hypertension. Pulmonary or cardiac complications may be seen. In the urinary type of infection due to *S. haematobium* the eggs are mainly deposited in the bladder wall and/or near the ureter causing painful micturition and blood in the urine (haematuria). The eggs deposited in the tissues become gradually calcified. Obstructive processes in the urinary system result in serious and eventually irreversible damage to the kidneys and renal failure, which are already discerned in early childhood. Moreover, there appears to exist a relationship between urinary bilharziasis and bladder cancer. Consequently, it is now generally recognized that the pathological manifestations of bilharziasis are far more serious than was previously assumed and that the infection may be an important cause of mortality, especially in adolescents and young adults.

The mode of transmission of bilharziasis is determined by the life cycle of the schistosome worms. The adult forms mature in the blood of a human being (or of another host), and the eggs are laid in the vesical plexus or the mesenteric plexus round the colon; the adult worms are capable of living for several years, the female producing eggs continuously. The eggs escape through the bladder or intestinal wall into the urine or faeces, and on contact with water, hatch, producing free-swimming larval forms, called *miracidia*, which must find suitable snail hosts within a day or perish. When a miracidium finds a suitable intermediate host it penetrates the skin and establishes itself in the snail, passing through several generations and multiplying to form further free-living larval forms called cercariae. These emerge from the snail and swim about until they find a human being. They then bore through the unbroken skin (or through the buccal mucosa if the water is swallowed), make their way to the liver, mature and mate. The two sexes then make their way to the terminal blood vessels near the bladder or colon, where the eggs are laid and the cycle begins over again.

It is thus evident that water plays a significant role at various points in the transmission cycle of bilharziasis. Water must first be contaminated by infected people, an occurrence which depends mainly on prevailing human habits and agricultural practices. Secondly, the presence of water of suitable velocity and temperature of adequate vegetation as well as of organic food is a prerequisite for the establishment of the specific snail populations that serve as intermediate hosts of the schistosomes. And lastly, it is again through contact with water that man contacts the infection.

It follows that any contaminated surface water used for irrigation purposes or production of electric power is dangerous, causing the disease to spread or making it more intense and debilitating in the individuals already affected.

[b] Carlos A. Alvarado and L. T. Bruce-Chwalt, "Malaria". *Scientific American* (New York), vol. 206, No. 5, 1962, pp. 86-96.

Treatment of the infection has been based so far on the use of antimonial drugs, which have a direct effect on the schistosome in the human body. This involves a lengthy course of treatment given under medical supervision, often repeated to achieve a complete cure, which is not very suitable for mass treatment. Recourse must therefore be made to other methods of controlling the infection.

Good results have been achieved by chemical treatment of snail habitats, using appropriate molluscicides to destroy the aquatic or amphibious snail hosts. When correctly applied, molluscicidal control measures have proved to interrupt transmission of schistosomiasis, thus preventing new infections and the further spread of the disease.

Other means of controlling and preventing bilharziasis are by modifying the environment of both the human and snail hosts of the parasite. In the case of the human hosts, the object is to alter their habitats in such a way that they no longer come into contact with water infested with snails. For the intermediate hosts it is necessary to change the ecology of the water in which they live so that these are no longer suitable habitats. Environmental control of snail habitats[c] can be very effective as a control device, the means of which rests also, to a considerable extent, on the personnel involved in irrigation management and water use, agricultural and crop production, water and soil conservation.

The best results can be expected by combining molluscicidal operations with environmental control devices.

Filariasis

In human filariasis there are two forms of the infection caused by filarial worms — one which is due to the parasite *Wuchereria bancrofti*, the other to *Brugia malayi*. They are both prevalent in vast areas of the world, the former in all tropical and subtropical regions, especially in the warmer parts of Asia, where some of the largest and most densely populated areas of endemicity exist. The latter spreads over much of South-East Asia and extends along the coastal regions as far north as Korea and into Indonesia. It is estimated that filariasis affects over 250 million people at present troughout the world.

Both *W. bancrofti* and *B. malayi* are nematode worms; the adult form lives in man, mainly in the lymphatic system. Their life span is approximately ten years, during which time the female worm produces innumerable microfilariae, which invade the lymphatic and blood vessels. These larval forms are ingested by blood-sucking insects when feeding on an infected man. They undergo a series of moults until the infective stage is reached where they enter a new host, during the vector's next blood meal.

Clinical filariasis may be acute or chronic. The common early manifestations of the two forms of the disease are painful swellings of the lymphatic vessels and glands of the groin, genitals and thigh. Characteristics of the chronic phase are hydrocele, enlargement of the lymph glands, inflammation of the scrotum and finally elephantiasis of the genitals and lower extremities. In *W. bancrofti* infection, elephantiasis may involve the breast and arms.

Some symptoms are more commonly encountered in certain areas. Others seem to be more characteristic of either one or the other type of the infection, e.g., *B. malayi* is more often associated with elephantiasis of the lower limbs, while in the chronic stage of *W. bancrofti* genital involvements are usually observed. Not all infected persons develop clinical symptoms, but the proportion of clinical cases is high, especially in highly endemic areas where the people are exposed to constant superinfection. In such areas 30 per cent of the adult population may be affected by elephantiasis and hydrocele. The severity of the filarial complications and their frequency determine the importance of the resulting disability and of the ensuing social and economic consequences.

The vectors of filariasis throughout the world are numerous and varied, being either culicines (*Culex, Aedes, Mansonia,* etc.) or anophelines. The culicine mosquitos constitute the majority of human filaria vectors. Enlargement of surface water bodies for irrigation and other purposes naturally increases the possibility for new breeding sites to be created and for the disease to spread or to become more intense.

The infection can be cured with the currently available antifilarial drugs. Chemotherapy alone, however, has little action on developed elephantiasis. Treatment is often associated with allergic reactions.

Control of filariasis can be effected by various methods which are either directed against the parasite through mass drug treatment or against the vector. In the latter case, larviciding or engineering devices, or both are usually employed to reduce breeding facilities.

Owing to the diverse habits of the vectors, attempts to control the disease by mosquito control alone have so far not given very satisfactory results. Furthermore, vector control alone does not affect the parasite in the human host reservoir and would have to be continued over a long period of time on account of the long life-span of the parasite. Mass treatment, on the other hand, has proved effective in many endemic areas. Depending on local circumstances, mass treatment supplemented by vector control measures seems to offer the best approach to filariasis control.

Onchocerciasis (river blindness)

Onchocerciasis is a vector-borne infection caused by *Onchocerca volvulus*, a nematode worm. It is most prevalent in Africa, extending from Senegal and Sudan in the north to Angola in the south. It also occurs in circumscribed areas of Mexico, Guatemala and Venezuela. The adult parasites live mainly in the subcutaneous tissues of the human host, where they may form visible nodules in which one or more worms are coiled up. The female worm discharges innumerable microfilariae during its life span, i.e., approximately 15 years. The mobile microfilariae are found in the skin of the entire body, but may also penetrate the eyes.

The infection is transmitted by certain species of blackflies (Simuliidae): *Simulium damnosum* in most parts of Africa, together with *S. neavi* in East and Central Africa, and *S. ochraceum, S. metallicum* and *S. callidum* in the New World. When biting an infected person the fly takes up one or more microfilariae which, in the course of several days, develop into infective larvae. These are in turn liberated at the fly's next human blood meal on the skin of another man, thus completing the life cycle. It requires several months for the parasite to reach maturity.

The clinical symptoms of onchocerciasis, which are produced primarily by the microfilariae, are slow to appear so that an early diagnosis of the infection is often difficult. Frequently, the earliest complaint is of itching of the skin (pruritus), which can be extremely severe. At a later stage thickening and depigmentation of the skin may be observed. However, the most serious onchocercal lesions are caused through microfilariae that have reached the eye, leading eventually to impairment of vision and ultimate blindness. Typical lymphatic swelling called "hanging groin" is another complication of the infection.

---

[c] *Snail Control in the Prevention of Bilharziasis.* World Health Organization, Monograph Series, No. 50 (Geneva, 1965).

The severity of the disease is usually related to the degree of exposure. In highly endemic areas, such as occur in large river systems — the Volta River Basin for instance — the incidence of blindness in the rural population may reach 10 per cent or more, and some of the most fertile valleys have been abandoned by the riverine populations.

As mentioned above, the infection depends for its transmission upon the presence of a *Simulium* vector species. Furthermore, its distribution and intensity depend chiefly on the density of the vector population. Common to all *Simulium* vectors is their requirement for flowing or turbulent water for the development of their aquatic stages (that is, egg, larval and pupal stages) which takes from ten to forty days. Particularly favourable conditions are, therefore, found at waterfalls, rapids, spillways etc. The adult *Simulium* is most readily found close to its breeding site, but can fly for considerable distances, up to 50 kilometres or even more in the case of *S. damnosum.* This ability to fly long distances is of significant consequence in the spread of infected areas and the planning of control operations.

For the treatment of the disease drugs are used which kill the parasite, thus curing the infection. Treatment, however, is often complicated by unpleasant side reactions and of little benefit to those cases in which permanent damage, especially to the eyes, has already occurred.

Control of the infection aims therefore at interrupting the transmission, which can best be achieved by attacking the vector population. The larval stage of *Simuliidae* is highly susceptible to insecticides, and dosing of water courses with DDT at regular intervals can greatly reduce and even eliminate the black-fly population.

Distomatosis (fascioliasis)

This disease is caused by species of *Fasciola* or *Dicrocoelium* and affects several mammalian hosts. It may also constitute a danger for man under special conditions. These parasites are usually found in the bile ducts. Aquatic and amphibious snails, species of *Lymnaea,* serve as intermediate molluscan hosts for *Fasciola* species, while land snails which require moist habitats serve as hosts for *Dicrocoelium.* The infective or metacercarial stage of *Fasciola* is readily acquired in endemic areas through the ingestion of vegetation and possibly water containing the cysts, while ants containing the metacercariae of *Dicrocoelium* cause the infection when accidentally ingested.

Symptoms in animals are those of mechanical and toxic irritation of the liver parenchyma which may reach the stage of necrosis and fibrosis of the liver and possibly death of the host.

Symptoms in man are not typical and the disease is difficult to diagnose and often goes unnoticed.

The economic losses caused by distomatosis in animals are considerable.

Control of the infection aims at interrupting the transmission cycle, either by controlling the parasite in reservoir hosts, or by eliminating the intermediate snail hosts.

Effects of water and agricultural development schemes on parasitic diseases and their control

In many tropical areas water development schemes are the key to economic and agricultural development. This implies, on the one hand, better utilization of existing water resources, mainly for agricultural purposes or electric power production, or, on the other hand, the draining of swamps and marshes for land reclamation and pisciculture. Dam constructions, irrigation schemes and man-made lakes are some of the major devices to achieve these aims. Along with the economic benefits arising from these schemes, they can, however, affect the epidemiology of parasitic infections, thus usually increasing the health hazards of man. The realization of the health implications and the early implementation of control devices can greatly reduce or even prevent these health hazards.

Dam construction

The construction of a dam, for whatever purpose it is built, inevitably affects the river up- as well as down-stream. Up-stream of the dam the water level rises over long distances, sometimes creating lake-like water reservoirs, the water edges are pushed inland, and the velocity of the water is usually reduced considerably.

The changed situation can have either a detrimental or a beneficial effect as regards water-related parasitic diseases. As far as vector-borne diseases are concerned, former breeding sites may be covered by water over large areas. The reduced velocity and turbulence of the raised water will be unfavourable for the breeding of the *Simulimu* vectors of onchocerciasis, thus reducing or even eliminating transmission sites. The effect on other anthropod vectors depends especially upon the type of new river banks and their vegetation. Knowledge of the ecology of the various anthropod vectors prevalent in the area will facilitate the implementation of measures to create conditions unfavourable for their existence.

A nearly stagnant water up-stream of a dam, often accompanied by rapid growth of aquatic vegetation, provides ideal living conditions for the snail intermediate host of bilharziasis, and thus creates a potential danger for a wider spread and increase of transmission of the infection in the area, with all its detrimental effects on the community. The most appropriate methods of bringing this hazard under control are by the careful designing of the dam and reservoir, by the application of molluscicides to the water or weed control, or both. In larger water reservoirs snail hosts are usually concentrated near the margins and may only occur along certain parts of the shore line, in which case the treatment might be limited to infected parts of the water.

