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WATER RESOURCES DEVELOPMENT, A VITAL RESPONSIBILITY OF THE CIVIL ENGINEER

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"A people that is alive, will build for its future."
Inscription on memorial on the closure dike of the Zuider Zee, Netherlands

INTRODUCTION

THE advancement of a better human environment for all nations requires the creative and rational organization of human and of natural resources. Who can deny that this nation has been particularly blessed with both kinds of resources and that this has enabled us to reach a height of living standards and of opportunities for human growth still unmatched in the world. With this rise of national stature we have also inevitably achieved power and we have thus become involved in responsibilities of a scope and complexity, which we only gradually begin to comprehend. In this emerging conception of our world-wide obligations the achievement of an unassailable protective and defensive position for ourselves and our friends had first priority. We have accepted this burden and have carried it without sacrifice of our essential political beliefs in human dignity and freedom.

However, this, at best, has only bought us a limited time to carry out equally essential tasks which have arisen from the forward march of practically all humanity towards a better life, which as yet remains undefined in all its aspirations and complexities. But the prime components of future progress in the building of a free society every-

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where, whether in highly industrialized or in under developed countries, are inherent in the basic desire of all for a better human environment. It is in this area that our profession has found traditionally its major justification for its distinctive service and in which it must assume in the future expanded responsibilities for the effective control and the creative forming of human environment involving the fundamental resources of air, water, and land. The great problems in this area, both present and extrapolated to the future, are undoubtedly associated with new developments in the following fields:

1. Properly integrated use of land for purposes of the individual, the community, the industry
2. Transportation and physical communication systems
3. Conservation and development of water resources

Before dealing with the last of these in more detail a few remarks are in order on the general characteristics of these problem areas in relation to our profession. However diverse the technical problems may be in the areas listed they all have in common an increasing dependence on policy decided by large private and public agencies. This is by reason of the increasing magnitude and scope of many of the projects, where important economic and social factors and the commitment of major portions of the public income often outweigh the technical questions.

By contrast, the civil engineer has too often abdicated his responsibility in this area and has looked for professional rewards from the purely technical side of solutions. He has overlooked, however, that often thereby the very conception of the system or of the structures in question becomes narrowed down or frozen by other influences and that he has little part in the broad creative aspects of the structures he designs. Thus the public also has come to see in him increasingly the technician only, to whom certain tasks may be assigned, but it does not depend on him any more for originating and stimulating new aspects of its environment. This trend must be reversed if civil engineering wants to lay continued claims on being a profession; professional stature comes from exercise of responsibility, knowledge and insight in all the forces shaping major engineering works. The civil engineering profession must recapture a sense of mission with a look to the future and this involves a conscious effort to define its future tasks, to keep educating itself, to promote the advance of knowledge through research and the free exchange of ideas, to take seriously the education of its younger members to professional attitudes and requirements.

In an attempt to focus attention on the future tasks before the profession, I have tried in the following to outline briefly only that field with which I can claim some acquaitance. I am sure that the others mentioned above offer similar opportunities for reflection on the present role of civil engineering and for a view of what we might strive for in the future. This area, to which I must restrict myself by leaning and by experience is much in the news today both in the national and in the international scene and is comprised by the commonly accepted term of Water Resources Development.

Water Resources—General Remarks

That water is needed for almost all forms of human activity is saying the obvious. It is also obvious apparently to most that it is always available at relatively little cost. What has not been obvious to most of the public, however, is that in the future the available supplies will greatly and rapidly shrink in relation to the growing needs of the economy and of the population. It is only in recent times that experts have pointed to this trend in alarm and that in more recent months the representatives of the people under Senator R. S. Kerr of Oklahoma have assembled a wealth of information on the future critical needs for water for our own nation. In many foreign countries these needs are now the most pressing, and great investments are made to expand opportunities for growth through sometimes giant development schemes. Indeed in recent years we have witnessed serious political repercussions in our relationships with other nations as a consequence of our unwillingness to cooperate in such schemes. It may be surmised that our technical assessment of such needs is often inadequate in this area as well as our political appreciation for the vital aspirations of these countries.

It is apparent that water resources development is not only a technical problem area, but that it involves a wide array of economic, social and political questions as well.

What Are Water Resources?

