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TRANSFER OF WATER KNOW-HOW FROM HIGH TO LOW LATITUDES — SOME PROBLEMS AND BIASES

by

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Contets:

Abstract

The formidable goals set by the United Nations Water Conference suggests that transfer of knowledge by expatriate "experts" will continue to play a central role in technical assistance. The author discusses some of the important differences in conditions between industrialized countries in high latitudes and developing countries in low latitudes. Crucial disparities include differing generations of water demand, different water availability conditions and differences as to susceptibility to man-made environmental changes. Certain concepts may be differently understood (effective precipitation), others heavily misleading ("normal rainfall"). The interaction between water and land is even more important in low than in high latitudes. In response to the UN Water Conference, the gravity center of the IHP has changed and the Second Phase will give increased stress to developing country hydrology and to transfer of knowledge and adaption of "imported" knowledge to local conditions.

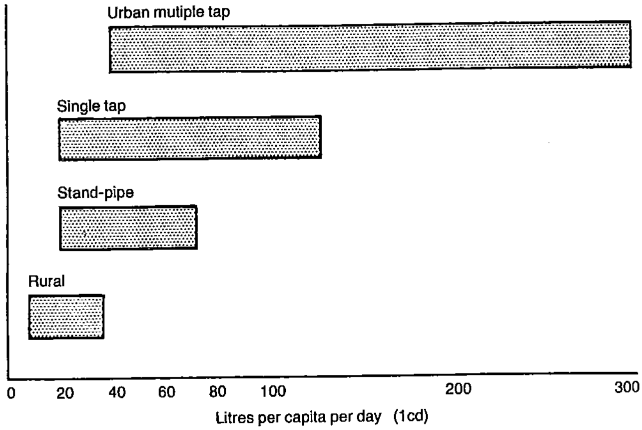
1. *Continued importance of expatriate ''experts''*

Among the fields where the Nordic countries have been very active are two increasingly interconnected fields of international collaboration: technical assistance to developing countries, and research within the International Hydrological Programme. If one accepts the formidable goals of the United Nations Water Conference, held in Mar del Plata in 1977, and if the manpower needed to reach these goals is compared with the present education in developing countries, it seems that for a large part of the work, these countries will have to continue to rely on expatriate ''experts''. In other words, technical assistance and transfer of knowledge from industrialized countries in high latitudes to developing countries in low latitudes will continue to play a central role in decades to come.

This simple fact makes it tremendously important to look closer on past experience of such knowledge transfer. We all know that it has not always been very successful but met numerous unexpected problems. Part of the problem might be that much of the work was based on exaggerated ideas of similarities between conditions in the two regions. It might therefore be useful to look closer on some important pitfalls created by differences in climate, physical environment, water needs and problems. The main ideas of this paper are further developed in the author's contribution to the work ''Water and Society: Conflicts in Development. Part 2. Water Conflicts and Research Priorities'' (FALKENMARK *et al* [4]).

2. *Water demand — a question of climate and socio-economic development*

Several authors have during recent years stressed the dynamical character of the water development process (*e.g.* SEWELL [10], KOVÁCS & DAVID [5]). The successively broadening array and increasing number of water needs during subsequent phases of socio-economic development might be simplified by thinking of different generations of water demands. The *first* generation has to do mainly with the biological needs for survival. It includes the amount of water needed for a hygienic standard, high enough to allow an acceptable state of public health, but also a certain amount of water to grow the food necessary to secure a certain minimum level of nutrition. The *second* generation of demands includes the water uses for securing the agricultural surplus and industrial development needed to create a basis for export. This generation includes water-power production, water supply of industry, irrigation water for large-scale agricultural production, water for urban development etc. In modern western societies, the *third* generation of demands, finally, covers recreational uses, leisure fishing, tourism, nature and wildlife



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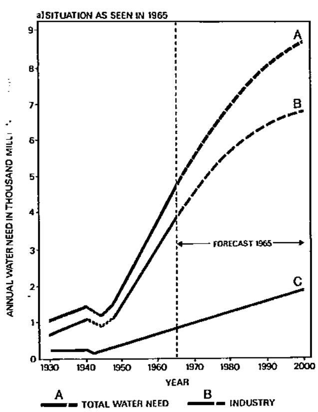