The down-stream effect of a dam construction is usually the opposite to that up-stream. The outflowing water is mostly very turbulent and remains so for some distance, creating thereby very favourable breeding conditions for *Simuliidae* but preventing the establishment of snail populations. As the aquatic stage of the black-fly is highly susceptible to insecticides, a dosing of the down-stream water at intervals is most effective in eliminating or reducing this vector population, at least to a negligible level regarding public health importance. For larger dams insecticide treatment devices can be built in to the construction itself; in others, the dosing has to be done in the most conventional way. Undoubtedly the water dosing for the purpose of *Simulium* control will have some effect on the other insect populations, which also use the river as their breeding sites.

The possibility of controlling the water flow and water level from the dam is another means through which a certain detrimental effect both on insect breeding and on the snail population can be exercised.

The health hazards involved in smaller dams, usually created for irrigation purposes, lie mainly in the favourable breeding conditions they provide for the vectors of onchocerciasis, involving often the spillways themselves. The specific design of the spillways, controlled fluctuation of the water level and the proper maintenance of the dam site are control methods additional to insecticide dosings.

Irrigation schemes

Any system which brings surface water to dry areas where water was previously scarce or non-existent requires very close attention with regard to its possible effect on water-related parasitic diseases. Not only may specially favourable conditions be created for the proliferation of water-dependent vectors or intermediate hosts but also the increase or ingress of human population may provide specially favourable opportunities for disease transmission.

Chief among the parasitic diseases involved in irrigation is schistosomiasis, because ideal conditions for snail breeding may be provided by the network of waterways created. Canals, channels, weed-choked ditches and drains may all provide ideal conditions for snail proliferation, while the periodic flow of water provides means for the rapid dissemination of snails throughout the entire irrigation system. Bilharziasis is undoubtedly one of the main health hazards to be faced in the many large irrigation projects developed or being planned in Africa and in the Middle East.

Control measures are based initially on careful survey to establish the identity of the dominant invading snails, their main breeding foci and their seasonal abundance. A great deal can be done to eliminate such breeding places, or prevent their occurrence, by careful attention to the engineering aspects of irrigation systems. The provision of clean-edged canals, channels and storage reservoirs, the avoidance of stagnant backwaters and weed-choked drainage ditches, combined with the intelligent use of water control may all help to reduce the extent of suitable snail habitats. Combined with those measures, snail control operations using molluscicides can then be organized to the best advantage. Recent experiments have indicated that with certain molluscicides the steady distribution of water throughout the entire irrigation system may facilitate effective distribution of the chemical to all snail habitats, particularly when the molluscicide is applied continuously — at very low concentrations — over a period of several weeks at a time.

Supplementary measures such as careful site selection of human settlements, prevention of bathing or washing in water inhabited by vector snails, provision of piped water supplies, and provision of sanitary facilities can all be combined to assist in breaking the transmission cycle.

Fish ponds

In certain countries fish ponds have long played a predominant part in providing essential food. Extension of this practice and improved methods of fish management are continually being encouraged in developing countries, particularly by international organizations such as the Food and Agriculture Organization of the United Nations (FAO).

The main parasitic disease health hazard involved is that in some situations, but not all, the artificial fish pond may provide ideal sites for breeding of the snail intermediate hosts of bilharziasis. In such cases snail control by conventional application of molluscicide may have undesirable effects, either on the food fish themselves or on the microflora and microfauna on which the fish feed. In such conditions the exact choice of molluscicide and dosage has to be carefully calculated so that an adequate safety margin exists between the dosage sufficient to produce an effective snail kill, and the minimum dosage likely to have an adverse effect on the fish.

It seems likely that the current WHO-co-ordinated programme on molluscicide screening and evaluation will sooner or later produce a more ideal "selective" molluscicide, i.e., one with a sufficiently wide margin of safety to be used for effective snail control in such places while leaving the fish quite unharmed.

Population movements

Water or agricultural development schemes are very frequently connected with movements of populations. These may involve either temporary migrant labour forces engaged in construction work or the resettlement of population groups taking advantage of the improved conditions. Both raise health problems in relation to water-related parasitic diseases which cannot be overlooked.

Temporary labour forces coming from different, often faraway places, can be the source of numerous parasitic infections. Through them new foci of transmission may soon be established if environmental conditions are favourable and the necessary vector or intermediate host is present. It is equally likely that the health and labour potential of the labour force will be seriously impaired by infections that are endemic in the area of work. The same considerations apply even more forcefully to population resettlement, since the population will remain in the area and is expected to build up a prosperous community.

Once the prevailing diseases and the potential transmission hazards in the area foreseen for the development project are known, preventive measures must be applied, the nature of which will depend on the specific problems encountered, the size of the human population involved, duration of exposure, and other relevant considerations.

Annex V

PROBLEMS OF RESERVOIR DEVELOPMENT[a]

Problems and opportunities

Although reservoirs are generally planned to solve one or more primary problems, such as a need for hydroelectric power, their construction generates innumerable secondary problems, many of which have proved to be very serious. Recognizing that no two reservoirs are alike, this paper is intended to indicate which of these secondary problems might require consideration under given sets of circumstances. It is also intended to furnish guidance as to the type, planning and timing of studies needed for their solution. In so doing, it draws heavily on experience gained, particularly during the past decade, by the Food and Agriculture Organization of the United Nations and the World Health Organization.

Primary and secondary problems

Most development projects which include the creation of a large reservoir are initially conceived for a limited number of purposes. Normally these purposes include one or more of the following: generation of electricity; water storage for irrigation, industrial or domestic use; flood control; regulation of flow for navigation.

In nearly all instances the costs and benefits of the project for such primary purposes have been carefully estimated and evaluated well in advance of final planning, and the financing of the project has been based chiefly thereon.

A host of secondary problems have arisen in connexion with reservoir projects, some of which may have been included in the foregoing evaluation but most of which problably have not. Representative of those which may have been included in the cost estimates are: charges for reservoir clearance; direct costs (such as new housing) associated with resettlement of displaced people; reimbursement for loss of valuable buildings and of land, forest and mineral resources due to flooding; and other direct costs that can be evaluated easily.

On the benefit side, attempts have occasionally been made to evaluate an expected increase in fishery outputs and to a less extent the possible earnings from increased tourism and recreation.

Often the few extra benefits and costs noted have not been adequately evaluated, leaving serious gaps in the over-all economic appraisal of the project. In addition, a large number of other secondary problems, which are extremely difficult to quantify in terms of benefits and costs, have been overlooked or ignored. These problems include:

Over-all economic impact of the project on the region or the country;

Establishment of adequate land and water use priorities and planning through the affected basin;

Effect of resettlement on the human resources of the region or the country;

Effect of the changed environment on health and productivity of both man and his domestic animals, including new threats to health through the inadvertent improvement of habitats for certain diseases and aquatic vectors;

Effect on fish and wildlife resources of the new environment created by the dam;

Neglect of opportunities for improved agricultural practices, especially on seasonally inundated and exposed foreshores;

Effect of the changed environment on growth of noxious plants, especially water weeds;

Possibility that the new lake may cause earthquakes.

Secondary problems such as the foregoing are admittedly difficult to quantify, but methods are becoming available for their study. These methods are continually being improved through research and experience on existings projects.

Anticipation is the first key to the solution of the secondary problems that may arise when reservoirs are built. The second key is the timely engagement of the requisite multidisciplinary expertise at the earliest possible stage of planning, the careful co-ordination of expert findings, and, as a result, the inclusion in the cost/benefit analysis of other factors in addition to those normally included in such analyses. Dam engineering, with all its complexities, is a much more straightforward operation than the solution of all the ancillary social, economic and ecological problems that arise before, during and after the dam is built and fills the reservoir with water.

In spite of obvious interrelationships, the studies required to solve the secondary problems of reservoir development can be grouped conveniently by subject-matter categories:

Economic studies in the broadest sense, including multiresource use on a regional or national basis;

Studies of sociological problems;

Studies related to land use, including land-use planning, along with agriculture, livestock and forestry production opportunities and problems;

Studies related to the aquatic environment, including fishery development, ground-water use and recharge, and water quality control;

Studies in the broad field of public health in all its aspects;

Investigations into the special problems related to aquatic nuisance plants.

Economic and social problems

The creation of a man-made lake has a profound effect on the way of life of local residents, particularly farmers, fishermen and traders. Human problems are no less important than en-

[a] Selections from a report on "Man-made lakes", prepared by Karl F. Lagler, FAO Consultant, and published by the Food and Agriculture Organization of the United Nations. All illustrations and much of the text have been deleted, and the interested reader is referred to the full text for the details. The section on public health has been omitted in its entirety because of its duplication with annex IV to the present report.

gineering and economic problems, and must be investigated and solved if a productive community is to be established. Drastic changes in environment provide opportunities to alter and improve ways of life — including long-established traditions in fishing, agriculture and other forms of livelihood — as well as to improve community institutional and service structures.

However, changes in agricultural and fishery practices cannot be rushed. Nomadic habits, a subsistence economy, and such customs as shifting cultivation and casual fishing must give way to settled agriculture, systematic fishing and a cash economy. The people of the area need guidance from experienced advisers supported by government policies and services. Particular attention should be paid to the provision of services and institutions for the communities affected.

It follows that, when man-made lakes are to be created, land tenure and sociological studies as well as the teaching of other forms of livelihood must be initiated as soon as the siting of the project is determined.

Settlement, resettlement and related considerations

Among the most pressing and potentially costly of the secondary aspects of reservoir development are those which concern the people who must be evacuated from areas to be flooded and who must subsequently be resettled. Also present, however, may be problems of settling a new population in the foreshore areas and of transferring people into the region to maximize the benefits to be derived from the new resource potential.

The problems of resettlement are much wider than the merely mechanical or logistic aspects. Not only are the technical and economic requirements of new or altered enterprises involved but the human resource — both the individual and the community — must also be helped to become adapted usefully to the new physical, social and economic environment. In resettlement, human adaptation is a particularly complex process of individual and institutional adjustments demanding time, effort, resources (physical, financial, social and technological), and considerable support and assistance. The requirements for such assistance cannot be guessed at any more precisely than can engineering specifications for a dam or irrigation works.

Systematic background investigations are needed of the rural society to be affected by the creation of a lake, along with an objective appraisal of the extent of the human resource development required by the technical and economic change foreseen. Also required are specifications for the type and timing of supporting facilities needed, the maintenance of social controls, the development of leadership, new local organizations, patterns for administrative relationships with and within the new communities, and provision for succeeding generations.

Evacuation

Where a reservoir is to be constructed, the entire population and its possessions must be moved from the area to be inundated, preferably timed to avoid loss of a season's agricultural crop. Such a removal is usually fraught with many stresses, and it requires resettlement into new areas that are either uninhabited or already occupied. The arrival of the transplanted people on their host community raises a different set of problems than those encountered when unoccupied areas are settled.

Population transfer

Where the man-made lake provides resources for development in excess of the manpower of the relocated and host populations, it may be advantageous to bring in additional people to make full use of the new resource potential. Such action has direct economic and social implications for the reservoir area as well as for the areas from which the population will be drawn.

Food and health

It may be necessary to supply food on an exceptional scale until a resettled or transferred population has re-established its productive capacity, and to provide supplementary health control measures for man and livestock where they are moved to a different environment. Food aid in such instances has been provided by the World Food Programme, and other forms of help (farming tools, fish nets etc.) have been granted by the FAO Freedom from Hunger Campaign.

Some of the most serious health effects may be mental, resulting from people being uprooted from a familiar environment around which their way of life was organized. This environment was not merely of relevance in a physical sense but also had an important social and psychological meaning. When people have to be resettled into a markedly different physical and social environment in combination with the economic and technical changes required, social conflicts and tensions may result, leading for example, to the exploitation of the weak by the strong. Serious psychological stresses and social tensions can result unless adequate and appropriate provision is made for the adjustment of the settlers. The new environment acquires personal significance for the settlers through their participation in such activities as the selection of home sites, the planning and construction of housing and other facilities, and in the formation of community organizations.

