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ABSTRACT

Relating the supply of scientific manpower to the educational potential of the general population and the productive capacity of the educational system, this study disaggregates independent projections of scientific manpower supply and demand to yield projections for water resources manpower. This supply of engineers, natural scientists, and social scientists is projected at 3.3 million for 1980, compared to a demand for 3.5 million. Supply and demand relationships for the 1970-1980 decade show a 10 percent deficit of engineers, a 5 percent surplus of natural scientists, and a 7-8 percent deficit of social scientists. The supply of water resources manpower is projected to reach 154,000 by 1980, with 55,000 in research, compared with a demand for 267,000 with 95,000 needed in research. Critical shortages are forecast in several disciplines: ecology, hydrology, water resources planning, water quality, and watershed management. [Not available in hard copy due to marginal print size of original copy.] (BH)

LOUISIANA WATER RESOURCES RESEARCH INSTITUTE

BULLETIN 4 MAY 1970

WATER-RESOURCES MANPOWER
SUPPLY AND DEMAND PATTERNS TO 1980

JAMES E. LEWIS

LOUISIANA STATE UNIVERSITY
BATON ROUGE

The LOUISIANA WATER RESOURCES RESEARCH INSTITUTE was chartered by Louisiana State University to:

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Finally, I wish to thank my wife, Ann Allen Lewis, for her usual high level of editorial and critical contributions.

As is customary, I must absolve the above-named persons of any responsibility for errors and omissions in the study; those are reserved for me alone.

James E. Lewis
Baton Rouge
15 July 1969

EDITORIAL NOTE

The financial support for this study (A-015-LA) was provided by the Office of Water Resources Research, U.S. Department of the Interior, under Title I of Public Law 88-379 (Water Resources Act of 1964).

Doctor Lewis, formerly Assistant Professor of Geography at Louisiana State University, is now at the University of Virginia. His specialty was Economic Geography (measurement, location, and theory of economic activities). This bulletin, which is also his project termination report, presents Dr. Lewis' thinking on future water-resources manpower.

Charles W. Hill
Research Associate

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TITLE: WATER-RESOURCES MANPOWER: SUPPLY AND DEMAND PATTERNS TO 1980

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CHAPTER I

SUMMARY

GENERAL CONSIDERATIONS

Can we satisfy the demand for water resources manpower in the coming decade? The numerical values resulting from analyses and computations serve to emphasize one conclusion: planning for optimal utilization of water-resources personnel and funds will be meaningful only if the planners understand the interplay between supply and demand in the national manpower pattern.

The present national policy regarding mission priorities, established by the relative size of Congressional appropriations for the various activities, determines the height of the bid-price/shortage spiral of science manpower. The demand/supply relationship is altered when intra- and inter-mission competition occurs. If national priorities are established irrationally, the manpower pool will respond irrationally, within limits.

Two basic factors limit the supply: the biological capacity of the general population, in terms of native intelligence, ability, and potential capability; and the productive capacity of the educational system, in terms of both the total number of graduates and the number of graduates in specific disciplines or fields.

MANPOWER PROJECTIONS

Independent projections place the supply of science manpower--engineers, natural scientists, and social scientists--at 2.6 million in 1975 and 3.3 million in 1980. The 1980 demand, projected at slightly more than 3.5 million, rests on the assumption that the present relationship between national research and development programs and their expenditures will remain relatively unchanged. The total demand would increase by 15 percent if the goals established by the Presidential Commission were to be met.

The differences between projections of the supply and demand for science manpower in the 1970-1980 decade are: a 10 percent deficit of engineers, a 5 percent surplus of natural scientists, and a 7-8 percent deficit of social scientists. These are national projections.

The supply of water-resources manpower is expected to reach 154,000 by 1980. Of this total, about 55,000 persons would be engaged in research. The 1980 demand for water-resources manpower is projected at 267,000, with 95,000 being needed in research. In contrast to the national (overall) figures, the shortage of scientists appears to be more severe than that of engineers. Critical shortages are forecast in several disciplines: ecology; hydrology; water-resources planning, development, and management; water quality; and watershed management.

RECOMMENDATIONS

Measures which will increase the water-resources manpower and improve its utilization include:

- Improved public-relations programs to attract prospective water-resources personnel
- Strengthened relationships with job-development programs
- Utilization of remote sensing in all phases of water resources
- Increased participation by other disciplines in water-resources research.

CHAPTER II

BACKGROUND AND SCOPE OF STUDY

INTRODUCTION

The expansion of water-resources programs has created many unfilled professional and technical positions in this important field. Research professionals are now in short supply. If the present research is to be brought to fruition in the coming years, many more administrative and operations-oriented professionals, technicians, and supporting personnel will also be needed. Although the problem of water-resources manpower has been slighted, it has not been ignored. However, neither its present nor potential dimensions are fully apparent.

In its 1966 publication, "A Ten-Year Program of Federal Water Resources Research," the Committee on Water Resources Research took note of the additional demands that the water resources research program would place on the nation's manpower pool. The Committee felt that the needed manpower (4,000 professionals at the federal level alone) would be drawn from a number of disciplines, none of which would suffer unduly. This relatively safe assumption was based on the interdisciplinary nature of water resources research.

The Committee noted further that "an uncertain factor in this prediction is the presently unknown requirements of the Federal (and State) agencies for similarly qualified manpower." The Committee then stated that an investigation of water resources manpower requirements was planned to determine the validity of these opinions.

Apparently this study had not been completed or commissioned by March, 1968, when the present study was proposed to the Office of Water Resources Research.

In June, 1968, the OWRR contracted for a separate manpower study with Surveys and Research Corporation of Washington, D.C.

DATA ON MANPOWER REQUIREMENTS

Firm information on water resources manpower requirements appears to be limited to the data in "Manpower and Training Needs in Water Pollution Control" [U.S. Senate, 1967], which contains estimates that more than 30,000 new professionals will be required by 1972 in pollution control alone. In addition, nearly 25,000 new technicians and at least 22,000 operators will be needed in the same field.

Other aspects of the demand for water resources personnel are presented in the Annual Reports of the Office of Water Resources Research for 1966 and 1967. These reports express the opinions of that agency's advisory panel and contain representative statements concerning the problems of the state water resources research institutes. For the most part, these statements are subjective and qualitative (rather than quantitative), but this fact does not diminish their significance.

In 1966, the OWRR Annual Report stated that a major problem of the water resources research program was the lack of qualified and interested personnel. The state water resources research institutes and centers felt this pinch in particular because they are responsible for conducting and coordinating most of the research.

In 1967, manpower was still a major problem, but the OWRR advisory panel recommended that any study of it be turned over to the National Science Foundation because the subject is peripheral to the mission of OWRR. Not only that; few scientific personnel would leave their major research interest to examine this type of problem. Yet without sufficient qualified personnel, the program ultimately must die.

The general tenor of the institute directors' comments (noted in the annual reports) was that manpower was and is a critical problem that will be overcome in time. This optimism is probably based more on wishful thinking than fact, although an impressive upturn in both undergraduate and graduate interest in water resources is apparent. However, it can be shown that less than half the estimated number of professionals needed in water pollution control alone would be produced, even if the student enrollment in "water related" courses in 1966 (1,300) and 1967 (1,500) were to double over the next five years and all such students were to attain professional stature within that time.

SUPPLY AND DEMAND RELATIONSHIPS

Furthermore, supply and demand relationships in water resources cannot be isolated from the demands for other professional and technical personnel, because other professional fields and research programs have their manpower requirements, too. Some of these, such as oceanography, the Sea Grant programs, and public health, draw from essentially the same manpower pool as water resources; at any given time, the same students may be enrolled in "water related" courses. Thus, the count of potential water resource personnel may be highly inflated.

Crucial manpower problems also exist in the health professions, social work, teaching on all levels, and other fields. Their projected future manpower requirements in these fields, as well as immediate needs, are at least as great as those in water resources. This study attempts a preliminary identification of the total manpower requirements for all professions and an estimate of their impact on the availability of water resources personnel during the coming decade.

OBJECTIVES

The basic outline of this study was shaped by four main objectives:

Identification of estimated manpower requirements for major scientific and technical programs and in industrial and occupational categories on the national level;

Identification of estimated levels of production of professional, technical, and other elements of the national labor force;

Comparison of estimated manpower requirements with estimated manpower production at the pertinent educational and skill levels; and

Evaluation of the effect of the more general manpower supply and demand patterns on the availability of water resources personnel.

These four objectives furnish the theme of the report. Before they are considered, however, we need a conceptual basis for the analysis of manpower supply and demand. We must also examine the fundamental policy conflicts that affect the supply and demand for mission-oriented manpower.

This report is only a preliminary analysis and interpretation of the problem. For economy of both time and money little new data were collected. Rather, effort was focused on data currently available from the U.S. Department of Labor, the National Science Foundation, the U.S. Office of Education, other governmental agencies, and professional associations.

It is felt that this initial investigation has answered the question: Can the demand for water resources personnel in the coming decade be satisfied? The answer is not optimistic, but it has added substance to the assertion than an understanding of the interplay between supply and demand in the national manpower situation is a prerequisite to planning for optimal utilization of water resources personnel and funds.

CHAPTER III

GENERAL CONCEPTUAL BASIS AND PROBLEMS OF ANALYSIS

INTRODUCTION

The study of patterns in the supply, demand, and distribution of manpower has been a "crisis" type of American research, one that comes to the fore during and immediately after national emergencies and during high rates of unemployment--only to languish in the background until the next crisis. This statement in no way denigrates the continuous flow of excellent studies and reports from both governmental and private agencies. But only in the post-Sputnik era, and especially since 1960, has scientific and technical manpower been given other than emergency-stimulated study.

During the past four decades, manpower studies have varied with the level of economic activity or in response to the special problems of acute national emergencies. In the depression and post-depression eras of the late 1920's and the 1930's, jobs for the unemployed had to be found or created. The demand of World War II was different: to find personnel for the military and other tasks essential to the war effort. The postwar demobilization period brought its own peculiar problems while the nation's industries converted from military- to civilian-oriented production. Returning servicemen had to be re-integrated into both the work force and an economy that was substantially different from that of the pre-war period. The Korean War brought further new demands as the United States attempted to conduct a limited war and, at the same time, maintain the civilian orientation of its economy.

Scarcely had the nation recovered from the Korean War effort when the first artificial satellite, Sputnik, was placed into earth orbit by the Soviet Union. New demands on manpower: Where to find the American scientists and engineers needed to compete with this new thrust of the Soviet Union toward scientific, and possibly, military pre-eminence? Where to find the schools, the colleges and universities, the teachers, and the professors to produce the scientific and technical manpower capable of meeting this challenge? These questions gave a new facet to manpower research--developing people for jobs.

Adding to the impact of Sputnik was the economic recession of the late 1950's and the early 1960's, with the demand of finding work for the unemployed and the problem of worker displacement that resulted from the increasing automation of routine tasks. Here was a continuation of the more familiar manpower problem--jobs for people.