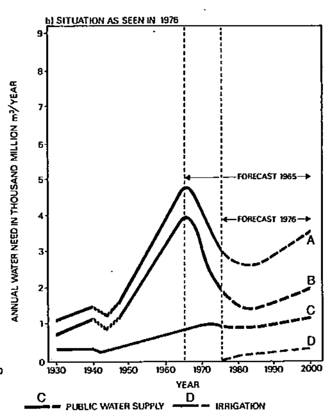

b c

Fig. 1. *Water demand for withdrawal uses during different generations*

a. Already during the *first* generation, water demand increases as substeps are taken to make water more easily accessible in the habitats.
(from UNITED NATIONS [14])

b. During the *second* generation, industrial demand contributed to a substantial increase of water demand in Sweden.

c. *Third* generation demands for higher environmental quality in Sweden lead to a substantial increase in water use efficiency and hence a decreased gross water demand both for public water supply and industry.
(b and c from FALKENMARK [3])

conservation, preservation of water landscapes, etc. In response to a far-reaching environmental degradation in these societies due to second generation activities, this generation has even led to certain claims for non-exploitation of water resources.

Water needs are often presented on a per-capita-basis. Even if there is a continuous shift towards higher demand already during the first generation as different substeps are taken to make water more easily available in the village (fig. 1a), the needs increase substantially when passing from the first to the second generation. When passing on to the third generation, the demand is more quality- than quantity-oriented, and development of higher water-use efficiency may even reduce the quantitative needs (fig. 1b).

There are clear differences also in the way in which the two groups of countries advance from one generation of water needs to the next. In many countries, already industrialized, it took several centuries to pass the stages of the two first generations. In less developed countries the process will hopefully be more rapid, even if it is much more complicated. In the first place, knowledge is now available on the environmental mistakes made by the industrialized countries, and could be applied already when planning for the second generation demands. Secondly, the resource situation in the tropical zone differs substantially from that in high-latitude countries. This makes it necessary to embark already at an early stage on multipurpose water projects, which include certain second-generation measures when solving the problems of the first-generations needs.

Under the water-scarcity conditions of many developing countries in tropical regions, water-resources planning therefore constitutes a necessary measure already at an early stage of development. In countries with water-surplus conditions, where there are ample amounts of water available to satisfy increasing demands, water development is possible in a piecemeal manner without regular planning for a much longer interval of time.

In most developing countries, there is also a substantial increase of population. This implies that planning has to be performed with a new unborn ''shadow'' population in mind. Future-oriented scientists in India use the expression the ''Second India'' (CHATURVEDI [2]). Due to the continuous increase in the population, the absolute amount of water needed increases successively, even without any increase in the standard of living. This ''automatic'' increase of water needs has evidently to be met in order to keep the standard of living already attained.

3. *Water availability — a question of hydrology and technology*

In water management, water needs have to be matched against water availability. In ecological surveys precipitations has often been used as the element characterizing water availability in general, thus introducing a deceptive short-cut between meteorology and ecology without enough regard paid to the interplay between water and soil. However, water resources assessment is considerably more complicated than just rainfall statistics. This is due to the fact that different water uses depend on different kinds of water. Primarily, one has to distinguish water availability for plant production from water availability for satisfying human supply needs.

Water availability for plant production is characterized by the amount of water present in the root zone that can be taken up by the plants. This water is recharged by the amount of water infiltrated into the soil. The infiltration could therefore be taken as an index of this water availability.

Water for withdrawal can be taken either from the groundwater aquifers, or from the surface-water bodies. In this case, water availability is constituted by the water flow in these environments; in the aquifers by the annual — or rather the long-term — recharge, in the rivers by the dependable flow, i.e. the base flow available in the river during the dry season.

Furthermore, one should also distinguish between potentially, readily and actually available water resources. The potentially available resources correspond to the naturally circulated water in the hydrological cycle. The actually available resources change with the technology used to make part of that water easily accessible to the user (wells, canals, tanks, etc). These resources may be successively augmented by more sophisticated control measures. For instance, the soil moisture can be augmented by soil conservation measures or by irrigation. The groundwater availability can be enhanced by augmenting infiltration and percolation (for instance by reforestation) or by artificial groundwater recharge. The dependable river flow can be increased by storing flood water in surface or subsurface reservoirs, by augmenting the recharge of groundwater aquifers drained by the river, or by importing water from an adjacent river basin. Also such measures as artificial production of water through desalination or rain-making activities can be used to improve local water availability.