Settlement area

Potential areas for irrigation around a man-made lake are usually limited by physical factors, such as the contour of the land. Whether for irrigation or for dry-land farming, however, investigations must be made to determine the most suitable areas for irrigation or other development and of the methods to be used.

Public works and housing

Resettlement may entail new buildings for housing, schools, community and health centres, recreation and public offices (police, administration), along with storage, primary processing and market facilities, roads and other transport facilities, domestic water supplies, and waste removal and sanitary installations. Depending on the circumstances, it may be possible to compare the economic implications of the choices for resettlement in large villages or towns, small villages or individual farms.

Although the task of clearing land for dwellings, cultivation and recreational activities may be undertaken to a varying extent by the farmers themselves, costs are inevitably entailed that are logically chargeable to reservoir construction. The expenditure for such work is often relatively high and may continue for several years. Experience gained from earlier projects is of help in discovering the most economical system. For example, the incentive to clear land provided to individuals through food aid, perhaps with the help of the World Food Programme, may be more effective than cash advances.

Rural structure

The construction of a man-made lake often offers a convenient opportunity for the introduction of badly needed economic and social structures. Such structures may involve the system of land tenure, individual or communal ownership, co-operatives, credit institutions or a redistribution of land to form economic farm units, all of which may not only directly affect human relationships but also have a major influence on the economy. Faulty social and agrarian patterns can stultify progress; in contrast, well-adapted patterns can greatly help economic development. Socio-economic studies are required to determine the feasibility of a project and its likely rate of implementation by the local community.

Management assistance and related activities

One of the most effective forms of assistance for new settlers around man-made lakes is to provide guidance that will maximize production and earnings from fisheries or from foreshore agriculture per unit of area, investment or labour. As a result, for many, their resettlement would not only be to a new and hopefully more acceptable habitat but also to higher production levels and to improved standards of living. Both farm and fishery management assistance include plans for technically and economically valid enterprise structures, taking into consideration existing obstacles — whether technical institutional social, economic or financial — to improved production. Such assistance should also show how to overcome existing shortcomings at the local, regional or national level with a view to facilitating settlement.

Management assistance at farm or fishery unit level is particularly valuable in the early stages of a lake project, as, for example, where lake fishing or irrigation is new to a country or region, and where there is little knowledge either among the fishermen, farmers or the extension staff as to how to operate under the new conditions. Research, advisory and training services can be costly, and it may take a long time before fishing and farming can be brought to reasonable efficiency. Obviously, the opportunities, needs and costs for improvement in farming and fishing techniques must be recognized and planned well in advance of construction operations.

Credit

In developing countries most schemes for resttlement, including the improvement of fishing or farming, require a progressive approach, probably including more credit on better terms than was formerly available. In particular, where farmers are compelled to move because of the submergence of their lands, exceptionally generous credit measures may be justified and, if so, this would have to be taken into account in the economic appraisal of the project. The same is true for fishermen in their shift from river to lake fisheries, which usually requires investment in different gear and boats.

Marketing products and developing co-operatives

Evaluation of production potential, including agriculture, fisheries, electricity and industry, encompasses marketing, both as to internal and external demand, and method. Market prospects have a determining influence on the pattern of investment to be recommended. With irrigation schemes involving heavy investment in terms of costs per hectare to be irrigated, it may be expedient to concentrate on the production and sale of high-value commodities to justify the costs; this may require creation of an internal market able to absorb increased quantities of the new product. Equal care has to be taken in selecting a specific crop for export by making sure that it is not already in overproduction in the world. One way of promoting specific cropping patterns and of helping small fishermen or foreshore farmers to ensure advantageous disposal of their products may be to create marketing co-operatives which guarantee to take end products at predeterminated minimum price levels. Assistance is required for the establishment and management of such co-operatives. Production co-operatives may also be needed for the supply of essential inputs, including seed, fertilizer and machinery for farmers, and nets, boats and motors for fishermen.

Clearing the bottom of the proposed lake

A decision as to whether or not to clear trees and brush from the areas which will form the bottom of the lake for navigational, public health or fishery reasons involves cost-benefit assessments and should be a part of the earliest planning for a reservoir. Experience at both Lake Volta (no clearing) and Lakes Kariba and Kainji (partial clearing) affords examples of the economic and practical consequences of different treatments of the lake floor. If clearing is to be done, it is necessary to determine purposes, areas, costs, timing and value of reclaimable timber, as well as methods of clearance and of disposal of the useless remains of trees and brush.

AGRICULTURE AND LIVESTOCK PRODUCTION

Foreshore agriculture and livestock production

The alternately exposed and inundated shores of large man-made lakes have opportunities of unusual promise for the cultivation of short-term crops and as managed forage areas for livestock. The uses to be assigned will depend on topography and soil type as well as on crop suitability determined by previous experiments. Topography and soil type are particularly significant features for estimating potential production, among other things because of the relation of slope and soil composition to water retention during the seasonal drawdowns of the reservoir.

Early planning stages of reservoirs may advantageously incorporate analyses to disclose the qualities of potential drawdown areas, perhaps by aerial photography and photogrammetry coupled with representative soil studies on different degrees of slope. Sometimes crop experiments can be started on suitable sites in advance of initial flooding; often there will be available considerable local experience on short-term crops derived from the flood plain agriculture of the river to be drowned by the reservoir. The creation of a new foreshore habitat for agriculture can offer a good opportunity for the introduction of high-yielding crop strains.

Livestock production in the foreshore areas may be helped by the availability of aquatic plants which can be harvested from the water and useful from the standpoint of public health and recreational convenience, as it may help to control the nuisance caused by overgrowth of aquatic plants. However, there is only a limited amount of information currently available concerning the practicability and the value of using the aquatic plants for animal feed.

Where land slopes gently away from a river course that will be flooded by an impoundment, vast reaches of shallow water may develop. A disadvantage of shallow-water zones is their tendency to increase the area of inundated land which becomes covered with an aquatic or swamp-type vegetation. In such areas, vectors of livestock diseases, in particular the snail vectors of liver fluke, can undergo an explosive expansion in population. Such vector hazards can be identified by early study of the topography of the land that may be flooded and the distribution of vectors and diseases in the river system.

There may also be a tendency to overgraze around new areas of standing water, especially where no other sources of water are readily available for livestock. The situation can be alleviated by controlling the access of livestock to the water; however, in many circumstances this method is uneconomic.

A build-up in livestock population can also cause pollution of the water resource, and this may be important when water is required for drinking purposes, either by the animals or by man.

Finally, mention may be made of the possibility of increasing animal-protein feed as a by-product of developing the fishing industry in a new man-made lake. This may be commercially significant only where the supply of fish offal or trash fish or both is substantial.

Irrigation from lateral dams

Not infrequently, a man-made lake must be protected from excessive siltation and loss of holding capacity by the construction of auxiliary lateral dams or control structures on tributaries known to carry heavy silt loads. In some instances it may be feasible to construct flood or controlled irrigation schemes in a nearby area, but at a lower level than such lateral dams. By this means, the silt may be spread beneficially over potential croplands and increase fertility instead of being harmfully deposited in the lake. The water stored by lateral dams may also be useful due to the drawdown of water in the main lake. Aquacultural use of water in or from auxiliary impoundments is also possible, sometimes jointly with agricultural use, as in rice-paddy fish culture which simultaneously produces crops of rice and fish.

Pumped irrigation

By pumping from a man-land lake, it may be possible to bring under irrigation considerable bordering areas. Such areas could include foreshores that are seasonally exposed by the drawdown of the reservoir, or adjacent land at higher elevations. A careful cost/benefit analysis should precede any large investment in pumps and conduits. Pumping installations might be from floating rafts or at the land end of canals or tunnels originating in the lake. Clearly, it would be necessary to investigate whether it would be more beneficial to use water for irrigation above or below the main dam; still further consideration would be necessary for schemes with a hydroelectric component. Should extraction from the reservoir for irrigation be large, it might affect the design of the dam and, in particular, that of the spillway. Economic appraisal at an early stage of planning would be needed to evaluate all aspects of pumped irrigation, especially the relationships to the over-all secondary uses to which the water might be put and to its effect on public health.

Reduction of inundation zone and use of gravity irrigation

Where the edges of a man-made lake are likely to spread in shallow sheets of water over wide areas of a gently sloping plain, the amount of inundation may be advantageously reduced and controlled by the construction of dikes or bunds. In addition to protecting the lands shoreward of dikes from unwelcome inundation, there will also be a decrease in evaporation loss from the surface of the lake. Keeping the reservoir from spreading into shallow areas may also be of benefit to public health and help to control the spread of aquatic plants. The possible elimination of needed fish-spawning or nursery grounds must, however, also be considered. In favourable circumstances polders may be created below the highest level of the lake, and these may be irrigated by gravity; drainage problems might arise but could be alleviated, as the low-level stage of the lake should be well below the base of such polders.

Drainage of swamps

Where swamps will be unavoidably created by the construction of a man-made lake, such areas can often be identified in advance. Swamps may originate from inadvertent damming of ground water or flooding with surface water. Whatever their origin, they may induce undesirably high evapotranspiration losses. But, with care, steps can be taken in advance for the control of such swamps.

Prior evaluation of swamp drainage for land reclamation will require a multidisciplinary approach. The land may be valuable for agriculture and livestock; and drainage may benefit public health by destroying the habitat for aquatic disease vectors, such as malaria mosquitoes and schistosomiasis snails. There may, however, be overriding values against drainage, such as reduction of the ground-water level, destruction of fish and wildlife habitat, elimination of subsistence and tourist fishing and hunting grounds, and unfavourable desiccation of forest sites.

Forestry and forest product industries

The opportunities and problems involved in deriving benefits from, or providing benefits for, forestry have been almost consistently overlooked when man-made lakes have been planned. If forestry is considered at all, it is generally in relation to its effects on the efficiency of the water storage and distribution system. Nevertheless, the over-all relationship should be regarded from two points of view — the effect of forestry on the lake and the effect of the lake on forestry.

Effect of forestry on a man-made lake

Forests have both a protective and a productive function in their environment. In their protective role, they may influence the changes in the environmental conditions brought about by a large impoundment, particularly through the soil and water conservation functions of forest establishment and management. The productive aspect is generally complementary to this and can improve not only the over-all economics of a project but also adjust land-use balances within the local economy covered by it.

Upstream catchment zone

In constrast to artificial plantations composed mainly of single species, existing indigenous forests commonly form more stable ecological communities and may therefore be more effective in protecting unstable catchment soils. However, under appropriate management, both types of forest can form an effective catchment cover. Generally the forest can also perform a significant economic role by providing immediate cash returns, employment for local or resettled communities, and material required for domestic use and for construction.

If existing forests on the up-stream catchment are to be utilized for wood production, the manner in which logging and road construction is carried out can have important effects on both stream-flow and water quality. If adequate regeneration is slow, operations involving large-scale clearing or burning can be followed by increased flood peaks and sediment loads. The extensive use of insecticides and herbicides in forestry, as in agriculture, can have serious repercussions down-stream. If, however, the possible dangers are realized, adequate precautions can be taken to permit economical forest exploitation without down-stream damage.

Afforestation or reforestation can often provide the means for the rehabilitation of large bare areas in up-stream catchments resulting either from natural causes or from mismanagement, such as overgrazing. The reduction of soil erosion and the improved infiltration and water retention capacity of forest soils, combined with the eventual provision of commercial wood crops, can both directly and indirectly raise the general level of catchment protection. Again, protection-oriented management systems will need to be applied in the harvesting of the wood crop, so that the primary objective of the afforestation programme is not impaired.

In areas of unstable soil, where flash floods occur, streambanks are a major source of erosion sediment. Afforestation or the improvement of existing forest stands adjacent to watercourses can often be combined with engineering works to provide successful stabilization measures.

In addition to the direct effect on the lake itself, afforestation or the reservation of existing forest stands may provide village woodlots as local sources of fuel and construction wood. The planting of trees for shade and recreational shelter in new town sites can also be considered an important function of forestry in the man-made lake environment.