The water resources of a continent, country, or region comprise potentially all sources of water, whether available as moisture in the atmosphere, as rain appearing on the surface, as water available by access to shore lines of inland bodies of water or of the seas, as groundwater in subsurface storage basins or subterranean streams. Thus the sciences involved in the study of water in these forms are the geophysical sciences of meteorolgy, geography, geodesy, hydrology, geology, coastal oceanography, or some of their many branches.

What Water Resources Are Available?

Only a small portion of the potential water sources is readily available, much of the water is lost by transpiration and evaporation, by seepage and by discharge into salt water basins. Immediately problems of water conservation arise for agricultural, sanitary, and hydraulic engineers, through ponding and stream regulation works, detention in major reservoirs, control of plant cover, as far as the water yield is concerned.

Water Quality and Reclamation

Scientists and engineers have been waging an ever intensified struggle to produce or to reestablish the water qualities desirable for various human pursuits. Contaminants are inherent in the natural as well as in the human environment; sediments must be removed, human and industrial wastes must be reduced to acceptable levels including particularly wastes from nuclear plants. Water must be processed by chemical and biological means for prime or secondary use by industrial plants and again before it is released into natural drainage systems.

Specific Water Use and Control

The major portion of normal runoff is controlled by means of retention basins and is put to multi-purpose use. The most important phases of utilization in addition to water supply for human and industrial consumption are power, irrigation, and navigation. Additionally major benefits are attained with respect to flood control, recreation, and the preservation of wild life.

Engineering of Water Resources

The provision of adequate water supplies of desirable quality for all the uses listed has been traditionally the field of sanitary and of hydraulic engineers with various degrees of specialization; in basic research concerned with the water cycle and with the flow phenomena in all types of hydraulic structures; in the application of the various sciences to water control in quantity and quality; in the design and construction of all structures and finally in the operational, administrative, and overall planning phases of the water economy. Needless to say with the ever increasing demands, engineering processes, and evaluations have become increasingly complex and require an ever broadening base in practically all the pertinent sciences.

FUTURE OUTLOOK

While in our country the present use of water is estimated at not more than 10% of the average rainfall, the use in percentages of readily available supply with all of our conservation and control measures is over 50% and the estimated use will exceed this available and fixed supply by 1980. In figures quoted by the U.S.G.S. the present rate of use of 300 billion gallons will double by 1980, as compared to a readily available supply of slightly over 500 billion gallons.

It is apparent that extraordinary efforts will be called for within our lifetime and that these efforts must include the application of new scientific ideas and technical measures, as well as new attitudes in the economic and social spheres of water resources development. While in other countries of comparative population density and industrial growth, the problems are similar, the nature of the water problem in the so-called under-developed countries varies all the way from more critical conditions to requirements of more effective control and utilization of abundant supplies. The potential benefits from comprehensive plans for a wide complex of problems such as these are unquestionably most substantial for all countries.

RESEARCH FRONTIERS IN WATER RESOURCES

The Report of the Select Committee on National Water Resources of the U. S. Senate estimates that up to 54 billion dollars will have to be spent in the U. S. alone on just two facets of the water problem in the next 20 years, provision of adequate quantity through storage and of acceptable quality by human and industrial waste collection and treatment. This does not include and provide for watershed protection, flood control, navigation, hydro-power, irrigation, plant and wild life conservation, and recreational use. This report also puts major emphasis on river basin planning by the states with the help of the U. S. Government and on the importance of research and development for new sources and for optimum and economic use of existing sources. It also calls attention to research coordination and better mobilization of public opinion in support of water resources activities. There can be no doubt, that a serious and concerted attack on this problem is imminent in view of the detailed and urgent needs set forth in this report. It is not intended to elaborate here greatly on this phase, but it will rather be attempted to list a few of the new developments in the field to illustrate the scope of new ideas and the activities needed in various fields to develop new technologies.

Water and the Atmosphere

In this area might be listed the development and the appraisal of methods to increase the precipitation rates particularly in more arid regions. This includes hydro-meteorologic forecasting and weather modifications. The control of water losses to the atmosphere is another phase of conservation including measures to reduce evaporation from surfaces of reservoirs by chemicals or shielding, the change of vegetative covers near reservoirs and streams and over other land areas from water wasting to water conserving types, the protection of exposed ground surfaces against evaporation by proper shaping or by application of artificial mulches. The possibility may also be considered of extracting water directly from the moisture of the air through use of excess heat power.

