

## CAREER OPPORTUNITIES IN WATER RESOURCES RESEARCH

E. D. Eaton<sup>1/</sup>

Water resources research, and the opportunities it offers for a professional career are such stimulating subjects that they often tempt me to talk for longer than my allotted share of the program. To avoid that temptation, this afternoon I will touch only briefly on "why, what kind, and how much water resources research?;" and use a few illustrative examples to indicate the scope of opportunity.

The "why" of water resources research, it seems to me, has been well demonstrated by the three previous papers by Dr. Agee, Professor Hernandez, and Professor Clark. Their papers have made evident the importance and urgency of developing improved answers for many problems of water quality management. Although certainly it is true that action to protect water quality need not, and should not, be deferred awaiting completion of research, it also is clear that effective economically practicable water quality management for many of the streams in the Southwest, as well as elsewhere in the United States, requires greatly increased knowledge and understanding of the processes involved. This also is true of virtually all other aspects of water resources management from urban hydrology to waterfowl protection. Research, in a sense, is among the most needed and the most promising activities in water resources conservation and utilization.

It is always difficult to estimate quantitatively the justifiable magnitude of research effort, but one or two business-type computations may be indicative. For example, a recent paper by Hands and Kube in the Harvard Business Review for October 1966 estimates that in the next 30 years investment by industries and municipalities in water quality protection facilities will be not less than \$110 billion. Comparable estimates of investment in major engineering facilities for streamflow regulation and water storage exceed \$200 billion during about the same period of years. Research to increase the effectiveness of investment in water facilities by no more than 3 percent, therefore, justifies research expenditures averaging over \$200 million a year. This alone is substantially greater than current expenditures for all water research. Without pursuing further such calculations (which all too easily might degenerate into a mere numbers game), there is evident need and justification for substantial increase of the current level of water resources research effort.

The excellent paper just presented by Dean Leyendecker has clearly stated the importance both of research that seeks to provide fundamental

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<sup>1/</sup> Associate Director, Office of Water Resources Research, United States Department of the Interior, Washington, D. C.

understanding of physical processes, and of research that is readily transferable to practice--something confusingly termed "applied research." As Dr. Leyendecker has indicated, both kinds of research are needed in the fields of physical sciences such as hydrogeology and hydraulics, and also in many of the life sciences that deal with biological processes. Professor Hernandez' discussion this morning exemplified the involvement of civil and sanitary engineering, and also the involvement of social sciences in seeking definition of "feasible means of treatment." Usable concepts of such criteria call for employment of operations research and systems engineering as well as of the conventional technical disciplines.

The "systems" may be macro-systems such as river basins or major metropolitan areas; they may be micro-systems such as individual industrial or agricultural enterprises; and, in fact, they may be systems of public administration, laws, and regulations. There now is wide consensus that as we engage increasingly in problems of water resource management in a complex physical and social environment, operations research and systems engineering are increasingly productive approaches.

Against that background, what are current estimates of water resources scientific personnel requirements? At the present time, water resources planning, facilities construction and operation, research and university teaching are the principal activity of approximately 10,000 professional-level people in the United States. Of these, the largest number are engaged in facility planning, design, and construction; while about one-fourth of that number are engaged in water resources research. These numbers may be expected to double within the next 5 to 10 years, depending to considerable degree on the capability of universities to produce professionally qualified people.

Research activities are of major significance in this connection because they have twofold effect. In addition to producing the scientific knowledge and understanding needed for the effective and practical solution of water resources problems, research also is a principal means for production of high quality technical practitioners. The association with senior faculty members that is afforded to advanced students engaged as research assistants is an important element in trained manpower development.

Broadened technical participation is becoming increasingly evident in water resources activities, especially so in water resources research. In addition to physical scientists and engineers, water resources planning, operations, and research now involve significant numbers of the life scientists and social scientists. Furthermore, although water resources activities may continue in the future, as they have in the past, to be preponderantly the responsibility of Federal and state agencies, there is already evident an increasing industry concern that enlarges participation of consulting engineers, private research institutions, and in the case of certain industries, significant numbers of professional corporate employees.

By and large, professional water resource career opportunities in public agencies, private industry, and universities are likely to remain preponderantly in the traditional professional categories of engineering, physical, life, and social sciences, and law. There is, however, increasing recognition of the need for professional personnel to have understanding of and capability in multi-disciplinary approaches to resource problems, and also of the relationships of natural resources to urban environments.

I hope that these brief comments convey to you my conviction that there are promising opportunities for careers in water resources research which will be professionally rewarding and personally stimulating.