Shoreline zone

Forests can be managed or established so as to provide very effective filter strips between the high-water level of the lake and the remainder of the catchment. In this way it is possible to insulate to some degree the reservoir itself from the worst effects of such factors as overgrazing, high human population density, and substrate movement, and thus to improve lake shore stability. Where a shoreline is in an extremely arid area, the establishment of such shelter belts may be difficult, but irrigation water pumped from the lake may overcome the difficulty.

Trees transpire large amounts of water owing to their extensive root systems and their dark foliage which may absorb greater amounts of solar energy than the light-coloured surfaces. Whereas this comparatively high transpiration rate varies with the local climate, a forest is likely to romove more moisture from the soil than a less tall form of cover, such as grass. Thus, where drainage is important, tree planting may be advantageous, but where soil moisture must be conserved, a less dense, shallow-rooted plant cover may be required. Of course, the protective function of forest cover must always be weighed against its water-using function, and may frequently be of overriding importance.

Effects of a man-made lake on forestry

The effects of the creation of a man-made lake on forestry are either direct and physical or indirect. Direct effects are represented by changes in the water table, including the drowning of trees, and possibilities for irrigated forest production. Indirect effects include improved transportation and labour resources which can make economically possible the afforestation of an area otherwise too inaccessible or lacking available manpower.

One of the first results of constructing reservoirs is that trees must often be drowned. Riverine forests which are casualties during the filling of new reservoirs sometimes contain valuable timber, such as species of Khaya in Africa. Early planning can lead to the salvage of such merchantable timber prior to flooding, with possible related benefits to navigation, public health, fisheries and aquatic weed control.

Up-stream

In the up-stream catchment, the direct effects of the lake on forestry are likely to be insignificant, but the indirect effects may be quite considerable. Of particular importance could be:

Bringing inaccessable areas within range for commercial utilization through improved communication;

Lowering timber transportation costs by floating or rafting;

Extending the supply zone for large-scale wood-using industries.

The availability of low-cost hydroelectric power and large quantities of water may also assist in the development of forest and wood product industries which may otherwise be impossible, even though the forest resource is large.

Around the lake

Following impoundment, the altered ground-water pattern in the vicinity of the shoreline may simplify the establishment of plantations or the management of existing forests. However, some problems will inevitably be associated with the fluctuating level of the lake and hence of the water table. Within a middle strip around the lake conditions may be ideal for tree growth, whereas near to the lake the soil may be too wet, and farther away it may be too dry. If the soil moisture in the middle strip changes drastically with changes in the lake level, finding a suitably tolerant tree species may be impossible. If the fluctuation in lake level can be minimized, forest production can be greatly improved. Most trees that tolerate periodic flooding are less tolerant of stagnant than of flowing water, and for this reason a reservoir margin may be a less suitable site for indigenous species than the former river margin.

When establishing forest plantations, either for the benefit of the man-made lake system itself or to exploit the environmental changes brought about by the lake, the introduction of species new to the area will certainly be considered. It is essential that large-scale planting should be preceded by small-scale trials of species or varieties. In attempting to make the right choice of species for planting, an ounce of local experience is worth a pound of expertise under different ecological conditions. But a grain of properly controlled experimentation is usually better than either. Careful soil survey and differentiation of the assorted sites available for planting should go hand in hand with species trials. The creation of a man-made lake is therefore not likely to be followed in a short time by a large-scale change in species composition of forests in the area.

Industrial and subsistence fisheries

The potential fisheries of a new man-made lake are of three kinds: industrial (commercial), subsistence and recreational. Together they constitute one of the earliest and most easily gained returns from a man-made lake. The first two are considered here; recreational or sport fishing will be taken up under the heading of tourism. There is no problem of conflict among these three types of fishing in large man-made lakes that is without solution if adequately studied. For example, although it has sometimes been alleged that the quality of sport fishing may be adversely affected by commercial fishing, under proper management systems the two types can be complementary and can greatly increase the net economic benefit derived from the fishery resource.

As with most other secondary aspects of reservoir construction, the disciplines of fisheries and related hydrobiology should be represented at the earliest stages of planning. Fishery expertise will be required to evaluate the effect of the engineering works and the proposed land and water uses (especially the projected water régimes) on the living aquatic resources and to avoid costly losses of aquatic production.

Fairly lengthy pre-impoundment research and study are required to make predictions of future fishery potential for economic assessment and planning. The components of such investigations are:

Species composition and relative abundance of stocks of the riverine fish population, both down-stream and up-stream from the proposed dam site;

Soil types and their extent and distribution in the basin, especially in relation to the spawning grounds;

Location and characteristics of tributary streams, including character and amount of silt load;

Areas and rate of siltation;

Extent and volume of water available for fish production, including water-level régime and flushing rate;

Nutrient impact from run-off and tributaries;

Thermal and chemical stratification probabilities;

Current and historic yields by species in the riverine fishery.

Combining this local information with experience recorded elsewhere, including testing the validity of similar estimates of production, will enable a fishery scientist to make predictions of future fishery yields. Alternative predictions based on alternative forms of engineering work will asist in making the best decisions as to the location and design of the dam. Design features that might be affected would include:

- Vertical location of draw-off structures, such as penstock (sluice gate) openings;
- Need for, and character of fish passes or devices for controlling the movement of fish;
- Best water régimes for the fishery component of an economically optimized multiple water use scheme.

Early predictions regarding the aquatic resources that may bear on engineering works and on land and water-use planning are many. Detailed discussion follows on some of the most important of these.

Planning for optimal development

The fishery of a new reservoir can develop fortuitously or it can be developed on the basis of an orderly economic and scientifically conceived programme. If the development is allowed to be haphazard, net yield is likely to be far below the maximum sustainable, and overexploitation of at least some key stocks is likely to take place. Furthermore, fishermen are likely to become entrenched in inefficient methods of fishing and catch disposal from which it may be extremely difficult to disengage them.

If, prior to impoundment, valid predictions are made as to the character and natural development of the fish stocks, and if the optimal manpower and investment schedule in different kinds of fishing is carefully planned, along with an adequate scheme for disposal of the catch for goods or cash, then an orderly development may result. As part of this development, a system of catch statistics to give yield and value by species in relation to fishing cost and effort must be instituted as the primary indicator of the adequacy of the plan of fishery development. These statistics are also the basis for early identification of overfishing or underfishing of species stocks, and are therefore a first key to rational management of the resource.

It often becomes evident early in the planning of fishery development programmes that the fishermen themselves are in need of education and re-equipment. A vigorous fishery extension programme can meet this need but, to be successful, it should go into operation at a very early stage of planning so as to offset the shock caused by the sudden appearance of a new man-made lake.

Additional planning for optimal fishery development will include:

- Appraisal of relevant aids to navigation and marine safety requirements;
- Provision of systems for landing, handling, storing, processing, transporting and marketing the aquatic produce, possibly through fishermen's co-operatives;
- Organization of a fishery trade school;
- Development of an advisory system on the investment of venture capital in the fishery;
- Financing as required, by means of bank loans, of both the fishermen and the fishing industry. Supporting services that may need to be developed include the supply of fishing gear, boats and ancillary goods and repairs.

The whole plan for the orderly development of the fishery resource depends on early and vigorous interaction for planning among fishery scientists and technologists, resource economists and engineers.

Changes in fish fauna from river to reservoir

In an impoundment made by damming a river, its natural stocks of fishes result from the stocks previously present in that river. Although it is possible to alter the composition of the species stocks later, the initial fishery is most often dependent on natural stocks; only rarely have fish been eliminated from a river system by the use of poisons prior to damming and an effort made to establish from the outset, by intentional stocking, a fish population of the desired species composition.

Assuming a mixed species population in a river before impoundment, can the contributions of these species to the reservoir population be predicted? The answer is yes, to a limited but continually improving degree of accuracy. The better the knowledge of the ecological requirements of the species, the more accurate can be the prediction. Especially important components of this knowledge, for prediction purposes, are reproductive requirements — for example, the character of spawning grounds and the means for access to them, food and feeding habits, and temperature, oxygen and current requirements.

In a riverine fish population one may expect a range of species requirements extending from quiet water to moving water. Thus some species will inevitably be encouraged by impoundment and others discouraged. Similarly, riverine populations are often low in predominantly plankton-feeding fishes while in a lacustrine situation there is often a very substantial population of plankton feeders. This fact reflects the prevalent difference in available microscopic plant and animal life (plankters) in the two habitats, and represents a direction of ecological change that comes with impoundment — change that can be very significant for fish production. In a reservoir made by damming a river, therefore, not all of the newly created habitats may be fully utilized by the expanding populations of native riverine fishes. For example, in Lake Kariba, Zambia, the open water was little used and led to the experimental introduction of a small freshwater herring, *Linothrissa miodon*, from Lake Tanganyika. Such introductions, of course, may be dramatically successful or catastrophic for the over-all fishery. They must be preceded by intensive research.

Throughout its depth, temperature of even a large river is quite uniform although unstable, since it fluctuates with daily changes in air temperature. Upon impoundment, the temperature, except in headwater and surface zones, becomes relatively stabilized and in the depths may change greatly only with the seasons. The change from riverine thermal conditions to those of the impoundment will affect both the abundance and the distrubution of the various fish species differently, sometimes predictably.

In flowing river water there is normally saturation of dissolved oxygen from surface to bottom. However, at least seasonally in many impoundments, this gas may be in saturated solution only in the surface waters and be so deficient in stagnated depths that fish cannot survive there. Where this occurs, that section of the impoundment must be discounted, at least seasonally, for fish production. Such an adverse effect may be compounded by the development of hydrogen sulphide from organic decomposition in stagnated depths. This gas is injurious to aquatic life and its presence in water can also cause damage to hydroelectric turbines. Since adverse chemical stratification is associated with thermal stratification, it can be partially overcome by the positioning of the water outlets in the dam.

Possibilities for improvement during construction

Advantageous opportunities exist for the improvement of fish habitat and of fishing grounds prior to the first flooding of a man-made lake. Part of the advantage is that some of these improvements can be made only with difficulty or not at all once the reservoir is permanently filled. Only seasonally exposed areas can easily be altered once the reservoir fills. This means that fishery experts should study the possibilities of fish habitat improvement at the earliest planning and feasibility assessment stages of proposed man-made lakes.

Illustrative of habitat improvement procedures that may be evaluated for applicability is the installation of spawning grounds for preferred species. The application of this procedure requires prior knowledge of substrate spawning requirements and of the greatest extent and depth distribution under water of the suitable substrate. Where it is lacking at the proper depths, desired substrate may be exposed by stripping off an overlay of topsoil.

Devices that concentrate fish for capture, such as piles of native brush, may be anchored on barren lake bottoms. Their location may be marked with buoys that will rise with the flooding water to guide fishermen to the sites and aid navigation among them. Such devices may be particularly useful where desert grounds are flooded, and also valuable for concentrating fish near centres where people are likely to be concentrated and desirous of subsistence or recreational fishing.

The improvement of fishing grounds has often taken the form of the removal of obstructions which would limit the efficient operation of likely types of fishing gear. A common means of such improvement has been to remove trees and brush prior to initial flooding in areas of permanent inundation. This derives from the strong resistance to deterioration of wood permanently submerged in fresh water. Loss and damage to gear such as gill nets, long lines and trawls can certainly be reduced by clearing. Nevertheless, clearing also means that sheltering cover and foraging grounds for fish are removed. Because of these conflicting concerns, clearing proposals require early and individual evaluation for each new impoundment.

Evaluation must also include recognition that transportation and public health needs are to be taken into consideration at this time.

Dams as physical barriers to fish movement

A river system plays a vital role in the life cycle of migratory species of fish — it is a route up or down which spawners reach their spawning grounds, and fish in their young life history stages reach their feeding grounds. For such species an obstruction like a simple dam can spell doom. For, not only may the dam prevent migration up-stream, but fish migrating down-stream may not survive the effects of passage through the turbines, or, if led into irrigation ditches, they may be stranded and die.

If a fishery scientist is called in to advise early enough in the planning and feasibility studies on a dam, some unwanted direct effects of the dam as a barrier may be overcome, often at surprisingly low additional cost. In such instances the fishery expert may determine the need, feasibility and characteristics of appropriate fish-passing devices and fish-guidance structures. Thus, in carefully planned and executed dam systems, uneconomic barriers to migratory fish stocks may be minimized if not contempletely overcome.