Surface Water Control

Once water is available on the ground, problems arise with either direct retention or proper channeling or drainage to further use. Flood control should embody both phases and raises questions on forecasting, sediment transport and avoidance of erosion, maintenance of water quality before and after human use, reduction or promotion of seepage into the ground. For example, the interruption of river flow through a succession of reservoirs causes sediment deposition in these basins with gradual reduction of the capacity, excessive erosion and "digging in" of the intermediate channel sections, conversion of water quality with respect to oxygen content and temperature, consequences with regard to survival of wild life, such as of the salmon in the Columbia River. Inherent, therefore, in all these problems are basic studies not only of hydrology, but of soil physics, chemistry and biology in relation to hydraulic conservation measures and structures. New problems arise with respect to water supply, waste disposal, waste water salvage in relation to the modified flow regime, as well as through the tremendous increase in the recreational use of ponded waters.

Irrigation waters have become essential to food production, but have in turn raised many problems for efficient channeling, maintenance, excessive seepage and evaporation. Chemicals are being developed to promote the precipitation of suspended sediments, to seal the channel walls and to restrict the growth of weeds. As an example of one consequence of irrigation practice with which our laboratory has come into contact, the propagation of schistosomiasis, a wide spread tropical and subtropical disease, is traceable to various types of snails as carriers of the parasitic worms. A study of the possible hydraulic factors detrimental to snail survival is therefore underway.

Groundwater Resources

Groundwater has been tapped since time immemorial as a ready source of supply, yet our knowledge with respect to availability, quality and flow behavior is still quite inadequate. In addition to studies correlating the properties of soil and of granular materials to the flow of water, quantitative determinations of groundwater basins and of their supply are needed to assess its potential for use. Techniques for recharging of groundwater basins with treated waste water or excess surface water during floods are in need of further development. Closely related to this problem is the prevention of salt water intrusion into coastal aquifers and the study of the diffusion of salt water into fresh water basins as the result of excessive pumping.

Ocean Water Resources

The asset of ocean beaches and shore lines is a vital one to the economy of many states. Many beaches have been irreparably damaged by ill-advised structures and artificial inlets and expensive measures are necessary to preserve others. Most of these consequences stem from the difficulty of predicting the interrelation of wave characteristics and littoral sediment transport. Suitable structures are yet to be developed to cause the minimum damage to the natural equilibrium or to enhance the marginal value of some coastal areas. Physical oceanography in the shallow coastal areas is, therefore, an important field of research in order that offshore zones as well as shore lines and tidal estuaries may be made to serve their important role economically in the human environment. The awareness of efforts needed in this field as a part of the large research effort contemplated and recommended to the nation in oceanography generally must be promoted.

Major emphasis is given to publicly supported research efforts in desalting of ocean waters and of brackish waters. With major population centers along tidal shores and the rapidly decreasing fresh water supplies, this emphasis is fully justified. New methods are still desired and present methods are still subject to major changes in the applied technology. Scientific and economic factors are closely related and the impact of a major breakthrough in this area on the entire complex of water resources remains without engineering evaluation.

Finally, with improved technology, the use of tidal energy and of wave energy may be mentioned. Several projects of tidal power development have been carried to the point of detailed design and at least one of these is under construction in France. Wave power remains as yet unexploited, except for recently reported experiments in Russia.

Water Utilization

While many of the basic problems related to water resources development were discussed in the preceding sections in reference to the needs for water, an independent complex of problems arises as the result of the multiple use made of water after its supply has been provided and improved. Only a small portion of the water resources is developed for a single purpose such as for a water supply for human and industrial use, for hydro-power or for navigation. The norm for future development will be increasingly the multi-purpose development of entire watershed areas and river basins. While this problem has been with us for some time, it is believed that major contributions to further progress are now possible through the vast potential of modern methods of data collection and processing, of systems analysis by high speed computers, and thus of ready exploration of many complex situations for optimum overall function.

This applies also to the operational phases of the large systems of reservoirs such as exist in the Tennessee Valley, along the Missouri and the Columbia Rivers, which are to be adjusted continuously in accordance with the various demands of navigation, flood control, irrigation, and hydro-power. Hydro-power is the form most flexible and almost instantaneously responsive with respect to demand and load rejection in an electric power network. It is increasingly being used also for energy storage through pump-storage arrangements, thus increasing the overall efficiency of heat power—water power systems. Thus new techniques will certainly be under development in the future in new machinery as well as in new methods of integration of heat and water power.