With the middle and late 1960's came unprecedented rates of employment for the skilled and the professional--rates stimulated (artificially perhaps) by the manpower requirements of the Viet Nam war. (These years also gave little employment opportunity for undereducated, underskilled manpower, particularly in metropolitan core areas.) Inequalities aside, the problem confronted here is: How should skilled and professional manpower, particularly scientific and technical personnel, be allocated among competing demands in a high-employment economy? The specific problem--meeting the demand for water resources manpower--can be understood only in this larger context.

These highly-generalized observations of past patterns in manpower research are further complicated by two underlying trends: (1) the subtle shift, over the past two decades, from a production- to a service-oriented economy; and (2) the growing public awareness of man's ability to alter his physical environment, both positively and negatively, with a public demand for mitigation and correction of the negative impacts.

DEFINITIONS AND SCOPE OF WATER-RESOURCES MANPOWER

We will focus particuarly on manpower for water resources research and secondarily, manpower for water-related activities. Without our going into the difficulties of defining "research," a topic beyond the scope of this report and ably covered elsewhere, suffice it that we recognize research as broad activity that includes not only the so-called "basic" and "applied" researchers, but also those whose principal activity is other than research, e.g., administrators or teachers.

Unending difficulties arise when we attempt to categorize persons according to their scientific discipline, their source of research funds, or even the object of their research. For example: is the chemist focusing on the bonding structure of the water molecule doing water resources research? He may be a physical chemist interested only in the general field of molecular structure and bonding properties. His work may be funded by the National Science Foundation rather than the Office of Water Resources Research. Outside his laboratory, water to him may be a substance useful only for drinking, washing, and recreation. If his source of financing shifts from NSF to OWRR, does he become a water resources researcher?

This example is neither extreme nor silly; on the contrary, it is commonplace among most scientific disciplines. Further, we assumed that our chemist will maintain this research interest throughout his productive life. Much more common is the researcher who shifts his work focus several times during his career.

The solutions to such problems are not simple because they involve consideration of changeable priorities in research funding, alternate career opportunities, and changing work orientations within career fields, as well as recognition of the variable aspirations of the individual. Even if we were able to identify and interview each person in detail, we could hardly foresee the effects of all these influences on each career. The operational solution adopted for this study is not fully satisfactory. On the other hand, because few mission-oriented manpower studies have even recognized this fundamental problem, we may consider it an advance.

The technique, described in detail in Chapter VII, is, in brief, a method of extrapolating from the known composition, by discipline, of groups interested in or working in water resources research to unknown future compositions. Within the limits of the underlying assumptions, the projective techniques, and the available data, the results are consistent and accurate.

Water-Resources Manpower

To many persons, individuals such as the chemist described above should be excluded from any classification in water resources manpower because of their narrow interests. And it is true--both the goals and the connotation of such research are much broader and much more complex than those encompassed by any single disciplinary label, although geography, as the science of spatial variance and spatial process analysis; ecology, as the science of natural bio-systems; and systems analysis come closest to recognizing the total interrelatedness of earth systems. Except for systems analysis, which tends to produce mathematical models that are generations ahead of our data collection and processing capability, these fields are undermanned and underrepresented in water resources research.

Barry Commoner is undoubtedly correct in his observation that the "reductionist" attitude prevalent among scientists hampers the development of understanding at the ecological-geographical level, even though it immensely increases understanding at the molecular level. As he stated at a recent UNESCO conference [Carter, 1969, p. 1048]:

"The assumption is too often made that [a complex system] can be understood simply by looking at the properties of its isolated parts. . . . This is what leads to the substitution of molecular biology for the biology of natural systems. This is what leads sociologists to become psychologists, what leads psychologists to become physiologists, what makes physiologists cellular biologists, and turns cellular biologists into chemists, and chemists into physicists, and physicists into mathematicians. Everyone is looking for the higher science."

We might add that "everyone" is searching for a simple key to complex systems. However, must we believe that it will be found at the molecular level? All too commonly, an invitation to a biologist, chemist, or what-have-you, of any breed or stripe, to participate in a regional water resources project, for example, begins with his statement that the project team will first have to understand the structure of the water molecule, count the organisms in each acre-foot of flowing water (and the like) before undertaking the principal objectives.

Macroscale scientists realize that it would be best to understand everything in both itself and its interrelationships before making judgments at the macro-level; they also realize that this is impossible. The best course remaining to policy-makers, then, is to push forward on all fronts with the hope that the interchange of ideas and information among practitioners at the macro- and micro-levels will preclude any irreversible decisions that would ultimately prove damaging or self-defeating. It seems clear that the macroscale considerations are truly the water resource considerations, but the development of scientific knowledge has not yet reached the point where the macro- and micro-level can be separated--if ever they can.

With due recognition of the knowledge gaps in scientific water resources, the basic interdisciplinary character of water-resources research, and the existing ways in which it is conducted, the selection of disciplines for consideration in this study has been quite eclectic. About forty disciplines were chosen, although data gaps required that some be grouped at various stages of the analysis. Discussed later in Chapter VI, they range from agricultural economics to law, from geography to oceanography, from biology to physics. Also included are engineering and several of its subfields.

Time Frame

This study covers the 1970-1980 decade, with particular emphasis given to the latter half. The data were drawn primarily from the 1950's and 1960's, with some from as far back as 1900. Although most of the projections are made for 1975 and 1980, in a few cases the data were sufficient for projections to 1985, 1990, or 2000.

Education

From an educational standpoint, the study is concerned with professional water-resources manpower. Professionals are defined here as those persons with bachelor's, first professional, or higher degrees. (There is no connotation of "unprofessional" attached to those who do not hold degrees. Their number is limited and will decline as four years or more of college become recognized as minimum educational criteria for most water resources positions.) We are not concerned directly with technical and supportive personnel--laboratory assistants, research aides, and technicians--for whom high school, vocational school, or a two-year college followed by on-job experience may provide sufficient education and training. Where the data permit us, we will make appropriate references to these support personnel.

Data

At present, manpower data, especially for the scientific and technical fields, are collected by discipline or broad occupational categories. From such data we can determine how many bachelor, master, and doctoral degrees have been granted in a given field and then project the information [NSF, 1967; Simon and Fullam, 1968]. The U.S. Office of Education publishes annual reports on earned degrees conferred by discipline and a special series on engineering degrees.

We can determine also how many persons in a given field are primarily administrators, researchers, or teachers and in which of ten broad areas of federally-supported research they are working. However, we have no data on mission-oriented activities, e.g., water resources, atmospheric pollution, oceanography, and the like.

MANPOWER SHORTAGES

Every manpower study carries with it the implicit assumption of a shortage--a shortage of jobs or persons--but presumably this assumption prompts the study. In a perceptive article on science education, Alvin M. Weinberg suggested that while science is inherently inefficient, there are almost certainly large wastes of science manpower [Weinberg, 1962, p. 27]. Thus, inefficient use of our scientists contributes to one kind of shortage.

Manpower shortages are also claimed if the supply of a particular group falls below the level dictated by some social criterion or goal [Blank and Stigler, 1957, p. 3]. But such a shortage also involves the distinction between "need" and "demand." The setting of a goal may define the need for a certain number of qualified personnel, but if the money to pay for them is not allocated at the same time, the demand has not been established. This concept carries with it assumptions of both willingness and ability to pay.

A more common type of manpower shortage occurs when the supply of available workers increases less rapidly than the number demanded at the salaries paid in the recent past [Blank and Stigler, 1957, p. 3]. This meaning of shortage is particularly important in a discussion of scientific manpower because of the inherent time lag between the stimulation of supply by the offering of higher wages and the increase in supply after college enrollees have elected the scientific fields and completed at least four years of education. The other alternatives for satisfying this kind of shortage are: (1) field switching by existing personnel; and (2) utilization of less well-trained manpower where possible. Shortages of water resources manpower thus inolve considerations of goal-generated demand, increases in the supply of qualified college graduates, field switching, and utilization of less well-trained manpower.

Weinberg has identified two kinds of manpower shortages that might better be labeled causes. He notes that direct shortages in a field begin to be felt with greatly added federal sponsorship of work in that field. In contrast, derived shortages occur

> "when the federal government pours money into a certain field of science or technology [and] that field acquires glamor as well as funds for fellowships and training" [Weinberg, 1962, pp. 27, 28].

The direct shortages can be met, at least in part, by providing training funds at the same time that money is allocated for accomplishing a specific goal. But, there is no way of providing glamour to "the older, less glamorous" fields. This is not to say that the less attractive fields are less important; rather, "we divert our attention from the important to the glamorous, from the man on earth to the man in space" [Weinberg, 1962, p. 28].

The implications and analogies of Weinberg's comments for the field of water resources research apply directly. Only the growing realization of approaching crises--water pollution, deterioration of scenic areas, and extended droughts in normally well-watered regions of the nation--has led the American public to add some glamour to its accepted "free" good--water. The space program provides abundant evidence that international competition, combined with a spirit of vicarious adventure into the unknown, contributes more to glamour than some potentially-approaching crisis on earth. It will be interesting to observe the national attitude toward water resources research and development while it evolves over the next few years or until the next "crisis."

MISSION-ORIENTED VERSUS DISCIPLINE-ORIENTED MANPOWER

Definitions and Problem Areas

Since this study is apparently one of the first ventures into mission-oriented manpower research, it seems appropriate to draw the distinction between mission- and discipline-orientations as carefully as possible, and then to reflect on the consequences of the distinction as they apply to scientific research in general and to water resources research in particular. Mission-oriented manpower may be defined as that which is problem-oriented, as opposed to that which is identified by a particular object or method of study. The major problem areas facing contemporary America have been identified recently in "Goals for Americans," prepared by the President's Committee on America's Goals and Resources. Twelve areas of highest priority for attention and financial assistance were defined: agriculture, area redevelopment (domestic economic development), education, health, housing, international aid, national defense, natural resources, social welfare, space, transportation, and urban development. From a manpower standpoint, the commonalities of these apparently disparate problem areas are more important than are their differences, because:

1. They compete for the same funds
2. They compete in the same pool of professional and technical manpower
3. Within a given problem area, there is competition for funds
4. Within a given problem area, there is competition for manpower
5. Within and among problem areas, there may be conflicting goals.

At any given time there is a finite pool of professional and technical manpower trained in the traditional academic disciplines. Mission-oriented programs regard these academic disciplines as labels for possible scientific areas from which individuals might contribute to the overall problem. For example: Agriculture, economic development, education, health, housing, transportation, and urban development compete to a greater or lesser degree for the same basic supply of trained economists. Part of this supply, by virtue of specialized training or personal inclination, will be oriented more strongly toward one of the problem areas. For the rest, it is open competition; the most glamorous, best-funded problem area will take its pick of the manpower and leave a remainder to the other areas. Analogous situations can be cited for all the problem areas and for most academic disciplines (some still find their only home in universities).