Among the means of passing fish in both directions over dams and for related guidance systems that may be combined into sound economic investments are: fishways; fishlocks; fish lifts or elevators; systems of trapping at the dam and transport around it; guidance devices for fish to entry of fish passes and traps, or away from danger points such as inlets to irrigation ditches or penstocks.

The success of any such installation depends on the extent of knowledge of the physiology and behaviour of the species concerned. Often it will be necessary to undertake original and detailed field and laboratory studies, including experiments with models of proposed fish-passing or fish-guidance structures. From this point of view alone it is therefore of extreme importance that fishery experts be involved in the earliest stages of planning for dams across rivers.

Effects of altered water régime

Dams alter water flow characteristics down-stream and thus may affect aquatic stocks in many different ways including water velocity and volume of discharge, water chemistry, temperature and turbidity, and the stream's ability to purify its waters. There may also be alterations in the amount of living space for fish, including the extent of spawning, nursery and feeding grounds. In the estuarine tidal zone, a chemical change of potentially vast significance may be effected in salinity, probably in the form of an over-all net increase due to reduction of stream discharge. Any reduction in the net annual discharge also lowers the capacity of a stream for self-purification, especially as regards reduction in capacity for oxidation of transported organic material and reduction in the beneficial effects of flushing.

These effects and changes abviously include elements of danger vis-à-vis the maintenance of aquatic production. For example, reduction in living space means decreased production and the increased vulnerability of fish to predators and fishermen. Wide and sudden fluctuations in daily discharges through dams also reduce potential for aquatic production and place stress on indigenous species stocks. In extreme situations, the down-stream watercourse is alternately wet and dry each day and aquatic production is terminated. A further example occurs when oxygenless water or water laden with noxious substances passing through a dam may eliminate the desired aquatic productivity for some distance down-stream. As a specific example of such changes, by 1967 it had already been noted that adverse effects of the still uncompleted high dam on the River Nile near Aswan were manifest in the estuarine fisheries of the delta and were even detectable in the eastern Mediterranean.

Many potential adverse effects of altered water flow can be offset by careful planning. This planning calls for interaction between engineers and fishery scientists, with the result that any planned flow regulation may involve little or no compromise of the primary objective in creating the reservoir and may add significantly to the economic soundness of the whole scheme by eliminating any loss in fishery potential.

Effects of flooding and siltation

A common feature of man-made lakes is that historic spawning grounds for certain fishes are drowned. These grounds may be the riffles of streams, or quiet, backwater areas of specific depth, bottom and cover types that took a long time to evolve. In either instance the effects may be very damaging to certain species, since successful reproduction is of first importance to ultimate yield in a fishery. To a limited degree, the effects of such drowning are identifiable; countermeasures may be justifiable for key species and may be accomplished at least in part by habitat alteration prior to first flooding. Such habitat improvement may take the form of moving earth to provide alternative spawning grounds as the reservoir rises initially and subsequently rises and falls. Water level control during spawning season can offset the drowning of spawning grounds and alleviate the possibly even worse effect of the alternate drowning and stranding of nest sites. This is particularly important for such fishes as basses and sunfishes of the family *Centarchidae*, of various species of tilapia, and of many kinds of catfish.

Equally damaging can be the smothering of spawning ground or nests by deposits of silt, where the main stream and tributaries enter impoundments and also in waters adjacent to agricultural land or along windward shores where there is erosion by wave cutting. In order to guard against the potential threat of siltation to aquatic production, early and integrated planning is required of engineers, agriculturists, fishery scientists and soil conservationists.

Harmful introduction of exotic species

Sometimes the elevation of water levels or the construction of canals to cross natural drainage divides may result in the unwanted spread of certain aquatic plants and animals into areas not native to them. The outcome of such incidental introductions can be so serious that fishery, plant protection and public health scientists should be involved early in any such engineering planning. Intentional introductons of exotic aquatic plants, fishes and other animals should be undertaken only after extensive research.

Possibilities for aquaculture

The construction of a reservoir for water supply is the classical prelude to the development of a fish cultural enterprise down-stream from the dam. Early planning considerations for man-made lakes may advantageously include aquaculture in the over-all scheme for water use. One of the economic attractions of aquaculture it that it is essentially a nonconsumptive use of water, in contrast to irrigation agriculture which is very highly consumptive. Furthermore, per unit of land, aquacultural yields can under some circumstances far exceed those from agricultural production in terms of economic and protein returns.

A wide variety of plants and animals may be propagated in small ponds supplied with reservoir water; the variety is so great that market preferences can usually be readily supplied. Such plants include several kinds of water cress, water lettuce and water chestnut. Among the animals, most popular and productive are different species of fish; shrimp along with other crustaceans and shellfish; frogs, crocodiles and turtles are also among the prime potential of aquacultural produce. In some circumstances fish can be cultivated simultaneously with rice, the fish being a bonus crop and the rice yield being increased substantially by the presence of the fish. Some irrigation canals are readily adaptable to fish or aquatic plant propagation.

Although ponds or channels that can be supplied by gravity from a reservoir may be best for aquacultural purposes, the practicability of developing locally intensive forms of aquaculture within the arms of the reservoir basin or on its banks should not be overlooked at the planning stage. In some instances it may be feasible to lift water from the reservoir to supply ponds located above the normal high-water levels.

Experience to date indicates there is little likelihood that ponds for fish culture in the vicinity of reservoirs can ever be justified for purposes of planting native fishes in the reservoir for stock maintenance purposes. If, however, it appears likely that planting an artificially reared fish of a preferred species may compensate for its loss of spawning grounds due to impoundment, a feasibility study may well be undertaken. The provision of cultural facilities for exotics desired for later introduction should be considered during the planning stage, and also the possibility for establishing facilities for artificial rearing from which owners of small, sometimes domestic, ponds or rice paddies can secure the proper fish of the correct size for stocking their own water. Among the fish suggested to stock such water might even be Gambusia, for the control of malaria mosquitoes.

Wildlife, recreation and tourism

Man-made lakes, ecologically cataclysmic though they may be, often afford unusual opportunities for economic gain and for meeting the increasing demand for the development of wildlife resources and outdoor recreational facilities. Altering ecology as they do, and often isolating islands or long peninsulas, such new lakes also offer an opportunity for the conservation of open spaces and natural beauty, and the preservation of natural areas for study and enjoyment. In addition, forests within these areas may often be managed for multiple use including wildlife utilization, recreation and tourism. Controlled harvest of wildlife within conservation areas is sometimes desirable from a management point of view; at the same time, it provides an immediate economic return in meat and skins and ensures future returns from hunting, viewing and photographing wildlife.

Unless there is planning, feasibility analysis and implementation of proposed wildlife and recreation development at an early stage, economic losses may be incurred in the management and investment planning for wildlife, recreation and tourism for any man-made lake. To be noted in planning, the rescue of specimens of rare or valuable species of wildlife from drowning has not generally been justified from a strictly wildlife management point of view.

A programme for the conservation and development of wildlife resources in the vicinity of a new man-made lake might range widely from conservation planning for the immediate basin of the reservoir to the establishment of small natural reserves within the area, even on certain small islands that may come into being in the lake. Conservation planning for the entire basin may take the character of a watchdog operation to press for good conservation concepts in all the forms of land and water use — concepts that are often overlooked when early economic development alone is the prime moving force. Aspects that should be taken into account at the planning stage for conservation are discussed in the following four paragraphs.

How, by planning, can different uses such as tourism, recreation and wildlife utilization be developed, co-ordinated and integrated with other aspects of the management of the new lake or the entire drainage basin of which the lake is a part? Planners should identify the existing resource and the potential for its development; in particular, national parks, game reserves and other game and forest management areas that may be devoted to various recreational uses, such as camping, hunting for game and wildfowl, fishing, boating, swimming and water skiing.

Creation of a new lake will destroy some natural areas and create others, but early planning can ensure that maximum advantage is taken of opportunities to create new wildlife habitat in order to compensate for that which is lost; for example, auxiliary dikes may serve jointly for irrigation agriculture, aquaculture, and wildlife habitat maintenance.

Infrastructure for recreation and tourism development, such as tourist roads, harbours of refuge, marinas and tourist accommodation, should be constructed with over-all lake development in mind, and sited so as to preserve and take advantage of features of natural beauty.

The interpretation of natural areas and archaeological sites for visitors and the education of local residents in conservation are important parts of wildlife, tourism and recreation development programmes, and should be examined at an early stage in over-all planning.

All these considerations require the early formulation of policies for wildlife, recreation and tourism, the designation of an appropriate administration, and enactment of suitable legislation.

Navigation and water safety

Although provision of cheap water transport often appears among the primary considerations in the construction of man-made lakes — as in those of the Tennessee Valley Authority (which is concerned with the Tennessee River drainage basin in the United States of America) or Lake Kainji on the River Niger in Nigeria — aids to navigation and the codification and enforcement of water safety regulations are often considered of secondary importance. Early planning can help to overcome some of the problems,

For example, it may frequently be advisable to add to the costs of any projected man-made lake the expense to be incurred in removing dangerous obstructions to navigation. Included here might be:

Levelling of rocky outcrops;

Removal of trees, at least down to a safe level for navigation;

Preparation of hydrographic navigational maps and of radar charts for blind-weather travel;

Maintenance of information communication services on marine weather and lake elevation, and for use in distress;

Training and equipment of marine safety and rescue police services.

Transportation is inevitable on large man-made lakes whether or not it has been a primary purpose in construction. Consequently, feasibility studies of the whole project must include the costs of instituting and policing marine safety regulations and services. Earliest concern will often be over the lack of suitability of native riverine craft for use on a new area of water which may virtually be an inland sea. Special concern may well arise over water taxis and ferryboats. This should lead to the codification of regulations for design, capacity and requisite on-board safety equipment for all vessels, and to the etablishment of rules of road and vessel-handling procedures. Enforcement will involve both the training of officers and the education of boat crews and the general public.

It may be wise to consider at an early stage the possibility of a watercraft licensing system before tragedies occur and unwise investments are made in faulty hulls with inadequate equipment. Licensing provides a means for vessel inspection and certification, and for offsetting the costs of these and other policing services. Some income from this source and taxation systems for cargo landings at major ports may support, at least in part, the costs of port and navigational aid maintenance.

Another cost to be anticipated is the provision of docking facilities, not only for efficient loading and offloading, but also to keep stevedores and passengers out of the water where waterborne diseases are present. Experience has shown that such facilities are likely to be needed at road-ends around the reservoir and that the need will exist as soon as the reservoir starts to fill. If ramp devices are to be a part of the dock facilities, it is easier to construct them before the reservoir fills for the first time, although their location may be best defined by the first high water.

Water quality control

Man has proved himself to be unusually adept at fouling the surface waters of the earth. Even such extensive water areas as the Great Lakes of North America, segments of the oceans, and the world's largest rivers now show damage from pollution. Early thinking and planning relative to man-made lakes should include consideration of the water quality through the enactment of appropriate legislation, monitoring and enforcement, if they do not already exist.

Included in the uses of water quality standards are erosion control to minimize turbidity and siltation as withholding from the water of nutrient materials that may have unwanted side effects. The inflow of nutrient materials can stimulate the growth of waterweeds, including algae; common sources of such nutrients are drainage from fertilized agricultural land, domestic sewage and certain industries such as food canneries or processing plants. Domestic sewage effluents are also hazardous to public health.

Pesticides can have dangerous side effects and early plans for regulating their use in the basin should be carefully formulated. The following are examples of pesticides that may be used in or around man-made lakes in many parts of the world: herbicides for the control of nuisance aquatic plants; Molluscicides for the control of snail hosts of bilharzia (schistosomiasis); insecticides for the control of the insect vector (*Simulium*) of river blindness (onchocerciasis), mosquito vectors of malaria, the tsetse fly vector of sleeping sickness in man and cattle, and for the control of agricultural and forest insect pests.