Thus, the available water can be successively increased by different technological measures, but only up to a certain limit. This limit which may be denoted readily available resources, is defined by local physical and socio-economical constraints (DE MARÉ [8]).

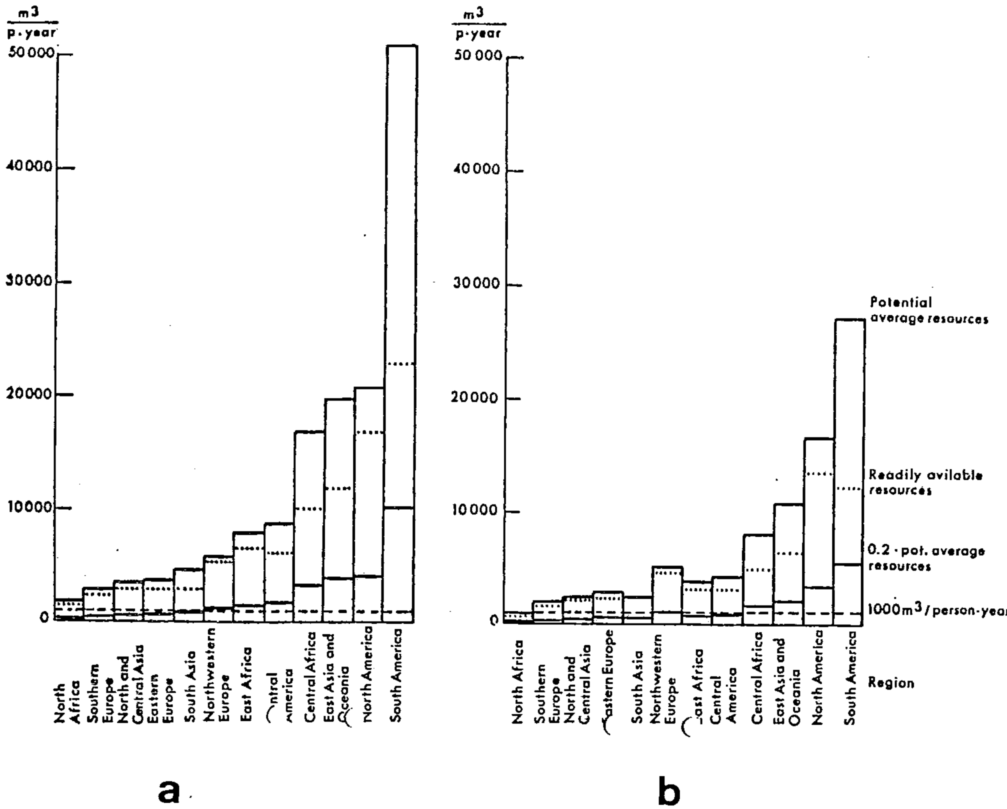

Fig. 2. *Average water resources available on a per capita basis in different world regions by 1973 (a) and 2000 (b)*
The figure shows potentially available resources and the resources readily available towards late stages of river basin development. Actual availability is indicated by roughly assuming the dependable flow to be 20 % of the mean flow. For comparison, the ultimate water demand during late stages of socio-economic development is indicated by the reference level 1000 m^3/person and year, based on different estimates in the literature.

To get an idea of the societal stress on the potentially available water the availability should be related to the population size. Fig 2. reveals that, in contrast to well watered high-latitude countries, water scarcity constitutes a major problem in large areas of the developing part of the world, including North Africa and the Middle East, East and South Asia, but also parts of Europe and Central America. Water might very well be a critical resource for the general development in large parts of these regions, especially when taking into account that the amount available per individual decreases as the population increases further. This introduces a time-operated thumbscrew on the available water.

4. *Hydrological dissimilarities may create problems*

In spite of the millenia-long understanding in Europe as well as Asia of water as a dynamic resource, water resources assessment has not been considered fully necessary as a basis for rural water development. It is not very long ago that such assessment was in fact considered rather as a research task rather than a necessary prerequisite for water development. In effect, as late as 1977, the UN Water conference draw particular attention to the importance of this seemingly self-evident routine activity.