Each problem area is comprised of sub-areas. If each problem area receives its appropriate share of the manpower pool, the sub-areas must then compete. Those with glamour and strong funding take their pick; the others bid for the remainder. At this level, the firmly-committed members of the pool form a smaller portion of the total and the competition is more open.

Mission-Oriented Personnel

The lack of previous studies of the supply-demand patterns of mission-oriented manpower, with the exception of certain critical fields such as health, social work, and, to some extent, science, demonstrates the existence of an implicit assumption: the supply of mission-oriented manpower is a direct function of the amount of money allocated to the mission. In other words, the question is assumed to be one of funding, not manpower.

This assumption is at least partly unfounded. The supply of scientific and technical personnel is not homogeneous in composition, nor is it infinitely elastic. We cannot substitute biologists for physicists any more than we can substitute attorneys for physicians. Each scientific discipline has its own requirements for specialized knowledge and capabilities. Furthermore, the sub-areas in each discipline are so specialized that within the broad field of biology, for example, we cannot substitute molecular biologists for ecologists. The reductionist nature of science discussed earlier adds to the lack of substitutability by creating ever narrower work foci and ever narrower specialization.

The elasticity of manpower supply, in even the most general terms, is a myth. Even if the entire population were included in the supply, there would still be a finite limit. No amount of additional funds could increase the supply. In reality, the total supply of manpower is limited even more--to the civilian labor force, now defined as the population aged sixteen and over. Scientific manpower, which must come from the total, is further restricted by the uneven distribution of intelligence, ability, and potential capability--to say nothing of interest. The point is simply that raising the level of funding for one kind of mission-oriented research does not increase the total supply at all. It merely improves the bidding position of that mission relative to other missions and enhances its ability to proselytize. If this point is not considered before national policies are decided and priorities established, the high-priority missions will have to outbid each other for manpower. On the other hand, well-funded lower-priority missions will be able to outbid higher priority programs.

The scientific manpower supply and demand situation is actually not so simple, but the subject of substitutability and elasticity is fundamental to a more detailed discussion of mission-oriented manpower after we separate it into its two major components: the "true," or confirmed mission-oriented professionals and their similarly oriented and dedicated technicians; and the "swing-group" professionals and their support personnel.

The Confirmed Professionals

Confirmed professionals are interested in a certain area--for example, water resources. To them, this area, as an object of study, offers personal and professional satisfaction. They may not even feel the necessity of rationalizing their efforts by stressing a personal view of the fundamental need for water by man. The principal aspect differentiating this manpower group from the swing-group is its relative stability of proportionate size, regardless of public perceptions of crisis or fluctuations in the funding level of the mission. If they receive reasonable salaries and recognition for their work, these scientists productively continue their inner-selected line of research. They may be less amenable to influences that would direct their research toward externally-determined goals. Consequently, true professionals may be slower in making direct contributions to a specific mission than members of the swing-group.

The Swing-Group Professionals

The swing-group professionals, in contrast to the confirmed professionals, have little or no firm commitment to a specific area of study; hence they have no particular difficulty in shifting their work focus from water resources to health, urban development, space, or other orientations. If the members of this group have a single, common characteristic, it is managerial ability. Persons with this ability have a broad grasp of complex problems, can foresee the ramifications and consequences of solutions to those problems and discern the value of alternatives and options among possible solutions, and know how to assemble and guide the diverse scientific and technical skills required in mission-oriented research. Thus, nothing disdainful is intended in the phrase "swing group." On the contrary. The mental facility to perform capably while changing from one mission to another or moving among mission sub-areas without undue loss of time places a swing-group professional among the most sought after of researchers.

For all practical purposes, this is the group that is bid for in manpower competition. Whenever a national policy decision affects the funding and glamour of a mission orientation, the competitive relationships of all missions are altered and the bidding process leads swing-group personnel from one mission to another.

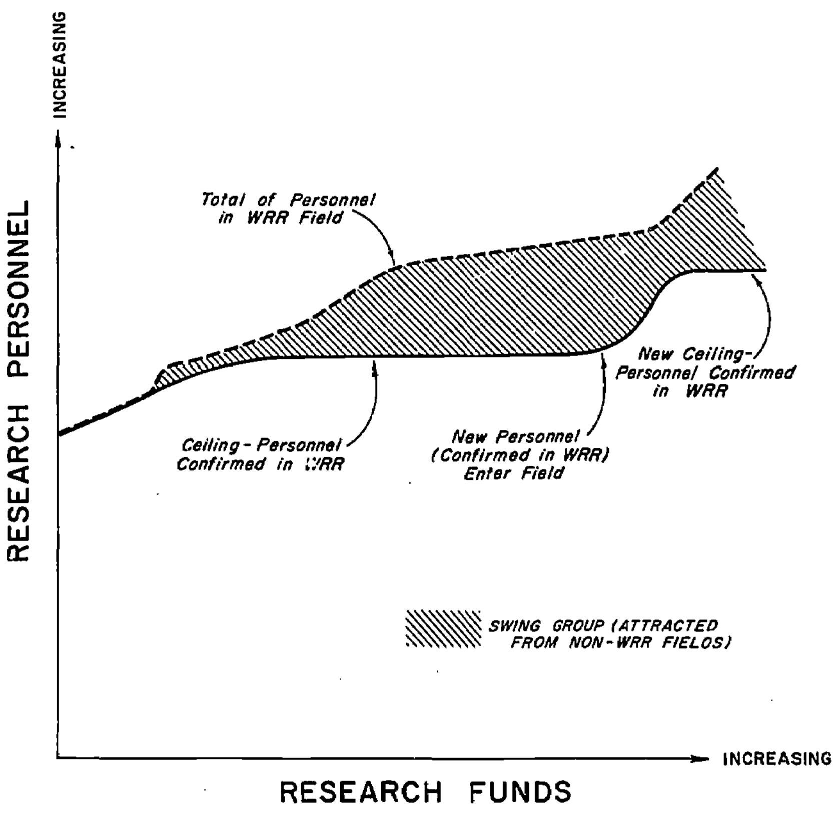
A diagram of these relationships is presented in Figure 1. The horizontal axis measures increasing levels of funding for a specific mission, in this case water resources. The vertical axis measures increasing numbers of water resources personnel, including both confirmed and swing-group professionals. As the level of funding increases, a "ceiling" is reached at which all the confirmed professionals are engaged in water resources research. Before this ceiling is reached, however, some members of the swing-group have been bid away from other missions--as shown by the dashed segment of the curve below its intersection with the solid curve. After the ceiling is reached, the expenditure of additional funds will serve only to increase the number of swing-group professionals being bid away from other missions. Finally, at the far right of the graph, the confirmed-professional curve turns sharply upward (ultimately to set a new ceiling) as new college graduates are attracted into water resources by the high salaries and strong funding. Even then, however, these new confirmed professionals will have been drawn from other possible mission orientations or academic disciplines to water resources--not by any intrinsic interest in the field, but by the relative level of funding, the glamour, and the salaries.

This pattern of manpower relationships among mission orientations appears to be worthy of further study. Certainly, the present discussion has been preliminary only. For example: the relative proportions of the two segments of mission-oriented manpower are not known at this time. Also, it is safe to assume that the bidding process-initiated manpower flows are not unidirectional. The volume and character of the reverse flow, which are not known, may well vary with differences in relative bidding ability. Lastly, it is not enough that only the student of manpower recognizes the interrelationships that have been discussed. If they are not taken into consideration at national policy-making levels, the spiral of bid-price/shortage in scientific manpower supply and demand relationships can be expected to climb ever higher as additional missions receive priority designation and increased funding.

Research Institutes

Another observation that has direct relevance to the overall problem may be appropriate since it affects the universities, our major science manpower producers. That the reductionist nature of science is antithetical to mission accomplishment has focused attention on the need for interdisciplinary research (in ultimate form, the systems approach to problem-solving). In response to this need, universities have, at a rapidly quickening pace over the years, established mission- or problem-oriented research institutes. At the same time, however, the object-oriented disciplinary pattern has held sway throughout the universities by virtue of their traditional departmental structure.

The outcome of this paradox is not clear yet, but two trends indicate what can be expected. First: the scope and number of post-doctoral research programs that have been organized on an interdisciplinary basis suggest that the traditional departmental structures of universities are not providing the education and training which are perceived by the advanced student to be most necessary to his career objectives. Second: mission-oriented university research institutes evolve, not infrequently, to the status of graduate-level departments by drawing students from an array of traditional disciplines and inculcating them with the interdisciplinary approach to mission-oriented research. Hence, the conclusion is that, in the future, more and more mission-oriented university research institutes will become recognized as graduate departments which offer their own interdisciplinary programs and degrees.



GRAPHIC MODEL

MANPOWER RELATIONSHIPS IN WATER-RESOURCES RESEARCH

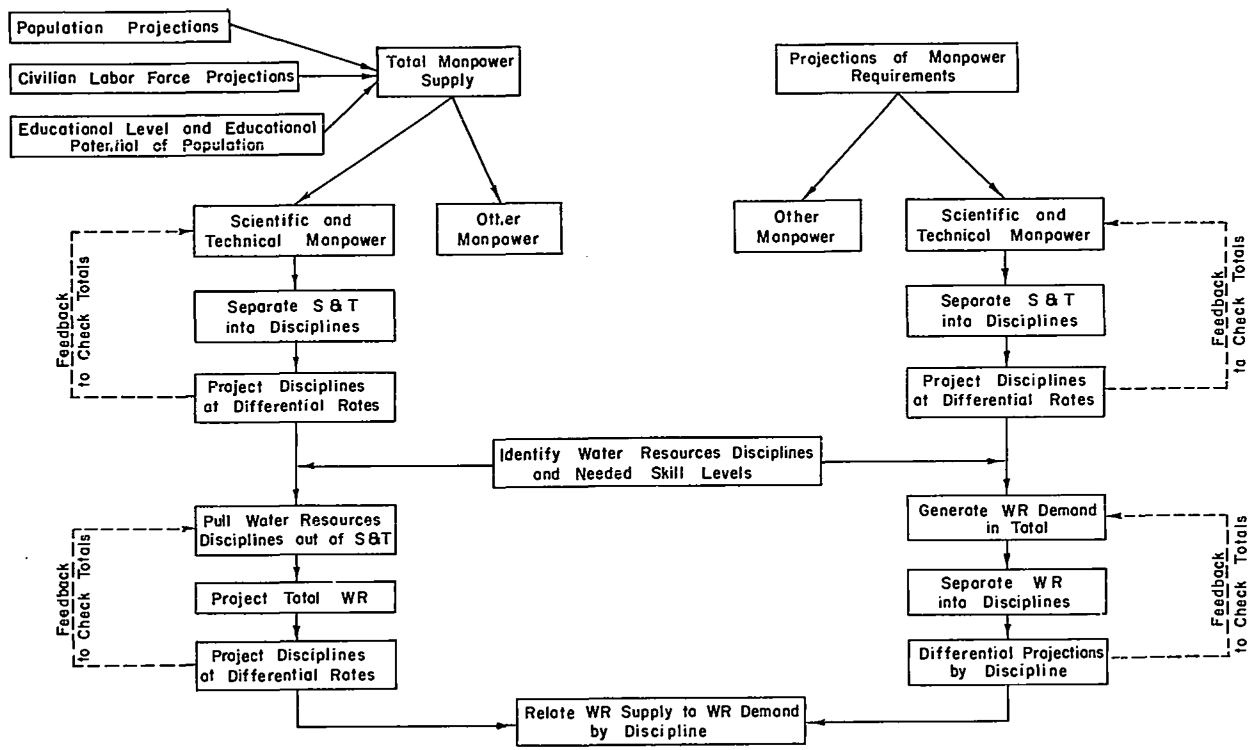
FIG. I

Whether this is desirable not only is beyond the scope of this study, but also is dependent on one's view of the question--from the standpoint of national priorities, national science policy, the universities, or the students. Clearly, the existence of these patterns and their portent for university education must be recognized and accounted for in the making of national policy.