Fish poisons may also be involved owing to local methods of fishing. All such chemicals and others, some of which may derive from industrial effluents, may have undesirable side effects on man or on the aquatic ecosystem; some can limit or destroy the capacity of water for fish production. The development of methods of direct government control of the use of toxicants in the reservoir ecosystem is therefore an important part of reservoir planning.

Early thinking on water quality control in new man-made lakes will find technical leadership in the fields of soil conservation, forestry, public health and fishery limnology.

Aquatic nuisance plants

By means of careful and early planning and action it is possible to avoid some of the hazards offered by aquatic plants to public health, fisheries and navigation in man-made lakes. Such lakes can be expected to provide good growing conditions for many kinds of plants, some valuable or relatively harmless, or both, others actively dangerous. If the problems posed by aquatic nuisance plants are to be avoided or, if necessary, solved, their early assessment is essential to preparation for a man-made lake.

Preliminary survey

Early planning or advice regarding a proposed man-made lake should include competent information on aquatic weeds. The first task would be to survey carefully the drainage area of the future lake for problem plants. If potentially dangerous plants are discovered in the upland drainage basin, but not in the future lake area itself, it may be possible to build barriers to arrest their spread into the future reservoir.

Quarantine

If the lake and its associated areas are free from certain dangerous plants which exist in nearby drainage basins or countries, then stringent quarantine precautions may be justified to reduce the risk of accidental or deliberate importation.

Measures to minimize risks from noxious plants

Removal of partially submerged trees

Where the crowns of many trees will extend above the water to provide shelter and support for aquatic plant communities, the application of herbicides may be extremely difficult and even impracticable. Considerations regarding the clearance of the future reservoir bottom should include the effect of both aquatic plant establishment and its control.

Lake installations

Those planning installations for a new reservoir should consider the possibilities of heavy aquatic plant infestation. A dam with an open spillway, for example, may enable large quantities of plant material to be discharged easily from the lake in time of flood, as on the Rio Lempa in El Salvador. In contrast, a spillway overflowing into a tunnel may run the risk of being blocked, as on Lake Apanas in Nicaragua.

Swamps

Extensive shallow-water areas may not only be wasteful of water due to evapotranspiration but may also provide habitats favourable to aquatic weeds — areas which, because of size, may be expensive or impracticable to treat. Keeping the lake out of such areas and, as far as possible, into areas with steeply falling banks can help to control littoral weeds. Steep banks, furthermore, may augment turbulence during storms and so break up floating masses of weeds. However, shoals may be important for fishes as spawning, nursery or feeding grounds and need also to be evaluated on this basis as well as for their public health implications.

Planning to control aquatic plant invasion

Conventional spraying methods

If it has been determined that an invasion of troublesome plants can be expected in a reservoir, a control plan should be prepared and costed which, if considered feasible, could be implemented when needed.

The plan should include ecological control and, perhaps, chemical control. Provision should be made for spraying equipment (land, water and airborne) and for supplies of the necessary herbicides. Cadre crews for the control operation may have to be trained in the recognition of plants, in preparing and handling herbicides, and in the operation and maintenance of the herbicidal distribution equipment.

An effective control plan would include a campaign of constant vigilance, continuing indefinitely, to attack any developing infestation at its earliest stage. Budgeting for a steady campaign to keep invading plants at a low level of infestation may prove to be wiser than waiting until the problem becomes overwhelming.

Biological control

The possibility of biological control — by habitat manipulation or by animals, fish, insects or diseases — is always attractive. Unfortunately, there are few examples of its successful operation. However, research into all methods of biological control is useful, and information on the latest possibilities should always be sought.

Losses caused by waterweeds

Evapotranspiration

Engineers frequently are unaware of the extent to which invading plants cause losses to stored water. If problem plants are present in quantity, local experiments to measure evapotranspiration would give an indication of the potential total water losses from these plants. The value of the lost water then becomes the basis for assessment of the costs of control.

Fish and fishing

Aquatic weeds compete with fish for living space. However, they also provide shelter and forage grounds, including an increased area for the production of food organisms. Sometimes the shelter they afford is so effective that some fishes become overcrowded and grow very slowly. Dense plant growths may interfere with fishing. Careful local evaluation is needed.

Utilization of aquatic plants

The question of whether or not aquatic plants can be utilized locally may be worthy of study. The most obvious use is as animal feed.

Annex VI

SALINE AND BRACKISH WATER CONVERSION[a]

In certain areas the desalination of local saline water resources, occurring either as sea-water or brackish ground water, may play an important role in the integrated development of a river basin. A short summary is therefore included here describing the current status and likely future development of desalination, together with a statement of some of the important considerations that pertain to the integration of desalination into an over-all water resource development.

TECHNOLOGICAL STATUS OF DESALINATION

Experience over the past decade of the use of desalination has confirmed it as an entirely viable source of water supply, at least in the technological sense. Expertise now exists which would allow the construction of sea-water conversion units, based on proven technology, to be undertaken with full confidence. Continued successful operation of such units does, however, require the existence at the local level of certain engineering skills and facilities.

In the area of brackish water conversion a reduced but still considerable level of operational experience exists. Recent trends have been towards more complete confidence in the operation of brackish water conversion units, although the treatment of certain brackish waters still presents technical problems. Advances expected in the next few years will in all probability greatly extend the range of brackish waters that can be treated on a routine basis.

The total capacity of major desalination units now installed throughout the world is of the order of 200 million gallons per day (mgd), nearly all of this having been installed, at a progressively increasing rate, since 1960. The greater part of this total capacity is made up of multistage flash distillation units for the conversion of sea-water; the residual is comprised of generally smaller vapour compression distillation and electrodialysis units, the last being confined to brackish water conversion.

The larger multistage flash distillation units are commonly of the order of 1 mgd capacity; more recently units up to 4 mgd capacity have been constructed. Developments currently in progress are aimed at providing the design criteria and engineering experience necessary for the construction of units up to about 20 mgd capacity. In anticipation of the results of this development work, serious consideration has recently been given to the design of installations on a semimodular basis with total capacities of up to 150 mgd.

Many of the multistage flash distillation units are dual-purpose plants, that is, they are integrated with electric power production plants. The complementary nature of a high-pressure steam requirement for power production and low-pressure steam (available as exhaust or by-pass steam from the power turbines) for a multistage flash unit can result in significant economies in the water and power production costs. Further economies are available from the sharing of common ancillaries, such as the water intake and other site services. In addition, the location of a water and power plant at a common site allows the use of the same supervisory and maintenance services for the two functions. Where water production capacity is only of the order of 1 mgd, it is only on this shared basis that these specialized, but highly necessary services can be made available without grossly inflating the product cost.

Vapour compression distillation of sea- or brackish waters is mainly confined to isolated areas with water requirements of the order of 10,000 to 100,000 gallons per day (gpd). A primary requirement in such applications is the avoidance of a need for the continuous manning of the water plant. The availability of essentially automatic small vapour compression distillation units, driven by either diesel or electric motors, meets this requirement.

The electrodialysis process, based on the removal under the influence of an impressed electric field of solutions through ion-selective membranes, has costs which are strongly influenced by both the initial salinity of the feed-water and the required product purity. As a result economic application of the process has been limited to the treatment of brackish waters with salinities up to about 5,000 ppm total dissolved solids; similarly, the achievement of product purities much better than 350 ppm total dissolved solids is rarely attempted. Beyond the influence of total initial salinity, the performance of the electrodialysis process is also sensitive to the composition of the feed-water; for example, the presence of a high sulphate component can detract from the plant performance and even small traces of certain contaminants such as iron or manganese can result in the need for special pre-treatment of the feed-water. The complexity of these influences usually requires that each brackish water source be thoroughly investigated before the use of electrodialysis can be recommended with confidence. In those areas where conditions have been established as satisfactory, excellent records of plant performance have been achieved at favourable costs. Most units to date have been in capacities up to the order of about 200,000 gpd although work is now in progress to establish optimal design criteria for units of 1 mgd and greater capacities. Similarly, recent and current development work shows good promise of producing significant reductions in electrodialysis costs.

The reverse osmosis process probably offers the greatest potential towards achieving a brackish water conversion process which is both economically competitive and inherently simple in its operation; its potential for large-scale sea-water conversion, however, cannot as yet be predicted. The process, based on the preferential transfer under the influence of an applied hydrostatic pressure of water rather than dissolved solids through specialized membranes, has attracted a research and development effort at a level unprecedented in desalination. While the process only recently moved from an experimental basis to one of the semi-commercial availability of units of about 100,000 gpd, it is to be expected that brackish water conversion units of

[a] Prepared by the United Nations Secretariat.

1 mgd capacity should be available by 1970. The intensity of interest in reverse osmosis has been enhanced by the expectation that the process will be capable of treating a very wide variety of products including waters contaminated by industrial and municipal sewage effluents.

Desalination process costs

A careful distinction must be made between the desalination process cost and the over-all cost of water as delivered from a fully developed water supply system based on desalination. The more restrictive term of desalination process cost is used to describe only the capital and operating cost of the desalination unit which is assumed to be located in immediate proximity to the source of saline water.

The process cost of sea-water conversion, based on multistage flash distillation, is most strongly influenced by size of unit cost of capital (interest rate); cost of energy, and the operating load factor. These parameters influence both the capital and operating costs of the unit, through economies of scale in capital costs and through their influence on the choice of the performance ratio of the unit, defined as the water production per unit of energy consumption. The selection of a high performance ratio plant, implying a high capital cost but low operating cost, will be favoured under conditions of low interest rates, high load factors and low energy prices. Under the converse conditions the selection of a low performance ratio plant will be favoured.

In the particular case where the total installed desalination capacity at any site is comparatively small, say of the order of 1 mgd, an additional important parameter influencing multistage flash distillation costs is the availability and cost of labour. Where the full cost of continuous manning of the plant must be borne by the water production, a serious inflation of water cost is likely to result. The more advantageous situation is that of a dual-purpose or coupled power/water plant where the costs of operating and maintenance labour can be shared by the two functions.

It is the wide variability of these important parameters, namely, unit size, interest rate, energy cost, load factor and labour cost, which cautions against the generalization of multistage flash distillation costs. However, under the particular conditions of essentially base-load operation, and assuming 12 per cent *per annum* fixed charges on capital — reflective of an interest rate of about 7 per cent *per annum* — process costs from a 1 mgd multistage flash plant can be expected in the range 85-125 cents/1,000 US gallons for low-pressure steam prices of 20-60 cents/m BTU. At unit capacities of 10 mgd the range of water costs is likely to drop to about 60-90 cents/1,000 gallons. A reduction in the plant load factor from base-load operation to, say, 50 per cent load factor will result in close to a 40 per cent increase in these water costs; similarly a halving of the annual fixed charges rate will result in nearly a 40 per cent reduction in the water costs.

Sea-water conversion costs from units of about 100,000 gpd and smaller are likely to be considerably higher than those quoted above. The higher specific capital costs of multistage flash plants at these smaller capacities, together with the requirement of continuous manning, usually preclude the use of this process for such applications. Under such conditions, vapour compression distillation units, designed for essentially automatic operation, are likly to prove more economic although water costs will almost certainly remain well in excess of $1/1,000 gallons.

The strong influence of interest rate, energy cost, and plant load factor is retained in the case of electrodialysis costs; the influence of unit size is, however, less marked. Beyond these parameters exists the strong influence of both initial feed-water and final product water salinities. With a feed-water salinity of, say, 2,000 ppm total dissolved solids and no particularly unfavourable constituents, and a required product purity of 500 ppm total dissolved solids, electrodialysis costs of about 30-35 cents/1,000 gallons might be achieved in a unit of 1 mgd capacity. These costs assume power at 1 cent/kWh, interest on capital at 7 per cent *per annum* and base-load operation.

Inadequate commercial operating experience exists at present to provide useful estimates of reverse osmosis costs. However it is certain that the economic success of the process will come first in the treatment of brackish waters with particular promise for the treatment of those brackish waters which at present are difficult to treat by electrodialysis. The extention of reverse osmosis technology to the economic treatment of sea-water cannot be predicted with the same certainty, although the nature of the process will make it attractive where simplicity of operation is of particular significance, such as in some small-scale applications.