It is the opinion of the author that the missing recognition of water assessment may be an effect of climatic bias. Evidently, the need for quantitative resource assessment looks quite different under water surplus conditions, when there is enough water anyway, and under water shortage conditions, when the size of the resource base presents a very definite physical constraint to local water development. In high latitudes, water development has mainly been a question of making water readily accessible by adequate technological means. In low latitudes it must imply first an estimation of potential and actual water availability, followed by measures to make enough water accessible for the intended users.

Water resources assessment is an important sector of applied hydrology and has been practised in the Nordic countries for more than a century (*e.g.* SIMOJOKI [11]). The experience of Nordic hydrologists could therefore come to valuable use also in technical assistance (NORDIC IHP-MEETING, NORD-TORPA 1978 [9]).

The hydrological conditions and the governing interaction between water, soil and vegetation are however extremely different in temperate as compared to tropical areas. Many things indeed differ when the groundwater is far below the ground surface as in the arid zone, and when it is close to the ground surface as in the humid parts of the temperate zone. Also the dept to the bedrock, and therefore the drainage capacity of intersecting rivers, might be quite different. In Norden, the soils are often thin so that the rivers drain most of the groundwater, whereas in areas with very thick soil packs, large groundwater flows may pass far below the drainage system of local rivers.

Even if the basic hydrological processes are similar in all physical environments, the size and relative importance of different water balance elements however varies between regions. Some central values for these elements might be used to typify main differences although there exists within each hydrological zone a wide interval of intrazonal variance (fig. 3). The large differences between temperature and tropical hydrology should be taken as a warning, when remembering that the existing know-how, as pointed *i.a.* by

BALEK [1], and expressed in graphs and equations describing interdependencies between meteorological, hydrological and landscape factors, is often based on temperate conditions, and cannot be automatically transferred to and applied in other regions. First, thumb rules, graphs and diagrams have to be checked by a study of the pecularities of local hydrology and the operation of hydrological observation networks.

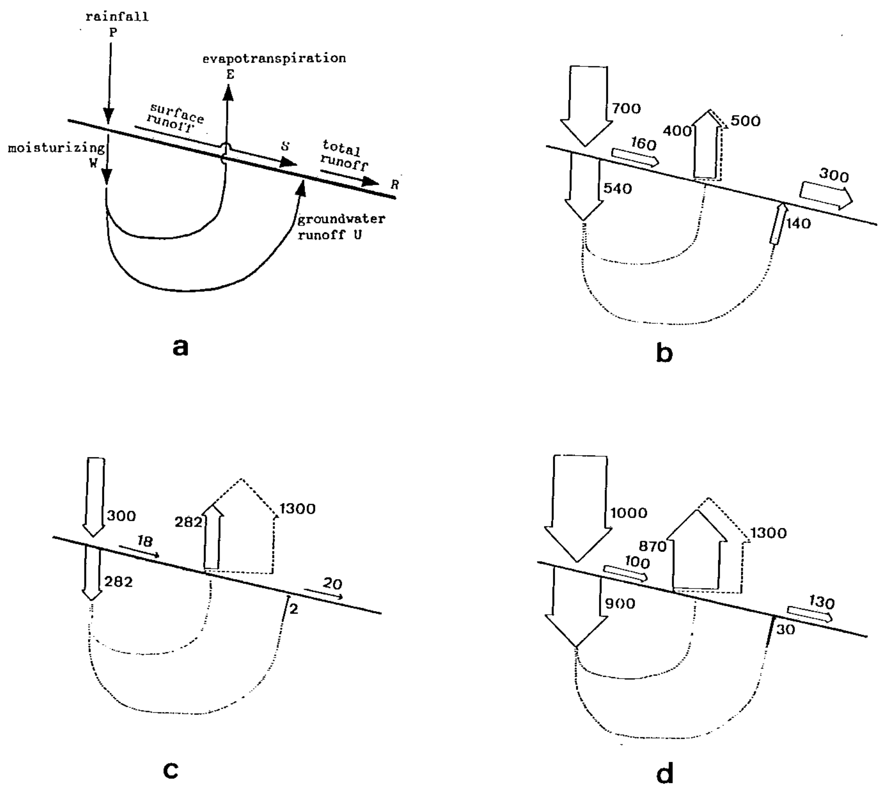

Fig. 3. *The relative importance of different water balance elements in different regions*
The figure visualizes the relative size of the main balance elements, when taking an aggregated view of the river basin as shown in figure (a), for different regions: taiga zone in figure (b), desert savanna in figure (c) and dry savanna in figure (d). Dashed arrow denotes potential evapotranspiration.
(Data from LVOVICH [6])