THE STUDY APPROACH

The approach followed in this study, presented in diagrammatic form in Figure 2, essentially consists of estimating manpower supply and demand and the relevant variables affecting them, and then determining what is necessary to bring them into balance. The six major steps listed below will be treated individually in Chapters IV through IX.

1. Estimation of Manpower Supply
   A. Determine the potential supply of manpower by population projections, labor-force projections, and analyses of educational levels and educational potentials of the population
   B. Separate the projected labor force into (1) science (highly-trained scientific, engineering, and technical) manpower and (2) other manpower
   C. Separate science manpower into disciplines and mission orientations
   D. Project the supply by disciplines and mission orientations at differential rates, with the total science manpower as a constraint
2. Estimation of Manpower Demand
   A. Determine the potential demand for manpower by assembly and projection of manpower requirements
   B. Separate the projected requirements into (1) science manpower and (2) other manpower
   C. Separate science manpower into disciplines and mission orientations
   D. Project the demand by disciplines and mission orientations at differential rates with the total science manpower as a constraint
3. Identification of Water-Resource Disciplines and Skill Levels
4. Estimation of Water-Resources Manpower Supply
   A. Disaggregate the water-resources disciplines from science manpower projections obtained by Step 1
   B. Project the water-resources manpower supply, by discipline, at differential rates, using the total water-resources manpower as a constraint
5. Estimation of Water-Resources Manpower Demand
   A. Estimate the demand for water-resources manpower by: (1) its relation to gross national product, research and development expenditures, national goals, or other representative values; and (2) disaggregate the water-resources disciplines from science manpower projections obtained by Step 2
   B. Project the water-resources demand, by discipline, at differential rates, using the total water-resources manpower as a constraint
6. Relating the Water-Resources Supply and Demand
   A. Identify the nature and extent of any surpluses
   B. Identify the nature and extent of any deficits



DIAGRAMMATIC OUTLINE — MANPOWER RESEARCH PROJECT

FIG. 2

CHAPTER IV

THE POTENTIAL SUPPLY OF HIGHLY-TRAINED MANPOWER

INTRODUCTION

The demand and supply patterns for water resources research and other water-related manpower can be understood only from the overall context of patterns of demand and supply for highly-trained manpower in general. The reasons have been discussed in the preceding chapter. This chapter treats the general supply and Chapter V, the demand. In Chapter VI, the needed academic disciplines and required skill levels of water resources manpower are identified and discussed. The following two chapters (VII and VIII) focus on the supply and the demand for water resources manpower. In Chapter IX, these are related and developed into the supply-demand pattern.

The supply of highly-trained manpower is limited by two principal factors: the biological capacity of the general population (native intelligence, ability, and potential capability), and the productive capacity of the educational system (total number of graduates and number of graduates in specific disciplines or fields). Of course, influencing and impinging on these factors are others, such as financial support, individual determination to attain a high level of training, socio-economic status associated with different levels of training, and the like. But, in the broadest sense, these are subsumed under the two principal factors. One additional source--other countries--should be mentioned. International immigration causes the "brain drain," which has received so much attention in recent years.

The inflow to the United States of scientific and technical personnel has increased over the past decade from less than 5 percent to about 10 percent of the annual U.S. output [U.S. House of Representatives, 1967, pp. 2-3]. However, the percentages of scientists and engineers have held fairly steady, at 1.5 to 2.0 and 7.0 to 10.0 percent, respectively. The largest increase in immigrants has been physicians, who now amount to over 26 percent of the annual U.S. output. Thus, for any single mission orientation, other than medicine, immigration is not a significant source of manpower.

What is significant, and of concern, is that more than half the immigrant scientists and engineers come from the lesser-developed nations, many as students who remain in the United States after being educated. A single mission area can have little effect in stemming this drain of capital and ability from the poorer nations, even if the appropriate action were known. However, each mission-oriented agency that funds training programs must recognize the existence of the problem and realize that the attraction of immigrant manpower is merely the international swing-group aspect, which, in the long run, can contribute nothing to solving the problem of manpower supply.

PROJECTIONS OF THE POPULATION AND LABOR FORCE

Current population estimates and projections (prepared by the U.S. Bureau of the Census) place the population of the nation in 1980 between 255 and 300 million. Participation of 40 percent of the total population in the labor force has held steady over the past two decades. It is expected to remain at that level through 1980. Thus, by 1980, the labor force will include some 100 to 120 million persons. The growth patterns and relationships of these population elements are presented graphically in Figure 3.

The steady increase in educational attainment in the population over age 25 is generally known. The rate of increase will level off, of course, as this age group becomes more nearly saturated with high-school graduates and as the proportion of college graduates in the age group rises. Educational attainments and potentials are discussed in detail in the following section of this chanter.

A striking similarity in the rate of increase of both non-agricultural employment and science manpower is shown in Figure 3. This similarity indicates that a decrease in the agricultural employment is occurring at about the same rate as the increase in science manpower, and it suggests the hypothesis of a direct relationship involving trade-offs of scientific and technological advance for agricultural manpower. However interesting, an investigation of this hypothesis is beyond the scope of the present study.

Generally, Figure 3 shows what we already know about the national population: (1) It is increasing steadily, but the widespread use of birth control techniques has reduced the rate of increase below that expected as recently as ten years ago; (2) The labor force continues to comprise a relatively constant proportion of the total population, although within the labor force the proportion of females is increasing; (3) The educational attainment of the population has markedly increased over the past decade, but the rate will level off somewhat in the post-1980 decade.

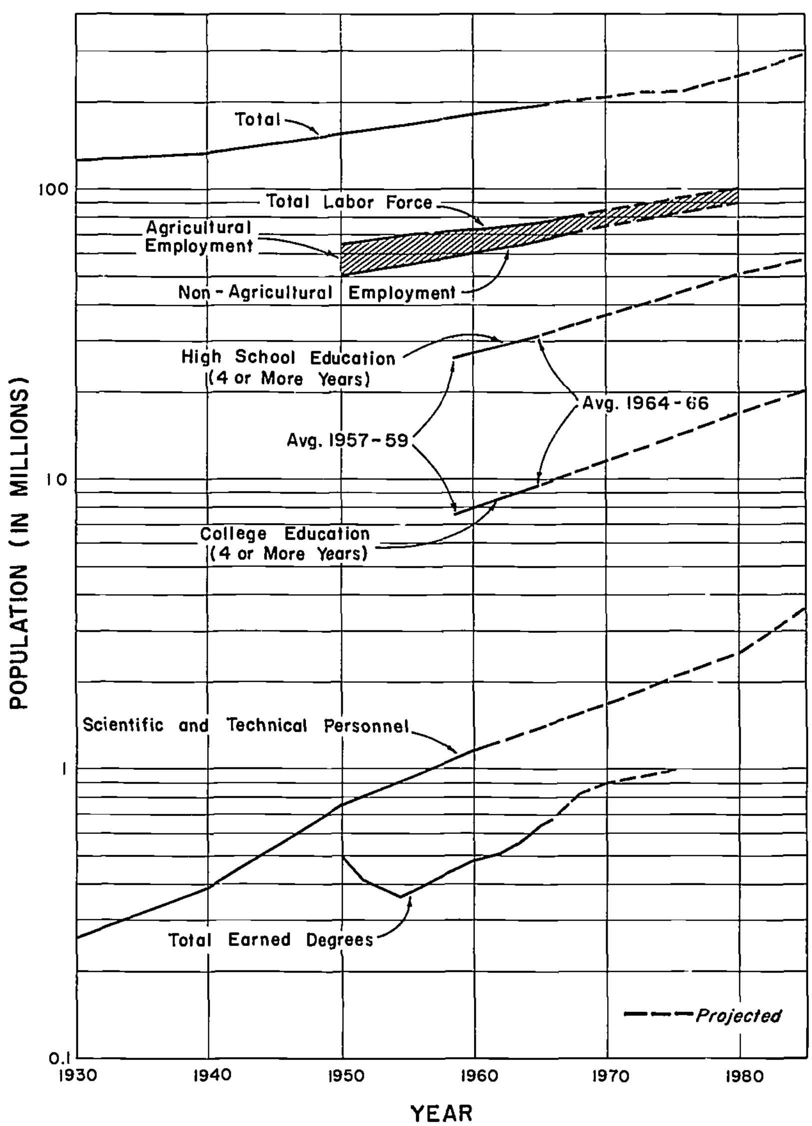
The data also show some population characteristics that are not generally recognized, but which relate specifically to scientific manpower. The growth of science manpower is faster than that of the total population, faster than the increase in educational attainment, and faster than the projected increase in total degrees conferred. Although a desirable ratio to be maintained between total population and science manpower or between labor force and science manpower is not known, the growth of science manpower is known to ultimately be a function of educational attainment in the population. And even this knowledge embodies the false assumption that some well-established ratio of science degrees to total degrees will be maintained into the future. We will return to this topic and its ramifications in the following chapter.

EDUCATIONAL LEVELS AND POTENTIALS

The supply of highly-trained manpower at any given time is a function of: the college enrollments at some earlier time; the educational attainment of the population; the size of the civilian labor force; the total population; the age and sex ratios of the total population; and the intellectual and socio-economic attraction of occupations that require high levels of training.

Wallace R. Brode made an excellent study of biological limitations on the potential supply of science manpower that is used as a model for this discussion of educational attainment and potential [1964, pp. 313-24]. He presented logarithmically-plotted data on the production of college graduates and its projected growth (Figure 4) which demonstrate that the college-age population in the late 1800's and early 1900's was so much more than the annual number of college graduates that population changes had little effect on the number of graduates. From 1920 to 1960, however, the nearly static size of the 18-21 yr group, with a gain in the number of college graduates, has led to a nearly saturated condition in which population fluctuations are reflected in college enrollments and graduations. Thus, while the number of college graduates increases, the rate of increase into the total college-age population is leveling off and paralleling the rate of population growth. Brode terms this "a ceiling of maximum utilization" [1964, p. 313].