Water supplies based on desalination

It is clear that a prerequisite to the use of desalination is the ready availability of a source of saline water and a means for disposal of the concentrated brine effluent generated by all desalination processes. In the case of sea-water conversion it is most unlikely that anything other than a coastal location will be considered when no real problems will be attached to feed-water supply or brine disposal. However at estuarial locations, or at locations close to sewage outfalls, the quality of the local feed-water may require special consideration.

In the case of brackish water conversion, the long-term availability of the feed-water supply and the compositional changes to which it may be subject under the influence of differing extraction rates require special consideration. At inland locations, the disposal of the concentrated brine effluent from the desalination unit must also be possible without serious detriment to other water resources, a condition which is not easily achievable in many locations.

Beyond the specific conditions of achieving satisfactory engineering operation of the desalination unit and disposal of the brine effluent, the more general and complex problem exists of ensuring that the over-all system is designed to meet the requirements dictated by the local pattern of water demand. Careful planning of the system design is essential to ensure that its operation can be maintained on a long-term basis at both a technically acceptable and economic level.

The most important aspects of system design may be categorized as follows:

(*a*) The provisions necessary to meet short-term and seasonal variations in water demand;

(*b*) The provisions necessary to ensure continuity of supply during desalination plant outages for maintenance;

(*c*) The provisions necessary to meet future long-term increases in water demand;

(*d*) In the case of a dual-purpose power/water plant, the influence of existing and future electricity demand patterns on the availability and cost of water production. The solutions to be adopted to meet these requirements will be strongly influenced by the conditions of the particular case; of particular significance is whether a single- or dual-purpose plant is employed and whether desalination forms the sole source of water supply or only part of a larger system containing conventional surface- or ground-water resources. Under the latter conditions significant economies may be achievable through the operation of the desalination unit in conjunction with the lower-cost conventional resources.

These and additional aspects of system design have been explored in some detail in a United Nations report, *The Design of Water Supply Systems Based on Desalination*.[b] The report illustrates the economic significance of those factors which may result in final water costs being markedly different from the more frequently quoted desalination process costs. Of similar relevance is the annual survey of the technical and economic performance of the majority of the world's desalination units undertaken by the United Nations and published under the title *First United Nations Desalination Plant Operation Survey*.[c]

No generalized statement can be made on by how much these system design factors will increase the resulting water cost beyond the simple desalination process cost; the magnitude of this influence will be entirely determined by local circumstances. However, in order to indicate the significance of these considerations, it can be noted that a 20 per cent increase over the process cost would be by no means unusual.

Future trends in desalination

The continued expansion of the installed capacity of desalination is clearly assured; there seems little reason to believe that the rate of this expansion will fall below the approximate doubling of capacity which has taken place every three years during the past decade.

Dramatic changes in technology cannot, of course, be foreseen. Such changes aside, continuance of the existing steady improvement of distillation technology is assured with a reflection in improved economies and a greater reliability of operation. It is to be hoped that the stage will soon be reached where distillation plants can be specified and operated on a purely routine basis without the requirement of rather specialized manpower disproportionate to the function performed. For the treatment of brackish water, and waters such as sewage effluents, very high expectations can be attached to the reverse osmosis process.

Research and development expenditures in desalination are currently running at the level of about $50 million per year. No attempt has been made here to summarize the many investigations which are being undertaken to improve existing processes or develop the many newer processes that are under consideration. Some appreciation of the development programme now in progress may be obtained from the references below.

In conclusion it should be emphasised that while this rather large programme of development is resulting in a continuing improvement in desalination technology and economies, the existing status of the technology already allows the confident use of desalination in areas where it can be shown to be economically viable and where the appropriate level of engineering expertise exists.

[b] United Nations publication, Sales No.: E.68.II.B.20.

[c] United Nations publication, Sales No.: E.69.II.B.17.

References and related United Nations publications

Water Desalination in Developing Countries (United Nations publication, Sales No.: 64.II.B.5).

Water Desalination: Proposals for a Costing Procedure and Related Technical and Economic Considerations (United Nations publication, Sales No.: 65.II.B.5).

United States Department of the Interior, Office of Saline Water, *Proceedings of the First International Symposium on Water Desalination, October 1965* (Washington, D.C., USGPO, 1967).

Proceedings of the Interregional Seminar on the Economic Application of Water Desalination (United Nations publication, Sales No.: 66.II.B.30).

The Design of Water Supply Systems Based on Desalination (United Nations publication, Sales No.: E.68.II.B.20).

International Atomic Energy Agency, *Proceedings of a Symposium on Nuclear Desalination held at Madrid, Spain, 1968.*

United States Department of the Interior, *Saline Water Conversion Report* (Annual reports for various years), Office of Saline Water (Washington, D.C., USGPO).

First United Nations Desalination Plant Operation Survey (United Nations Publication, Sales No.: E.69.II.B.17).

Solar Distillation as a Means of Meeting Small-Scale Water Demands (United Nations publication, Sales No.: E.70.II.B.1).

Annex VII

HELSINKI RULES ON THE USES OF THE WATERS OF INTERNATIONAL RIVERS

ADOPTED BY THE INTERNATIONAL LAW ASSOCIATION AT ITS FIFTY-SECOND CONFERENCE HELD AT HELSINKI IN 1966

CHAPTER 1

GENERAL

Article I

The general rules of international law as set forth in these chapters are applicable to the use of the waters of an international drainage basin except as may be provided otherwise by convention, agreement or binding custom among the basin States.

Article II

An international drainage basin is a geographical area extending over two or more States determined by the watershed limits of the system of waters, including surface and underground waters, flowing into a common terminus.

Article III

A "basin State" is a state the territory of which includes a portion of an international drainage basin.

CHAPTER 2

EQUITABLE UTILIZATION OF THE WATERS OF AN INTERNATIONAL DRAINAGE BASIN

Article IV

Each basin State is entitled to a reasonable and equitable share in the beneficial uses of the waters of an international drainage basin.

Article V

(1) *What is a reasonable and equitable share within the meaning of Article I 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; and*

(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.*

Article VI

A use or category of uses is not entitled to any inherent preference over any other use or category of uses.

Article VII

A basin State may not be denied the present reasonable use of the waters of an international drainage basin to reserve for a co-basin State a future use of such waters.

Article VIII

1. *An existing reasonable use may continue in operation unless the factors justifying its continuance are outweighed by other factors leading to the conclusion that it be modified or terminated so as to accommodate a competing incompatible use.*

2. (a) *A use that is in fact operational is deemed to have been an existing use from the time of the initiation of construction directly related to the use or, where such construction is not required, the undertaking of comparable acts of actual implementation.*

(b) *Such a use continues to be an existing use until such time as it is discontinued with the intention that it be abandoned.*

3. *A use will not be deemed an existing use if at the time of becoming operational it is incompatible with an already existing reasonable use.*

CHAPTER 3

POLLUTION

Article IX

As used in this Chapter, the term water pollution refers to any detrimental change resulting from human conduct in the natural composition, content, or quality of the waters of an international drainage basin.

Article X

1. *Consistent with the principle of equitable utilization of the waters of an international drainage basin, a State*

(a) *Must prevent any new form of water pollution or any increase in the degree of existing water pollution in an international drainage basin which would cause substantial injury in the territory of a co-basin State, and*

(b) *Should take all reasonable measures to abate existing water pollution in an international drainage basin to such an extent that no substantial damage is caused in the territory of a co-basin State.*

2. *The rule stated in paragraph* 1 *of this Article applies to water pollution originating*

(a) *Within the territory of the State, or*

(b) *Outside the territory of the State, if it is caused by the State's conduct.*

Article XI

1. *In the case of a violation of the rule stated in paragraph* 1(a) *of Article X of this Chapter, the State responsible shall be required to cease the wrongful conduct and compensate the injured co-basin State for the injury that has been caused to it;*

2. *In a case falling under the rule stated in paragraph* 1(b) *of Article X, if a State fails to take reasonable measures, it shall be required promptly to enter into negotiations with the injured State with a view toward reaching a settlement equitable under the circumstances.*

Chapter 4

NAVIGATION

Article XII

1. *This Chapter refers to those rivers and lakes portions of which are both navigable and separate or traverse the territories of two or more States.*

2. *Rivers or lakes are "navigable" if in their natural or canalized state they are currently used for commercial navigation or are capable by reason of their natural condition of being so used.*

3. *In this Chapter the term "riparian State" refers to a State through or along which the navigable portion of a river flows or a lake lies.*

Article XIII

Subject to any limitations or qualifications referred to in these Chapters, each riparian State is entitled to enjoy rights of free navigation on the entire course of a river or lake.

Article XIV

"Free navigation", as the term is used in this Chapter, includes the following freedom for vessels of a riparian State on a basis of equality:

(a) *Freedom of movement on the entire navigable course of the river or lake;*

(b) *Freedom to enter ports and to make use of plants and docks; and*

(c) *Freedom to transport goods and passengers, either directly or through trans-shipment, between the territory of one riparian State and the territory of another riparian State and between the territory of a riparian State and the open sea.*

Article XV

A riparian State may exercise rights of police, including but not limited to the protection of public safety and health, over that portion of a river or lake subject to its jurisdiction, provided the exercise of such rights does not unreasonably interfere with the enjoyment of the rights of free navigation defined in Articles XIII and XIV.

Article XVI

Each riparian State may restrict or prohibit the loading by vessels of a foreign State of goods and passengers in its territory for discharge in such territory.

Article XVII

A riparian State may grant rights of navigation to non-riparian States on rivers or lakes within its territory.

Article XVIII

Each riparian State is, to the extent of the means available or made available to it, required to maintain in good order that portion of the navigable course of a river or lake within its jurisdiction.

Article XIX

The rules stated in this Chapter are not applicable to the navigation of vessels of war or of vessels performing police or administrative functions, or, in general, exercising any other form of public authority.

Article XX

In time of war, other armed conflict, or public emergency constituting a threat to the life of the State, a riparian State may take measures derogating from its obligations under this Chapter to the extent strictly required by the exigencies of the situation, provided that such measures are not inconsistent with its other obligations under international law. The riparian States shall in any case facilitate navigation for humanitarian purposes.

Chapter 5

TIMBER FLOATING

Article XXI

The floating of timber on a watercourse which flows through or between the territories of two or more States is governed by the following Articles except in cases in which floating is governed by rules of navigation according to applicable law or custom binding upon the riparians.

Article XXII

The States riparian to an international watercourse utilized for navigation may determine by common consent whether and under what conditions timber floating may be permitted upon the watercourse.

Article XXIII

1. *It is recommended that each State riparian to an international watercourse not used for navigation should, with due regard to other uses of the watercourse, authorize the co-riparian States to use the watercourse and its banks within the territory of each riparian State for the floating of timber.*

2. *This authorization should extend to all necessary work along the banks by the floating crew and to the installation of such facilities as may be required for the timber floating.*

Article XXIV

If a riparian State requires permanent installations for floating inside a territory of a co-riparian State or if it is necessary to *regulate the flow of the watercourse, all questions connected with these installations and measures should be determined by agreement between the States concerned.*

Article XXV

Co-riparian States of a watercourse which is, or is to be used for floating timber should negotiate in order to come to an agreement governing the administrative régime of floating, and if necessary to establish a joint agency or commission in order to facilitate the regulation of floating in all aspects.

CHAPTER 6

PROCEDURES FOR THE PREVENTION AND SETTLEMENT OF DISPUTES

Article XXVI

This Chapter relates to procedures for the prevention and settlement of international disputes as to the legal rights or other interests of basin States and of other States in the waters of an international drainage basin.