New methods of water measurements may finally be mentioned here, by ultrasonic and electromagnetic means as well as by diffusion of radioactive materials; instrumentation based on novel applications of the physics of sound, electromagnetism, heat and radioactivity will certainly provide more convenient means of analysis and control and will make possible research in areas of fluid flow so far not accessible with conventional methods.

The Impact of Radioactive Materials

A special section is justified here in view of the increasing use of atomic power and of the large production of atomic fission and fusion materials, which have already had a major impact on water resources use and planning. The importance of the proper disposal of waste materials resulting from the atomic industry is already indicated by the extensive research activities in the Sanitary Engineering field. This area is the most critical one with respect to the further development of atomic plants since serious problems have already been encountered with the retention and eventual diffusion of contaminated waters into surface streams and subterranean aquifers. Disposal methods depending on the coastal zones of the oceans also are open to question in the future. Thus the area of engineering research in atomic waste treatment is constantly expanding and carries a major responsibility for the maintenance of proper human environment.

On the favorable side of the atomic products with regard to the water resources must be mentioned, however, the new perspective added to research in this field by use of these products as tracer materials. Studies of sediment transport with such tracers are still in an initial state of development, but already the important potential has been proved for such methods. Diffusion rates under complex natural conditions have been determined in estuary flow, the transport of silt has been followed in coastal areas as well as the movement of sand along shore lines under wave attack. Quantitative techniques remain to be investigated in addition to the established qualitative approaches. Subterranean aquifers may be explored with respect to flow characteristics and sources, seepage and permeability may be defined on a major scale, the mechanics of erosion and of sediment deposition may be unraveled on land surfaces, in natural streams and in large bodies of water. The employment of radioactive tracers for water measurement will certainly increase with new techniques acceptable to technical personnel and public alike, as the need for more quantitative knowledge develops for more effective planning and the more sophisticated use of water resources.

Economic and Social Problems

Economic and social problems raised through availability and development of water resources are of such wide scope and have so many direct and indirect consequences that it is obviously impossible to touch upon more than just a few examples for the purpose of this discussion. Thus complex areas and situations picked at random must serve here for illustration with only their overall significance being mentioned rather than their detailed structure. It is hoped that the background of these major problems is familiar enough to permit the immediate phrasing of some questions in this area of the discussion without further reference to technical problems.

National Aspects of Water Resources Research

The economic justification of project development has always received primary attention of the planning engineer. His analysis in this area, however, must necessarily be focused an extrapolation of readily foreseeable economic and social consequences rather than the intangibles of the future environment he helps to create. Many questions arise in this area of planning with respect to the latter aspects and as to whether it is possible to establish by research on the economic and social history of major projects certain guide lines for future planning.

What were the detailed effects, for example, of the TVA multipurpose development on the economy and the social patterns of the specific area it serves, as well as the benefits or disadvantages accruing to other areas of the country from this development? Were the costs properly allocated to the various advantages derived, such as navigation, flood control, power and general reclamation and conservation? Opinions on this vary as widely as the initial commitment of the experts to either private or public interest. What are the answers on the basis of objective evaluation by social scientists and economists in the light of regional as well as of national aspirations for future reference?

California has just voted a large commitment of its income to the large scale provision of water for multiple purposes to cope with its future economic and population growth. In the past, the development of the Imperial Valley and of the metropolitan area around Los Angeles were possible only through water from the Colorado River. Controversies, still partly unresolved, arose over the rights of other states to this portion of the river flow. Have these developments been the most beneficial from hindsight as compared to original anticipated results? What economic lessons may be derived for future developments? What will be the economic impact of the new water plan, conceived on a gigantic scale, on the community both local and national? What general principles with respect to suitable water rights and water law have been derived?

Many legal and economic questions arise with the development of almost any major water resource. A new Delaware River water compact has just been concluded after more than 20 years of separate ways by the four riparian states. Does this give a pattern of organization of more general interest and what were the political and economic factors involved in the final arrangement?