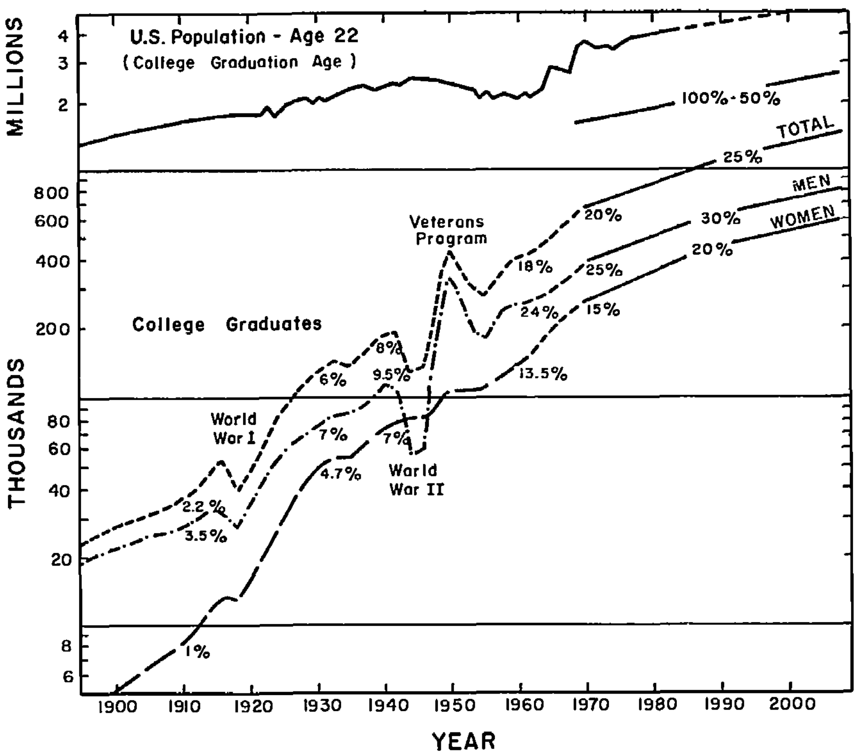
That such a ceiling should exist is difficult to deny, however fondly we wish for unlimited supplies of manpower (any kind) or dream of a country in which all persons have a college degree. (Important differences still exist between white and non-white educational opportunity



SELECTED CHARACTERISTICS
UNITED STATES POPULATION

Sources: Bureau of the Census
and Department of Labor

FIG. 3



Note: The percentages refer to the total in the category, for instance: 20% in the "women" line means 20% of all women in the age group graduated from college.

COLLEGE-AGE POPULATION AND GRADUATES

UNITED STATES 1895 – 2010

After Brade, 1964

FIG. 4

and attainment.) We are now graduating 76 percent of the relevant age group from high school. About 46 percent (in 1965-66) of the age group is admitted to college; about 20 percent receive a four-year degree (Table 1).

TABLE 1

ENROLLMENT IN INSTITUTIONS OF HIGHER EDUCATION AND BACHELORS AND FIRST PROFESSIONAL DEGREES CONFERRED COMPARED WITH POPULATION AGED 18-21, UNITED STATES, FALL 1946 TO FALL 1966, WITH ESTIMATES AND PROJECTIONS FOR SELECTED YEARS TO 1976

Years	A Population Aged 18-21	B Enrollment	C Bachelors and First Professional Degrees Conferred	Col B ÷ Col A (%)	[Col C ÷ Col A 4 yrs earlier] x 4 (%)
1946	9,403,000	2,078,095	136,174	22.1	
1947	9,276,000	2,238,226	n.a.	25.2	
1948	9,144,000	2,403,396	271,019	26.3	
1949	8,990,000	2,444,900	366,698	27.2	
1950	8,945,000	2,281,298	432,058	25.5	18.4
1951	8,742,000	2,101,962	384,352	24.0	16.4
1952	8,542,000	2,134,242	329,986	25.0	14.4
1953	8,441,000	2,231,054	304,587	26.4	13.2
1954	8,437,000	2,446,693	290,825	29.0	12.8
1955	8,508,000	2,653,034	287,401	31.2	13.2
1956	8,701,000	2,918,212	308,812	33.5	14.5
1957	8,844,000	3,036,938	340,347	34.3	16.1
1958	8,959,000	3,226,038	362,554	36.0	17.2
1959	9,182,000	3,364,861	385,151	36.6	18.1
1960	9,550,000	3,582,726	392,440	37.5	18.0
1961	10,252,000	3,860,643	401,700	37.7	18.2
1962	10,761,000	4,174,936	417,846	38.8	18.7
1963	11,154,000	4,494,626	450,600	40.3	19.6
1964	11,319,000	4,950,173	498,654	43.7	20.9
1965	12,119,000	5,526,325	535,031	45.6	20.9
1966	12,888,000e	5,885,000	551,040	45.7	20.5
1967	13,632,000e	6,348,000	594,862	46.6	21.3
1968	13,628,000e	6,739,000e	678,000e	49.4	--
1970	14,411,000p	7,296,000e	736,000e	50.6	--
1971	14,761,000p	7,627,000e	779,000e	51.7	22.8
1975	16,236,000p	9,088,000e	860,000e	56.0	23.3
1976	17,071,000p	9,841,000e	930,000e	60.0	--
1977			961,000e		--
1978			993,000e		--
1979			1,026,000e		25.3
1980			1,060,000e		24.8

e - estimate
p - projection

Source: U.S. Office of Education and U.S. Bureau of the Census

Where males are concerned, it is apparent that we are at or near our ceiling of capability. The Jaffee and Adams data indicate that the proportion of males entering college has hovered around 50 percent of the age group since the 1880's, with the exceptions of the World War II decline and the off-setting postwar increase, both of which were temporary [1965, p. 29]. Similarly, the proportion of females in the age group that entered college has remained near 40 percent since the 1880's.

Any proposed expansion of college enrollments in the hope of finding a few "late bloomers" or a new realm of untapped ability will have to take into account the fact that, in terms of ability, 80 percent of the students in the top quartile and 54 percent of those in the second quartile entered college in 1960 [Turnbull, 1968, pp. 5-10]. These percentages represent significant increases in these quartiles, up from 48 and 38 percent respectively in 1953. Yet, over the same time period, the percentage of the third quartile of ability going on to college remained at 32 percent; the percentage of the fourth quartile dropped one percent, from 20 to 19. Again, this does not mean that fewer people are enrolling in and completing four years of college. It does mean, however, that future increases in the number of enrollees and graduates will probably come about through sheer population increases rather than through the tapping of some reserve of talent hidden in the population.

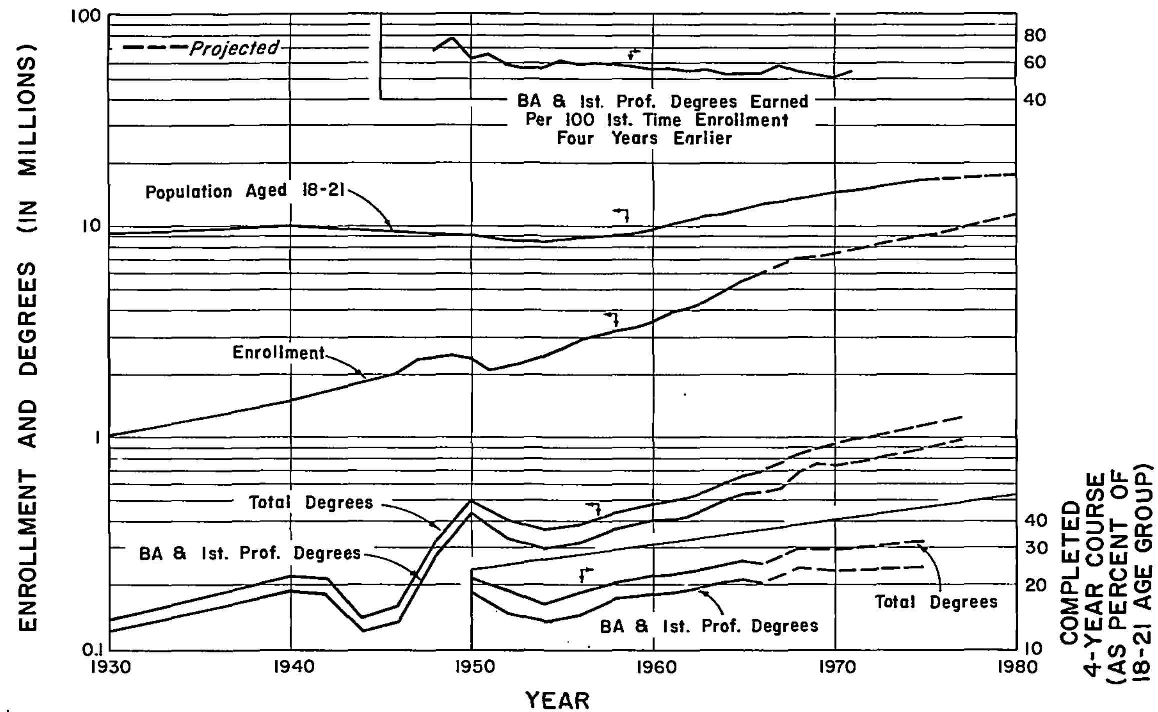
Other evidence for our having reached an apparent ceiling appears in Table 2 and Figure 5, which demonstrate a steady increase in the proportion of the population group aged 18-21 enrolling in college, with, however, the proportion receiving either bachelors or first professional degrees having increased less rapidly and steadily. Furthermore, the proportion of first-time college enrollees receiving bachelors or first professional degrees four years later has dropped from 60 percent in the early 1950's to nearly 50 percent. It is expected to remain at this level during the mid 70's. Part of this drop is due to: the increasing number of persons enrolling in two-year colleges and programs; the social status accorded those who have "attended" college; and increasing acceptance of the idea that the opportunity for a college education should be extended to all who desire it. Each of these factors has its effect to a different degree, but we cannot overlook this strong possibility: that college and university educational programs, in not being so effective as they might be, thus help the lowering of the retention rate.

TABLE 2

BACHELORS AND FIRST PROFESSIONAL DEGREES
AS A PERCENT OF FIRST-TIME ENROLLMENT
FOUR YEARS EARLIER, 1950-1980

Year	First-Time Enrollment	Year	Degrees Conferred	%
1946	696,419	1950	432,058	62.0
1947	492,846	1951	384,352	64.8
1948	567,191	1952	329,986	58.2
1949	554,608	1953	304,587	54.9
1950	512,427	1954	290,825	56.7
1951	467,999	1955	287,401	61.4
1952	532,310	1956	308,812	58.0
1953	565,969	1957	340,347	60.1
1954	624,910	1958	362,554	58.0
1955	668,064	1959	385,151	57.7
1956	714,966	1960	392,440	54.9
1957	721,547	1961	401,784	55.7
1958	772,292	1962	417,846	54.1
1959	818,280	1963	450,600	53.1
1960	923,069	1964	498,654	54.0
1961	1,018,361	1965	535,031	52.5
1962	1,030,554	1966	551,040	53.5
1963	1,046,417	1967	594,862	56.8
		Projections		
1964	1,224,840	1968	678,000	55.3
1965	1,441,822	1969	739,000	51.2
1966	1,378,000	1970	736,000	53.4
1967	1,439,000	1971	750,000	52.1
1968	1,496,000	1972	779,000	52.1
1969	1,567,000	1973	816,000	52.1
1970	1,651,000	1974	856,000	51.8
1971	1,731,000	1975	894,000	51.6
1972	1,807,000	1976	930,000	51.5
1973	1,872,000	1977	961,000	51.3
1974	1,941,000	1978	993,000	51.2
1975	2,004,000	1979	1,026,000	51.2
1976	2,040,000	1980	1,060,000	51.7

Sources: Earned Degrees Conferred for 1958-1967, Simon and Fullam, Projections of Educational Statistics to 1976-77, and independent projections.