Article XXVII

1. *Consistently with the Charter of the United Nations, States are under an obligation to settle international disputes as to their legal rights or other interests by peaceful means in such a manner that international peace and security, and justice are not endangered.*

2. *It is recommended that States resort progressively to the means of prevention and settlement of disputes stipulated in Articles XXIX to XXXIV of this Chapter.*

Article XXVIII

1. *States are under a primary obligation to resort to means of prevention and settlement of disputes stipulated in the applicable treaties binding upon them.*

2. *States are limited to the means of prevention and settlement of disputes stipulated in treaties binding upon them only to the extent provided by the applicable treaties.*

Article XXIX

1. *With a view to preventing disputes from arising between basin States as to their legal rights or other interests, it is recommended that each basin State furnish relevant and reasonably available information to the other basin State concerning the waters of a drainage basin within its territory and its use of, and activities with respect to such waters.*

2. *A State, regardless of its location in a drainage basin, should in particular furnish to any other basin State, the interests of which may be substantially affected, notice of any proposed construction or installation which would alter the régime of the basin in a way which might give rise to a dispute as defined in Article XXVI of this Chapter. The notice should include such essential facts as will permit the recipient to make an assessment of the probable effect of the proposed alteration.*

3. *A State providing the notice referred to in paragraph 2 of this Article should afford to the recipient a reasonable period of time to make an assessment of the probable effect of the proposed construction or installation and to submit its views thereon to the State furnishing the notice.*

4. *If a State has failed to give the notice referred to in paragraph 2 of this Article, the alteration by the State in the régime of the drainage basin shall not be given the weight normally accorded to temporal priority in use in the event of a determination of what is a reasonable and equitable share of the waters of the basin.*

Article XXX

In case of a dispute between States as to their legal rights or other interests, as defined in Article XXVI, they should seek a solution by negotiation.

Article XXXI

1. *If a question or dispute arises which relates to the present or future utilization of the waters of an international drainage basin, it is recommended that the basin States refer the question or dispute to a joint agency and that they request the agency to survey the international drainage basin and to formulate plans or recommendations for the fullest and most efficient use thereof in the interests of all such States.*

2. *It is recommended that the joint agency be instructed to submit reports on all matters within its competence to the appropriate authorities of the member States concerned.*

3. *It is recommended that the member States of the joint agency in appropriate cases invite non-basin States which by treaty enjoy a right in the use of the waters of an international drainage basin to associate themselves with the work of the joint agency or that they be permitted to appear before the agency.*

Article XXXII

If a question or a dispute is one which is considered by the States concerned to be incapable of resolution in the manner set forth in Article VI, it is recommended that they seek the good offices, or jointly request the mediation of a third State, of a qualified international organization or of a qualified person.

Article XXXIII

1. *If the States concerned have not been able to resolve their dispute through negotiation or have been unable to agree on the measures described in Articles XXXI and XXXII, it is recommended that they form a commission of inquiry or an* ad hoc *conciliation commission, which shall endeavour to find a solution, likely to be accepted by the States concerned, of any dispute as to their legal rights.*

2. *It is recommended that the conciliation commission be constituted in the manner set forth in the Annex.*

Article XXXIV

It is recommended that the States concerned agree to submit their legal disputes to an ad hoc *arbitral tribunal, to a permanent arbitral tribunal or to the International Court of Justice if*

(a) *A commission has not been formed as provided in Article XXXIII, or*

(b) *The commission has not been able to find a solution to be recommended, or*

(c) *A solution recommended has not been accepted by the States concerned, and*

(d) *An agreement has not been otherwise arrived at.*

Article XXXV

It is recommended that in the event of arbitration the States concerned have recourse to the Model Rules on Arbitral Procedure prepared by the International Law Commission of the United Nations at its tenth session in 1958.

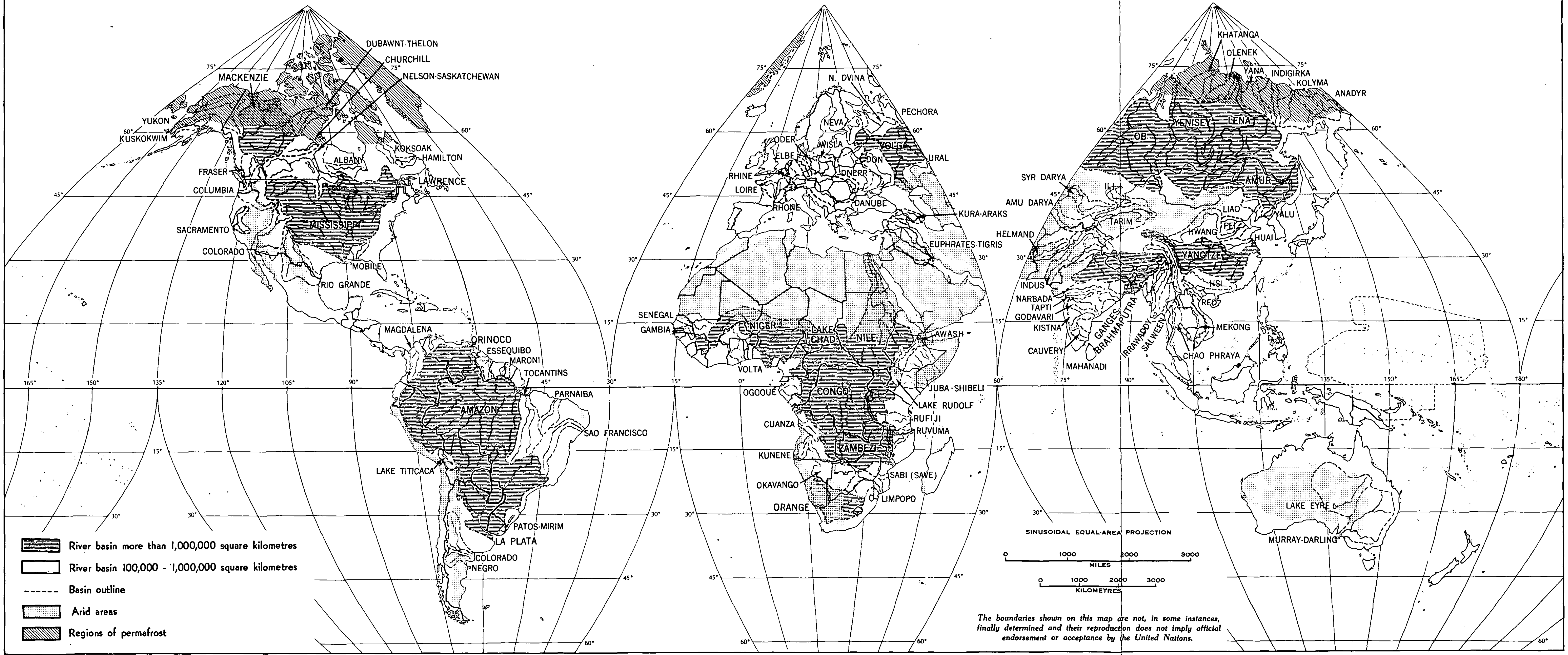
Article XXXVI

Recourse to arbitration implies the undertaking by the States concerned to consider the award to be given as final and to submit in good faith to its execution.

Article XXXVII

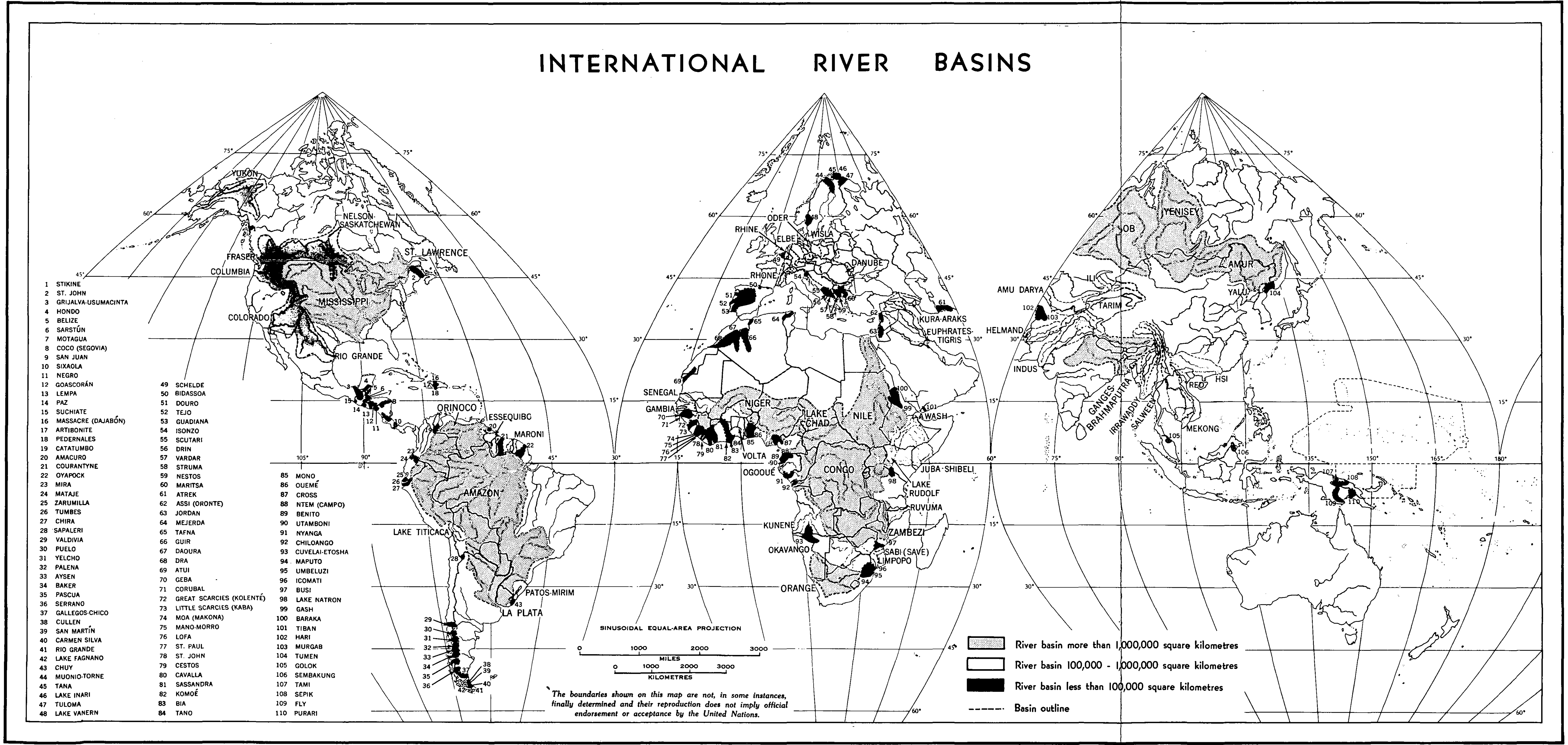
The means of settlement referred to in the preceding Articles of this Chapter are without prejudice to the utilization of means of settlement recommended to, or required of, members of regional arrangements or agencies and of other international organizations.

MAJOR DRAINAGE AREAS OF THE WORLD



The boundaries shown on this map are not, in some instances, finally determined and their reproduction does not imply official endorsement or acceptance by the United Nations.

MAP NO. 1025 REV.1 UNITED NATIONS
OCTOBER 1969



MAP NO. 1026 REV.1 UNITED NATONS
OCTOBER 1969

HOW TO OBTAIN UNITED NATIONS PUBLICATIONS

United Nations publications may be obtained from bookstores and distributors throughout the world. Consult your bookstore or write to: United Nations, Sales Section, New York or Geneva.

COMMENT SE PROCURER LES PUBLICATIONS DES NATIONS UNIES

Les publications des Nations Unies sont en vente dans les librairies et les agences dépositaires du monde entier. Informez-vous auprès de votre librairie ou adressez-vous à: Nations Unies, Section des ventes, New York ou Genève.

КАК ПОЛУЧИТЬ ИЗДАНИЯ ОРГАНИЗАЦИИ ОБЪЕДИНЕННЫХ НАЦИЙ

Издания Организации Объединенных Наций можно купить в книжных магазинах и агентствах во всех районах мира. Наводите справки об изданиях в вашем книжном магазине или пишите по адресу: Организация Объединенных Наций, Секция по продаже изданий, Нью-Йорк или Женева.

COMO CONSEGUIR PUBLICACIONES DE LAS NACIONES UNIDAS

Las publicaciones de las Naciones Unidas están en venta en librerías y casas distribuidoras en todas partes del mundo. Consulte a su librero o diríjase a: Naciones Unidas, Sección de Ventas, Nueva York o Ginebra.

Printed in the Netherlands
70—13018—October 1970—4,000

Price: $U.S. 1.50
(or equivalent in other currencies)

United Nations publication
Sales No.: E.70.II.A.4