The large differences between zones in fact make certain concepts misleading or even deceptive, when applied in another zone. Numerous developing countries are, for instance, situated in monsoon-dependent zones where intermittent periods of drought constitute part of the climatic characteristics. Based on high-latitude experience, rainfall statistics are often presented in terms of monthly and annual averages. This is however extremely misleading in areas with very large rainfall fluctuations between years. In fact, the incessant use of the concept ''normal rainfall'' might even contribute to the seemingly slow acceptance of these large interannual fluctuations — and therefore also intermittent droughts — as part of the climatic pattern which is normal for these regions. A further delay in this respect is, in fact, bound to result in new food catastrophes like the ones recently witnessed in the Sahel and elsewhere.

There are also important terminological differences between water surplus and water deficiency regions: for instance, in surplus regions the concept efficient precipitation refers to the non-evaporated part, whereas in water-deficient areas the opposite is true, *i.e.* efficient precipitation refers to what is taken up by the plants.

5. *Water and land are closely interconnected*

In terrestrial hydrology, the soil and the plant cover are crucial for local water availability conditions as recently restressed by LVOVICH [7]. In the soil, rainfall is partitioned between rapid surface runoff, water uptake by plants, and recharge of the groundwater that later forms dependable base flow in the rivers. In other words, soil and plants represent a kind of intermediary between climate and hydrology.

The generalized rainfall-runoff graphs clearly demonstrate the importance, for both yield and runoff regime, of vegetational cover and degree of exposure to erosion (fig. 4). Thus, in catchments with a rolling topography, out of an annual rainfall of 1,000 mm about 150 forms runoff, if the vegetational cover is poor and the erosional processes pronounced. The runoff is reduced by almost a factor of 4, if the vegetation is dense, so that large water quantities are used up by the vegetation (BALEK [1]). Not only the total annual runoff, but also its time distribution changes with shifts in soil characteristics and vegetational cover. When the soil is hard and impermeable, most water leaves the catchment as flood flow, charged with great amounts,of silt from soil erosion. When the soil permits much water to infiltrate, as is the case in forests, more groundwater is formed and the base flow increases.

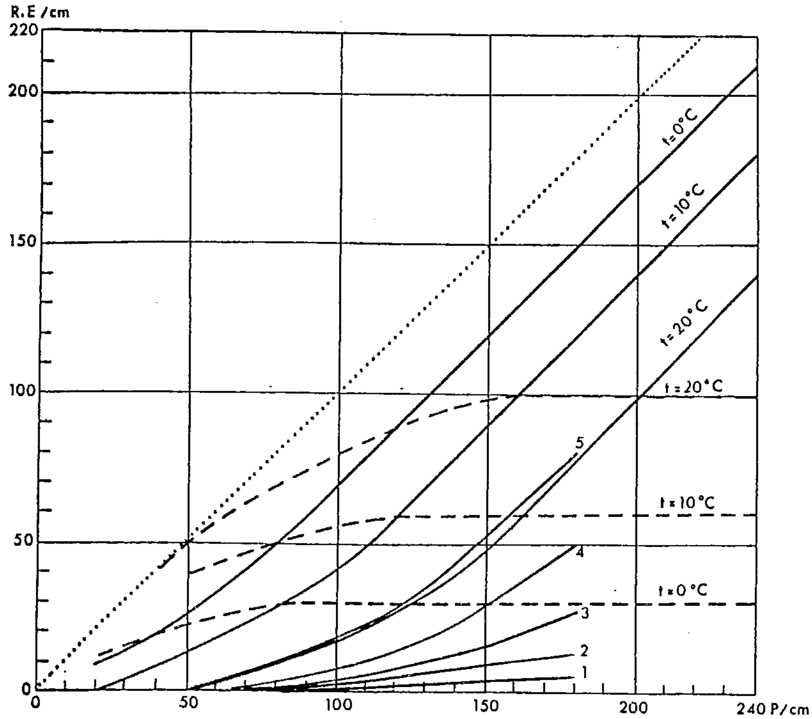

Fig. 4. *Not only climatic conditions but also soil and vegetation heavily influence the terrestrial water balance*

The figure shows the relation between evapotranspiration (E, datched lines) and runoff (R, full lines) for different amounts of annual precipitation (P) under different conditions:

(a) different climates, indicated by mean air temperature, according to the classical Wundt relations

(b) different soil and vegetation, according to Balek [1]

Legend: 1 = flat catchments with deciduous forest
2 = undulating woodlands, flat catchments with poor vegetation
3 = rolling catchments with dense vegetation, undulating catchments with poor vegetation
4 = undulating catchments with intermittent streams
5 = mountain slopes, rolling catchments with poor vegetation and pronounced erosion

Even in temperate climates, vegetation, soil and topography strongly affect the runoff conditions, which are thus modified by land-use changes. This dependence on vegetational cover and soil is however very much larger in the tropics, which leads to the conlusion that hydrological conditions in the tropics are much more susceptible to man-made changes within agriculture and forestry.

To this influence of hydrological conditions on soil and plant cover should be added the complementary aspect that water conditions are crucial for the soil cover. Evidently water plays two opposite roles from the point of view of the landscape. Moist soil as well as a protecting plant cover are important in protecting the soil from erosion during the intense rains typical for tropical conditions. At the same time, water is a main agent in causing erosion of unprotected soil surfaces. Under conditions of expanding desertification following from unwise land-use, the risk of water carrying away productive soils constitutes a major hazard to food production in over-populated tropical lands.

The countermeasures necessary to avoid soil deterioration by reducing the erosion risk on undulating arable lands are well known and widely applied in the tropics. They include terracing and reforestation. In some areas, *e.g.* Kenya, the organizing of work during colonial time however created a deep aversion to such measures. The main obstacles to the application of the existing knowledge may, therefore, sometimes be more socio-political than technical.

The close interplay between land-use and water availability on one hand, and between water and soil productivity on the other necessitates a much closer link between land-use planning and the planning of water projects than practised today. Degradation of the vegetational cover leads to increased and more rapid flood flows. Soil conservation, afforestation and other measures apt to increase infiltration are therefore important in increasing water availability by reducing losses of great amounts of water in rapid flood flows.

At the same time, it is a very unwise measure to install largescale water storage in reservoirs in a river without simultaneous development of land management and soil conservation in the river basin upstream of the reservoir. This has been experienced in the Tana river in Kenya, where the main part of the storage capacity of the Kindaruma reservoir has already vanished, due to sedimentation of silt, eroded from upstream lands. The present level of silting in that reservoir turned out to be as much as ten times that predicted by British consultants in the 1950's, the difference being blamed massive deforestation in the upper basin (WORLD WATER [16]).

6. *Water plays different roles in developing environmental impact*

Water is heavily involved in the development of enviromental impact from human activities. It is today realized that such impact is inevitable for most manipulations in nature in which water is involved. Experience of the sensitivity of the environment to man-made changes would seem to be an important part of the knowledge transferable from industrialized to developing countries. The vast occurrence of adverse environmental effects of natural resource development in industrialized countries contrasts however with tendencies in developing countries to give higher priority to short-term development goals than to long-term maintenance of the resource base in terms of groundwater availability, soil conservation, etc: ''In the developing world, which still lacks the infrastructure and readily usable resources required to meet the growing needs and aspirations of its peoples, the new kind of development must continue to have a strong physical orientation''. In the industrialized countries, on the other hand, the present situation is quite different. There, ''it will be necessary to reorient society's aims so that the entire population will have more opportunity for self-expression in the fields of culture, education, the arts and humanities'' (Tolba [12]).

The fact that goals and approaches are so different contributes strongly to difficulties in the exchange of information between industrialized and developing countries regarding environmental issues. Two aspects need to be taken into account. One is the extremely vast (and often even undefined) content of the concept ''environmental quality''. The other is the very complex role played by water in the development of environmental impact.

As to the concept as such, in fact the differences in the general goals might involve differences also as to the understanding of the concept. It might therefore be helpful to break down the concept into some more clear-cut subparts (table 1) in order to get better aware of potential pitfalls in future exchange of information.

As to the involvement of hydrological processes in environmental impact development, it should be remembered that water plays at least five different roles in the way in which these impacts develope, *i.e.* in the sequence of processes involved from primary manipulation to experienced ecological effects.

(1) Role of physical dispersion of pollutants both in dissolved form and in suspended form.

(2) Role of water in transmitting water-related diseases.

(3) Role of water in the erosion-sedimentation sequence of processes.