COLLEGE-AGE POPULATION
ENROLLMENT AND EARNED DEGREES
1930-1980

Sources: Bureau of the Census and U.S. Office of Education

FIG. 5

Such conclusions are supported by Jaffee and Adams for persons graduating from college [1965, p. 30]. On an overall basis, they concluded that about half, or a little more than half, the white men who began college between 1875 and 1950 eventually completed four years. About 40 percent of the nonwhite men and nonwhite and white women who entered college finished four years. Interestingly enough, their data show a leveling off of the curves for women and a downward turn of the curves for men in the last half of the 1940-1950 decade; in the latter case, this may represent the lag due to World War II mentioned earlier.

With respect to future enrollment in four-year colleges and universities, Jaffee and Adams state that "there is no indication in any of the historical data . . . nor in the attitudes of the students and their parents, that many more than 5 in 10 of the white male high school graduates and 4 in 10 of all the other high school graduates will enter four-year higher institutions" [1965, pp. 30-31].

Little supporting evidence can be found for the belief that an increase in financial aid to education significantly increases the proportion of persons entering college and receiving four-year degrees, although numerically, of course, many more people do enter college. Indeed, these data make it appear even more imperative that national policy be formulated on a wider base of information--at least on a basis that takes into consideration the apparent limits of the base population and the inter-mission and intra-mission competition for highly-trained manpower. Brode [1964, p. 315] has summarized these ideas quite well: "As we near the maximum utilization limits, our greatest effort should be turned toward improved quality, improved teaching methods, better utilization of our trained product, and a rational system of priority allocation of valuable personnel." How these efforts are to be carried out is another question--a question that must be answered if the scientific and technological abilities of the nation are to be directed toward the more prosaic national goals as well as those exhibiting large amounts of glamour. These types of fundamental decisions are the determinants of science manpower demand--the topic of Chapter V.

SUPPLY OF SCIENTIFIC MANPOWER

Using the preceding sections of this chapter as background, we can now project the supply of science manpower for future time periods. Although projections have been prepared by the Department of Labor and the National Science Foundation for 1960 through 1975, an independent projection with a broader interpretation of science manpower was prepared for this study (Table 3).

The two projections differ fundamentally in their interpretation of "science." The USDL projections include only the physical and biological sciences and mathematics; the independent projections, based on Office of Education statistics, include mathematics and statistics, engineering, physical sciences, biological sciences, agriculture and forestry, health professions, and general science in the category of "Natural Sciences and Related Professions" and also include data for the social sciences. Rosenthal's projection technique [1966, pp. 1262-66], developed for NSF, was applied to the Office of Education earned degree projections for the years to 1977 and to independent earned degree projections, based on the Office of Education series, for 1977 to 1980 [Simon and Fullam, 1968, pp. 34-39].

To these base data were applied the NSF and USDL estimates of graduates entering their field of training [National Science Foundation, 1964, pp. 150-51; Rosenthal, 1966, p. 1265] and USDL estimates of death, retirement, and transfer rates for scientists and engineers [Rosenthal, 1966, p. 1266]. Entrants into the science manpower pool, other than new graduates, increased from the 1950-1963 average (20,000 per year into engineering and 4,000 per year into science) at the rate of 4 percent per year--the growth rate for professional and technical manpower [Rosenthal, 1966, p. 1265]. Doctorate recipients were not considered new entrants on the basis of Rosenthal's evidence that "a majority of new Ph.D. holders are not new entrants" [Rosenthal, 1966, p. 1264].

TABLE 3

ACTUAL AND PROJECTED SUPPLY OF SCIENCE MANPOWER
1960-1980

Year	USOL			Independent				
	Science Manpower	Engineers	Scientists	Science Manpower	Engineers	Scientists	Natural Scientists	Social Scientists
1960	1,157,000[a]	822,000[a]	335,300[a]	1,245,000[c]	822,000[a]	473,000[d]	335,700	137,300
1961	--	--	--	1,336,700	834,800	501,900	354,900	147,000
1962	--	--	--	1,392,300	865,500	526,800	371,000	155,800
1963	1,271,700[b]	924,900[b]	346,800[b]	1,457,300	896,200	561,100	394,600	166,500
1964	1,311,100	949,600	361,500	1,521,500	929,200	592,300	413,900	178,400
1965	1,354,600	976,100	378,500	1,491,400	964,400	627,000	436,300	190,700
1966	1,403,400	1,006,600	396,800	1,663,100	1,000,100	663,000	458,800	204,200
1967	1,451,200	1,035,800	415,400	1,739,900	1,038,000	701,900	481,700	220,200
1968	1,495,000	1,059,200	435,800	1,829,000	1,080,900	748,100	509,900	238,200
1969	1,554,400	1,093,700	460,800	1,927,100	1,127,200	799,900	542,900	257,000
1970	1,625,900	1,134,500	491,400	2,029,800	1,175,300	854,500	577,600	276,900
1971	1,696,400	1,174,300	522,100	2,137,200	1,225,500	911,700	614,200	297,500
1972	1,767,500	1,213,900	553,600	2,247,400	1,276,500	970,900	651,700	319,200
1973	1,837,900	1,252,700	585,200	2,316,700	1,328,800	1,032,900	692,800	340,100
1974	1,910,600	1,242,300	618,300	2,481,500	1,383,000	1,098,500	735,900	362,600
1975	1,987,000	1,333,400	653,600	2,607,100	1,439,400	1,167,700	781,200	386,500
1976	--	--	--	2,731,400	1,497,900	1,233,500	821,700	411,800
1977	--	--	--	2,869,000	1,558,700	1,310,300	871,100	439,200
1978	--	--	--	3,007,200	1,619,600	1,387,600	922,000	465,600
1979	--	--	--	3,152,000	1,683,900	1,468,100	974,800	493,300
1980	--	--	--	3,302,200	1,750,500	1,551,700	1,030,000	521,700

[a]H. V. Stambler, "Scientists and Engineers, 1960-1970; Supply and Demand," Monthly Labor Review, v. 86 (November 1963), 1275.

[b]Neal Rosenthal, "Projections of Manpower Supply in a Single Discipline," Monthly Labor Review, v. 89 (November 1966), 1266.

[c]Base figure of 1,295,000 from National Science Foundation, Profiles of Manpower in Science and Technology (NSF 63-23), Washington: Government Printing Office, 1963.

[d]This figure for scientists includes physical and biological scientists, mathematicians, and social scientists.

The factors employed in the projection technique are:

1. Death and Retirement Rates: Engineers, 1.5% per year; Scientists, 2.5% per year
2. Transfer Rates: Engineers, 1.5% per year; Scientists, 2.5% per year
3. New Graduates Entering Degree Field: Engineering--bachelors, 80%, masters, 85%; Natural Sciences--bachelors, 25%, masters, 50%; Social Sciences--bachelors, 15%, masters, 35% (As used here, "bachelors" refers to the "bachelors and first professional degree" category.)

After these factors have been applied to the base data for each year, the projection technique consists simply of subtracting the deaths, retirements, and transfers from the supply for the preceding year and adding on the new graduates and other entrants to obtain the supply for the current year.

For engineers, the two projections vary more than expected, even though the same projection technique was used. However, the independent projections make use of more recent Office of Education data. Also, because the 1980 college graduates are now enrolled in elementary school, the independent projections based on the Office of Education series should be fairly accurate.

The supply of science manpower should reach 2,607,000 in 1975 under the assumptions employed here, and by 1980, 3,302,000. The question to be answered now, of course, is: How do these projections compare with the potential demand in 1975 and 1980?

CHAPTER V

THE POTENTIAL DEMAND FOR HIGHLY-TRAINED MANPOWER

EFFECT OF POLICY DECISIONS

Both long- and short-term factors affect the potential demand for highly trained manpower. Many can be traced ultimately to national policy decisions. Even further beneath the surface is the lay assumption that science and technology are able to solve any problem--given enough money and time. From such a viewpoint, the amount of money allocated to a problem establishes the priority of its solution, and thus, its relative demand for science manpower.

National defense, economic growth, environmental problems, such as air and water pollution, and social problems, such as urban unrest and blight, are assumed by contemporary Americans to depend primarily on the effective use and the imaginative powers of scientists. At the same time, however, continued technological progress must depend on the same scientists for creative "basic" research.

About 40 percent of all scientists are engaged in research and development. Because the federal government finances about two-thirds of these activities, its policy decisions directly affect the demand for science manpower. The indirect import of policy decisions on the manpower needs of suppliers and subcontractors for research and development projects is recognized here, but there is no measurable data. Industry-financed research, development, and production, university research and teaching, and other activities contribute further to the demand for science manpower. These factors can be estimated with reasonable accuracy if our assumptions are correct. What cannot be estimated are the pace and direction of scientific and technological progress (which is highly uncertain in itself) and the equally uncertain sequences of events that may be generated by a scientific breakthrough or a technological innovation.

ESTIMATES OF FUTURE DEMAND

The growth of the professional and technical occupational category, of which science manpower is a part, has been given substantial emphasis in the last four annual manpower reports of the President that were prepared by the U.S. Department of Labor [1966-1969]. These reports projected a 25 percent increase in this occupational category from 1965 through 1970. This increase is about twice the projected rate of increase for all other occupational categories [1966, p. 44]. Further, the USDL estimates that for 1975 the professional and technical category will be about 13 million--a 40-percent increase over the 1966 level [1967, p. 166]. Of course, within this broad category (9.3 million in 1966) will be differential rates of growth for each sub-category. Some will exceed 40 percent; some will be less.

In 1959, science manpower comprised about 15 percent of the professional and technical category. This proportion is expected to increase to 20 percent by 1970 [National Science Foundation, 1965, p. 4]. Extrapolating this rate beyond 1970 is one means of projecting the demand for science manpower. The NSF projections, extrapolated to 1980, indicate a demand for 3.6 million scientific and technical personnel for that year.