Finally what will be the eventual modes and rights of water utilization by individuals, communities, states, and federal agencies? What restrictions must be imposed in the future on water use and how can the public be reeducated to accept them? This includes also the planning of land use in major flood plains, and along river banks where in many cases today effective engineering measures taken to protect the public against major floods have been obviated by land development contrary to the requirements of the flood control schemes.

International Aspects of Water Resources Development

There is little question that water resources development is one of the primary keys to the expanding economies of the under developed countries and continents. Major projects in this area have caught the imagination of the peoples and have come to be accepted as the focal points of their hopes for a better life. The United States has traditionally almost contributed to the planning of such projects through its private and public technical agencies and to the education of technical scientific personnel in its own universities and governmental organizations. This effort will undoubtedly be expanded. While so far, however, this type of intellectual export was based primarily on the experiences with our own resources program and on the personnel which grew with it, our contributions in this area will have to be based on knowledge of foreign conditions and water resources and are to be measured increasingly against performance in the foreign field. Hence an effective "feedback" of experiences and a primary acquaintance with foreign water resources in relation to economic and social factors must be built into training and technical aid programs. Factors of universal validity and those restricted to specific conditions must be discerned to arrive at suitable solutions on projects for specific environments. Needless to say, accepted principles of economic analysis of projects valid in the U. S. with certain predictable technical performance criteria may have to be modified materially in conformance to different social and economic standards.

This discussion would not be complete without referring also to the political problems involved, when the water resources schemes contemplated involve the interests of several nations. In this connection may be mentioned the water dispute between India and Pakistan, the Columbia River Compact between the U. S. and Canada as well as the St. Lawrence Waterway and Power Development, the Colorado River Agreement between Mexico and the U. S., the conflict of interest between Egypt and the Sudan over the Assuan project, the Israel-Jordan dispute over the water of the Jordan. Many other such problems are still in the offing, which can either be resolved in a friendly "give and take" based on indisputable technical facts or be dragged out interminably to the detriment of the economies on either side.

Many international agreements on joint exploitation of water resources have a long history of successful operation. The Rhine is a recognized international waterway of benefit to all riparian nations. The Suez and the Panama Canals, while administered by single nations, are open to international transit and exist only through the mutual interest of all maritime nations. The Kiel Canal and the Bosporus are other examples.

International law is still in development, however, with respect to the exploitation of offshore resources, as witness the various fishery disputes in the Gulf of Mexico, Alaska, off Iceland, Chile and in waters near Russian possessions in the Pacific. As technology develops for the exploitation of mineral resources farther offshore additional problems will certainly arise, in which previous international agreements may provide helpful precedents. This is true also with respect to the problem already imminent of atomic waste disposal in the deep parts of the oceans.

In the next decades many of the arid regions around the ocean shores will certainly call on salt water conversion for the development of agricultural production. Should not some attention be given now with respect to the most economical use of such waters, the available power sources and the population trends. What will be the economic impact and the social consequences of a major breakthrough in this area of research, particularly for the nations presently incapable of economic expansion for lack of water. Perhaps this may seem far-fetched at present but it certainly challenges the imagination and upon detailed investigation may not appear as impractical as it now seems. Rapid implementation of suitable technologies in this area would certainly be a major contribution to the promotion of a better environment for many nations, with favorable political consequences.

Conclusion

This broad sweep of problems in water resources development through education, research, and planning shows that new and even fascinating demands upon our professional competences are ahead of us. I am sure that an equal challenge may be outlined in other fields, in urban redevelopment and in the planning of new communities, in new structural concepts and use of new materials, in transportation in urban and wider regions, in short, in conceiving and providing new dimensions to the future human environment.

There is no crisis in civil engineering as far as problems are concerned. The question of today is, does our profession have the internal strength to rise to these great opportunities and to assume the imaginative leadership, which the public rightfully expects from a profession. The question is not, does the public fail to recognize us as civil engineers, but rather, do the civil engineers provide the professional service the public must have for the betterment of its physical environment. We must be willing to accelerate our pace in advancing new knowledge, in adapting to practice the modern developments of our times. We must do better in encouraging and stimulating the young in our lines and in furthering their careers. We must build for the future with renewed determination.

Let me close with the words of a great engineer, who always thought of the future and thus had a great part in shaping it, Charles F. Kettering (of General Motors Corporation):

> *"Nothing ever built arose to touch the skies unless some man dreamed that it should, some man believed that it could, and some man willed that it must."*