(4) Role played by the water solution in the soil for maintaining crop growth and the fertility of the soil: imbalances causing soil deterioration by salinization and waterlogging.

(5) Role of water in maintaining the vegetation cover and the physical conditions of the soil as a protection from being carried away by wind deflation or water erosion.

Table 1. Some different aspects of environmental quality.

Aspects
(1) Resource base • soil productivity • groundwater availability • soil erosion • fish
(2) Health aspects • water-related diseases • unintended reuse of industrial waste water
(3) Preservation of habitats • stream valley vegetation • wetlands • endangered species
(4) Cultural aspects • archeological objects • water aesthetics

Differences both in concept understanding and in the relative relevance of the roles where water is involved in developing impacts in different physical and socio-economic environments invite to considerable cautiousness in future work. Also, hydrologists should play a much more active part in this work than hitherto experienced in industrialized countries, where the gravity center of environmental protection work during the 1960's and 70's lied on industrial anti-pollution measures.

7. Role of International Hydrological Programme in future transfer of water know-how

Education and creation of knowledge constitute crucial tools in speeding up the development process. Research is a critical part of this process. Most of the research has evidently to be carried out in developing countries. The building up of research experience, adapted to the different climatic and national conditions in the tropics is therefore an essential task, necessary not only in gathering understanding of local environment, physical as well as social, but also as a basis for education and training. The UN Water

Conference, in its very first resolution, therefore recommended that future phases of the IHP should be geared towards the goals set by the Water Conference (United Nations [15]). This introduces two different aspects on future IHP-activities: on one hand it is a question of developing the necessary understanding of hydrological processes in different regions. This understanding has to be complemented by a local information base on the water resources available in each country. On the other, it is a question of increasing the capacity of countries, in particular developing countries, to develop and manage their water resources so as to be able to reach these goals. This capacity cannot be reached if the planners and policy makers are not made aware of the relevance of water resources for socio-economic development. Policy makers also need to appreciate the fact that hydrological activities are long-term and continuous, and that short-term arrangements will not satisfy long-term needs.

In response to the recommendation mentioned, the IHP Council in its preparation of the programme activities for the Second Phase of the IHP, took an important step in moving the gravity center of the activities from scientific research towards transfer of knowledge to and between developing countries (Unesco [13]). The overall goal is to increase the capacity of Member States to apply advanced methodologies and technologies to the assessment, development and management of their water resources, and to support the development of national infrastructures in water resources. The programme activities have been developed with three main objectives in mind:

Objective	*Programme*
A. To improve the understanding of hydrological processes	A. Scientific programme
B. To improve the capacity of Member States to assess, develop and manage their water resources	B. Education and training programme
C. To create increasing awareness of the importance of rational water resources management for socio-economic development	C. Infrastructural programme

Great attention is to be paid to the need for transferring techniques, which can be applied to meet the needs of developing countries in their water management problems. Information "imported" from other regions has to be adapted to the conditions in the receiving region. Therefore, all programmes under the IHP are to take into account local, climatic, physiographic, cultural and linguistic conditions.

Also greater attention is now being paid to comparisons between regions, including hydrological similarities and dissimilarities. One activity of importance in this context is a planned textbook on comparative hydrology relating to the various hydrological regimes of the world. The results of this new emphasis should facilitate the transfer of hydrological ecperience from developed to developing countries with different hydrological regimes.

8. *Concluding remarks*

The IHP National Committees have great importance as a vehicle for regional and international cooperation in the field of technical assistance. In the Second Phase of the IHP, National Committees in industrialized countries are invited to take an increased part in the process of transfer of knowledge both by opening a dialogue with International Development Agencies in their respective countries, and by establishing direct bilateral cooperation with sister committees in developing countries.

In the Nordic countries, such a dialogue was opened already at the IHP meeting on "HYDROLOGY IN DEVELOPING COUNTRIES" held at Nord-Torpa, Norway 21—23 November 1978 [9], and was continued at the follow-up meeting on "Education and Training" in Uppsala, Sweden 24 September 1979. A continued regional cooperation on the extremely important issue of transfer of knowledge on water resources development to developing countries could be foreseen.

In conclusion, it is important that larger stress is given to the pitfalls of "climatic bias" in future work. Important dissimilarities in physical as well as relevant socio-economic conditions have to be further clarified as they might severely influence the effectiveness of the massive transfer of knowledge to be foreseen during the decade to come.

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