Another way of estimating the future demand for science manpower is to extrapolate the ratios of science employment to total employment. Colm and Lecht have estimated these ratios to be 2.8 percent for 1970 and 3.0 percent for 1975. Carrying this rate of increase on to 1980 yields a ratio of 3.2 percent [1964, p. 76]. The corresponding science manpower figures for these ratios are: 2.35 million (1970); 2.76 million (1975); and 3.20 million (1980). These projections are somewhat less than those obtained from the extrapolation of the NSF data and those obtained in the "comprehensive" approach discussed below. The difference may be attributed to the rapidly increasing share of total employment in the professional and technical category, an increase not reflected in the total employment figure.

Extrapolation of past trends is, of course, only one approach to the projection of manpower demand. If the relationships of the historical base period and the assumptions hold into the future, this method is as sound as any other. Because the conditions rarely hold, a more satisfactory method developed by the Bureau of Labor Statistics has been applied by the National Science Foundation to the demand for science manpower. The projections were made in "the context of a comprehensive evaluation of the Nation's manpower needs in all fields of work by occupation-by-industry projections [1965, p. 2]. The advantage of this method is that competing manpower demands are recognized and reconciled in terms of the potential labor force and its educational ability.

For science manpower, the demand at some future date is not controlled simply by inter-industry relationships. Because so many scientific personnel receive their financial support, either directly or indirectly, from the federal government, national policy decisions strongly affect the demand for science manpower. This point, made earlier in this study, is appropriately repeated here. As national policy decisions emphasize certain mission orientations, the demand for science manpower shifts accordingly. Thus, it would appear that projecting the demand for science manpower requires determining the future national policy. This task has been attempted by the President's Committee on America's Goals and Resources in its goals project with the National Planning Association [Lecht, 1966]. The work of this committee is now being used by the USDL as a guide for projecting the manpower demand by occupational categories. It may be argued that this approach measures manpower need rather than manpower demand, but, with the government figuring so largely in the demand, it is the only realistic approach. Given that the goals truly reflect needs, we may assume that national policymakers will be influenced by them and will emphasize the necessity and desirability of meeting the goals in the course of their deliberations. Thus, need will be translated into demand.

The 20-percent science component of professional and technical manpower discussed above, if applied to the 1975 requirements for professional and technical manpower, would indicate a demand for 3.16 million scientific and technical personnel. This figure compares well with the earlier extrapolation of the NSF projections (3.6 million by 1980) that indicates 3.12 million by 1977.

PROJECTIONS BY GOVERNMENT AGENCIES

Several projections of science manpower demand, summarized in Table 4, have a common, immediately obvious problem--the wide range of numbers projected for 1970 and 1975. The differences between the highest and lowest totals amount to about 500,000 and 1 million respectively. There is also some variation in the definition of science manpower, but not enough to explain such large differences. The inconsistency of these projections, the exclusion of social scientists, and other factors hastened the decision to compute an independent series of science manpower demand projections.

TABLE 4

ACTUAL AND PROJECTED DEMAND
FOR
SCIENCE MANPOWER[a]
1960-1980

Year	Total	Engineers	Scientists	Sources
1960	1,157,000	822,000	335,300	[Stambler, 1963, p. 1275]
1961	- - -	- - -	- - -	
1962	- - -	- - -	- - -	
1963	1,360,000	950,000	410,000	[National Science Foundation, 1964, p. 14]
	1,271,700	924,900	346,800	[Rosenthal, 1966, p. 1263]
1964	- - -	- - -	- - -	
1965	1,352,510	974,845	377,665	[EMC, 1964]
1966	1,400,000	1,000,000	400,000	[U.S. Department of Labor, 1967, p. 173]
1967	- - -	- - -	- - -	
1968	1,477,368	1,066,410	410,958	[EMC, 1964]
1969	- - -	- - -	- - -	
1970	1,854,000	1,313,400	541,200	[Colm & Lecht, 1964]
	2,121,900	1,458,800	633,100	[Colm & Lecht, 1964]
	2,350,000	1,669,000	681,000	2.8% of total employment
	1,954,000	1,375,000	580,000	[Stambler, 1963, p. 1275]
	2,032,000	1,484,000	548,000	[National Science Foundation, 1965, p. 48]
1971	- - -	- - -	- - -	
1972	- - -	- - -	- - -	
1973	1,631,588	1,167,223	464,365	[EMC, 1964]
1974	- - -	- - -	- - -	
1975	2,150,000	1,500,000	650,000	[U.S. Department of Labor, 1967, p. 173]
	2,254,200	1,601,300	652,900	[Colm & Lecht, 1964]
	2,591,800	1,803,100	788,700	[Colm & Lecht, 1964]
	2,760,000	1,960,700	799,300	3.0% of total employment
	3,160,000	2,244,900	915,100	20% of P&T employment for goals
1976				
1977				
1978				
1979				
1980	3,200,000	2,273,300	926,700	3.2% of total employment
	3,600,000	2,557,400	1,042,600	Extrapolation of NSF P&T at 20% of P&T

[a]Definitions of Science Manpower:

Stambler--Chemists, Physicists, Metallurgists, Geologists, Geophysicists, Mathematicians, Medical Scientists, Agricultural Scientists, Biological Scientists, Other Scientists (not defined).
NSF Scientific and Technical Manpower Resources--Physical Scientists, Life Scientists, Mathematicians.
Rosenthal--Physical Scientists, Life Scientists, Mathematicians.
Engineering Manpower Commission (EMC)--Physical Scientists.
Manpower Report of the President, 1967--Natural Scientists.
Colm & Lecht--Natural Scientists.
NSF Long Range Demand--Natural Scientists.

INDEPENDENT PROJECTION

The independent projection (Table 5), based on the projections summarized in Table 4, includes social scientists, intuitive perceptions of shifting demand patterns, and different growth rates. Social scientists, previously mentioned in connection with the manpower supply projections, have been included here for the same reasons. The intuitive perception of shifts in patterns of demand relates largely to engineers and social scientists. The summaries in Table 4 share at least one common aspect. The proportion of engineers varies within a small range (68.7 to 73.1 percent), with an average of 71 percent. There is no apparent reason for holding this ratio constant through time and, in light of the changing emphasis in scientific activities from the piecemeal to the holistic approach and the increasing recognition that engineers do not make very good social scientists, there are some good reasons to let this proportion vary. Thus, in the independent projections the proportion of engineers was permitted to drop in even steps from

63.4 percent (71 percent of engineers and natural scientists) in 1960 to 58 percent in 1970 and 53 percent in 1980. The proportion of natural scientists was increased only slightly, from 26 to 29 to 31 percent for the respective years. The proportion of social scientists was expanded from 10.6 to 16 percent over the projection period. These proportions should be much more realistic, even though they are based on the projected composition of the science manpower supply for these years.

TABLE 5

SCIENCE-MANPOWER DEMAND
1960-1980
(Independent Projection)

Year	Science Manpower	Engineers	Natural Scientists	Social Scientists
1960	1,295,000	822,000	335,700	137,300
1970	2,274,100	1,316,700	662,600	294,700
1980	3,511,600	1,861,500	1,095,300	554,800
		Growth Rate		
1960-1970	75.60%	60.17%	97.50%	114.65%
1970-1980	54.40%	41.36%	63.35%	88.26%

Note: Due to rounding off, totals may not agree with breakdown.

The growth rates, also based on inspection of the other projections, have been modified where appropriate. Varying rates were used for the total science manpower and its separate components--engineers, natural scientists, and social scientists. These rates were altered for each decade of the projection period. Compared to the previous projections, the independently-derived rates differ, both in the size of the 1960-1970 rate and in the proportionate reduction used to obtain the 1970-1980 rate. Also, the other projections gave no attention to social science manpower, but the growth rate projected here does not appear to be out of line with current demand patterns. The 1970-1980 rates for the independent projection are about two-thirds of the 1960-1970 values rather than the one-third used in the other projections.

SOURCES AND COMPONENTS OF DEMAND

The demand components and their sources are summarized in Table 6. The death-retirement-transfer components, although substantially larger than Stambler's estimates for 1960-1970 [Stambler, 1963, p. 1275], may be considered to be more correct, because they are based on the values calculated for the supply projection and on factors derived by Stambler and Rosenthal in their Bureau of Labor Statistics studies. (See p. 21)

From this table, it appears that the demand for science manpower will slightly exceed 3.5 million in 1980. This is a net value that includes replacements for death, retirement, and transfer losses.

The independent projections of supply and demand are compared in Table 7. For the most part, the pattern, as expected, exhibits significant lags in supply through 1970 except in the social sciences, where the shortage amounts to roughly 10 to 15 percent. In the 1970-1980 period, the lags are smaller--about 10 percent for engineering and 7-8 percent for the social sciences. For the natural sciences a small surplus in supply of about 5 percent is shown.

These projections indicate the science manpower that will be needed to maintain the status quo of national research and development programs and expenditures. Any attempt to meet the goals outlined by the Presidential Commission would require an additional 15 percent.

TABLE 6

CHANGES IN SCIENCE-MANPOWER DEMAND
1960-1980
(Independent Projection)

Occupational Category	Growth Demand		Death, Retirement, and Transfer		Total Demand	
	1960-1970	Yearly Average	1960-1970	Yearly Average	1960-1970	Yearly Average
Science Manpower	475,200	47,500	503,900	50,400	979,100	97,900
Engineers	207,600	20,800	287,100	28,700	494,700	49,500
Natural Scientists	175,400	17,600	151,900	15,200	327,300	32,700
Social Scientists	92,500	9,200	64,900	6,500	157,400	15,700
	1970-1980	Yearly Average	1970-1980	Yearly Average	1970-1980	Yearly Average
Science Manpower	410,500	41,000	827,000	82,700	1,237,500	123,700
Engineers	218,100	21,800	426,700	42,700	644,800	64,500
Natural Scientists	161,300	16,100	271,400	27,100	432,700	43,300
Social Scientists	131,200	13,100	128,900	12,900	260,100	26,000

Note: Due to rounding off, totals may not agree with breakdowns.

TABLE 7

CHANGES IN SCIENCE-MANPOWER SUPPLY AND DEMAND
1960-1980
(Independent Projection)

Occupational Category	Supply Increase	Demand Increase	Deficit	Surplus
		1960-1970		
Science Manpower	734,800	979,100	244,300	
Engineers	353,300	494,700	141,400	
Natural Scientists	241,900	327,300	85,400	
Social Scientists	139,600	157,400	17,800	
		1970-1980		
Science Manpower	1,272,400	1,237,500		34,900
Engineers	575,200	644,800	69,600	
Natural Scientists	452,400	432,700		19,700
Social Scientists	244,800	260,100	15,300	

Note: Due to rounding off, totals may not agree with breakdowns.

CHAPTER VI

ACADEMIC DISCIPLINES AND SKILL LEVELS NEEDED IN WATER-RESOURCES MANPOWER

SOURCES OF INFORMATION

As a mission-oriented program, water-resources research and related activities draw on a number of academic disciplines for personnel. Within these disciplines, skill and training levels vary from the bachelor's degree to the doctorate. Additional needed technical and supportive skills may be of non-degree levels. Any attempt to project or analyze the supply of and demand for water resources personnel is hampered at the outset by a lack of information on the existing quantity, quality, and other characteristics. It is felt, however, that the major required academic disciplines have been identified from the annual reports of the Office of Water Resources Research, the 1966 Membership Roster of the American Water Resources Association, and other sources.

Water resources-related personnel are much more difficult to identify. The present analysis is based on the 1968 staffing pattern of the California Department of Water Resources (generally conceded to be the best staffed state water resource department) in conjunction with a list of professional and technical personnel employed by the U.S. Department of the Interior during 1966.

All this information provides four different levels of insight into water resources manpower requirements. The OWRR data reflect the leading edge of water resources research--new fields and new areas of work that will shape the future manpower requirements. The AWRA roster includes not only many research professionals, but also the established practitioners in the field. The California data show what technical and supporting personnel are necessary for operating a state water resources department that serves as a model for the other states. The reports of the Department of the Interior, a broad-reaching collector agency, substantiate the other information.

OFFICE OF WATER RESOURCES RESEARCH

In each of its annual reports, the Office of Water Resources Research presents tabular data on: the numbers and academic disciplines of the principal investigators supported through the cooperative water resource research center program; the numbers and major fields of undergraduate and graduate students supported as research assistants; the numbers and disciplines of new faculty members added (presumably these are teachers relevant to water resources research); and the numbers and fields of new water-related courses. These data have been summarized in Table 8 for the years 1966 through 1968.

Any discipline averaging one percent or more in any one of the above four categories is listed separately. Thirty-one fields provide at least 95 percent coverage of the four categories. The percentages in the "other fields" segment, which includes forty-eight fields comprising 5 percent or less of the total for each category, are inflated because of undergraduates who switch fields to work as research assistants and by the method of reporting to the OWRR that may reflect joint departments or highly-specialized subfields. (The Office of Water Resources Research, understandably anxious to show that a wide variety of disciplines and fields is represented in its programs, will list the unusual field or subfield rather than the common one.)

TABLE B

DISCIPLINE COMPOSITION*
OF.ICE OF WATER RESOURCES RESEARCH
1966-1968
(Average Percent)

FIELD	PRINCIPAL INVESTIGATORS	STUDENTS	NEW FACULTY	NEW COURSES (WATER-RELATED)
Agriculture	--	1.43	--	--
Agronomy	2.22	1.60	2.03	3.18
Biology[a]	6.16	6.49	7.98	9.46
Botany	1.78	1.66	1.87	2.35
Chemistry	4.44	3.69	4.74	2.52
Earth Science	.18	.07	--	3.14
Ecology	1.14	1.27	2.03	3.45
Economics	8.23	6.10	7.59	4.04
Engineering	37.07	34.27	26.56	19.89
Fish & Wildlife	2.48	2.61	3.49	--
Forestry	1.57	2.63	2.03	1.37
Geography	1.47	.99	1.47	.39
Geology[b]	9.48	10.66	7.57	1.96
Hydrology	1.74	2.24	2.86	8.83
Law	2.84	1.80	1.69	1.89
Liberal Arts	--	1.15	--	--
Limnology	1.26	.35	1.20	2.32
Meteorology[c]	1.66	1.61	4.30	4.13
Oceanography	.23	.10	1.55	3.72
Physics	2.69	.87	3.02	1.16
Planning	.27	.26	.89	1.05
Political Science[d]	1.21	1.31	1.56	.62
Recreation	.46	.25	.34	1.70
Resources	--	.21	--	5.85
Sociology	.76	.68	1.09	.81
Soil Science	2.51	3.09	3.43	1.21
Statistics	.03	.14	.91	.22
Water Quality	--	--	--	1.94
Water Resources	.72	.21	1.36	1.83
Watershed Management	.14	.70	.12	1.95
Zoology	4.05	6.31	4.08	5.30
Subtotals	96.79	94.75	95.76	96.28
Others[e]	2.21	5.25	4.24	3.72
TOTAL	100.00	100.00	100.00	100.00

[a]Includes microbiology. [b]Includes stratigraphy, mineralogy, petrology, and seismology. [c]Includes climatology and atmospheric science.

[d]Includes government.

[e]"Others" includes: aerial photo interpretation, animal husbandry, anthropology, applied science, architecture (landscape), behavioral science, biostatistics, business administration, computer science, conservation, dental (pre-hygiene), education, electronics technology, ethology, fine arts, food science, geophysics, German, history, home economics, horticulture, industrial relations, instrument science and instrumentation, journalism, library science, marketing, materials science, mathematics, medicine, medical technology, mining, operations research, pharmacy, physiology, plant pathology, pre-medicine, pre-pharmacy, pre-veterinary medicine, public health, public relations, radiology, range management, sanitary science, taxonomy, textiles, toxicology, and veterinary science.

*Calculated from data in U.S. Dept. of the Interior [1966-1968].

Much of the work supported by the OWRR in this program is the vanguard of water resources research. Thus the data in Table 8 can be used, at least in part, as a basis for projecting manpower supply and demand patterns. For example: agriculture is represented only by students working as research assistants for principal investigators in other fields. New water-related faculty members or courses have not been added in agriculture. Hence the demand for water resources personnel with training in general agriculture can be expected to be virtually nil. On the other hand, "resources" shows no principal investigators, no new faculty, and only a small number of students. It does, however, show a large proportion of new courses. The logical conclusion is that experienced, broad-gauge experts in other fields, recognizing the need for persons trained in resource analysis, development, and management, have found it necessary to train these persons themselves. Thus, in a few years, we can reasonably expect to find some resources people among the principal investigators and new faculty members, as well as increases in the number of students in the "resources" field.

AMERICAN WATER RESOURCES ASSOCIATION

The American Water Resources Association membership includes research professionals, students, and practitioners engaged in water resource analysis, development, an. management. Only nine fields have at least one percent of the total membership (see Table 9). Because more than 26 percent of the members' fields were either not reported or not assigned to a specific discipline, the data are not suitably conclusive. Except for the fact that a large share of this "unknown" category consists of administrative personnel, we could assume that its percentage of fields would be about the same as in the known groups.

TABLE 9

DISCIPLINE COMPOSITION[a]
MEMBERSHIP ROSTER OF AMERICAN WATER RESOURCES ASSOCIATION
1966

Field	Percent of Total Membership
Chemistry	1.9
Engineering	40.1
Forestry	1.5
Geography	2.1
Geology[b]	11.0
Hydrology	5.8
Meteorology[c]	1.2
Soil Science	1.0
Water Resources Specialists	2.3
Subtotal	66.9
Other Fields[d]	2.8
Students	3.1
Unknown Fields	26.8
TOTAL	99.6*

[a]Calculated from Membership Directory, AWRA Water Resources Bulletin, 2, 37-62, Dec 1966.

[b]Includes engineering geology, geohydrology, and hydrogeology. [c]Includes climatology and hydrometeorology.

[d]Includes architecture, biology, economics, geophysics, horticulture, law, mathematics, planning, political science, recreation planning, and system programming.

*Due to rounding off, total is not exactly 100.00%.

CALIFORNIA DEPARTMENT OF WATER RESOURCES

The composition of the California Department of Water Resources (Table 10) is for the year 1968. In the opinion of the personnel services representative of that department, it represents an "average" staffing pattern [W. R. Atlee, personal communication, Department of Water Resources, State of California, August 13, 1968]. The table covers nearly 4,000 persons at professional and non-professional levels. To the extent permitted by the data, the positions have been grouped by function--administrative, supportive, and the like. Engineers were aggregated separately (about 20 percent of all employees were water resources engineers). This agency may, with certain reservations, be used as a guide for projecting the composition of national water resources manpower and related manpower requirements.

TABLE 10

STAFF COMPOSITION
CALIFORNIA DEPARTMENT OF WATER RESOURCES
1968

Occupation	Percent of Total Employees*
Accountants (all classes)	2.20
Administrative (all classes)	1.35
Construction Branch	10.28
Electronic Data Processing Group[a]	1.95
Engineering Aides	6.53
Engineers	30.33
Hydroelectric Plant Group	3.00
Land Group[b]	3.18
Maintenance Group[c]	6.88
Supportive Personnel[d]	20.25
Technicians[e]	11.45
Subtotal	97.40
Others[f]	3.37
TOTAL	100.77[g]

[a]Electronic data processing group includes: computer programmers, computer operators, EDP analysts, and operations research specialists.

[b]Land group includes: land surveyors, land agents, and land and water use analysts.

[c]Maintenance group includes: buildings and grounds, laborers, mobile equipment, water resource, and machinery repair.

[d]Supportive personnel includes: clerks (all classes), delineators, drafting and graphics, laboratory assistants and technicians, office machine operators, property clerks and inspectors, research writers, secretaries, and storekeepers.

[e]Technicians includes: communications technicians, control systems technicians, electrical engineering technicians, electrical and mechanical testing technicians, mechanical technicians, and water resource technicians.

[f]Others includes: architects, attorneys, biologists (water quality), chemists, dispatchers, drillers, economists, and specialists in geochemistry, instrumentation, photogrammetry, meteorology, precision electronics, recreation and wildlife research, seismology, soils radiology, statistics, and weed control.

[g]Due to rounding off, actual total is not exactly 100.00.

*Calculated from "Alpha Job Classifications Used by Department of Water Resources."

U. S. DEPARTMENT OF THE INTERIOR

As a broad-based resource management agency, the Department of the Interior may be classified somewhere between a research group and an operating agency. Its manpower requirements thus may be be the same as those of an agency focused solely on water resources. Yet, in several respects, the distribution by discipline of the professional and technical personnel (Table 11) parallels that of the other three data groups.

CONCLUSION

In comparing these four tables, it is interesting to note the similarity in the proportion of engineers: 30 percent in the California Water Resources Department; 40 percent in the AWRA; 42 percent in the Department of the Interior; and 37 and 34 percent respectively of the principal investigators and students in the OWRR cooperative research program. Consistent patterns probably exist for some of the other disciplines, but they are concealed by the nature of the data. Thus, the problem of estimating the disciplinary mix for future water-resources manpower supply and demand becomes one of intuition tempered by discernible trends and considered judgment. The mix has been estimated on a percentage basis. The derived percentages (Table 12) have been applied to the supply and demand totals computed in later chapters.

TABLE 11

PROFESSIONAL, SCIENTIFIC, AND TECHNICAL PERSONNEL
U.S. DEPARTMENT OF THE INTERIOR
OCTOBER 1966

Field	Percent of Total Employees
Physical Sciences	24.43
Chemistry	7.07
Geology	9.53
Hydrology	3.30
Mathematics and Statistics	0.62
Biological Sciences	26.81
Biology (General and Micro)	2.38
Agronomy	0.07
Soil Conservation	0.85
Soil Science	1.29
Botany	0.10
Forestry	4.65
Fish and Wildlife	11.71
Soil Sciences	3.17
Economics	1.62
Geography and Cartography	2.30
Geography	0.35
Engineering	42.16
Civil Engineering	21.97
Sanitary Engineering	2.05
Others[a]	1.12
TOTAL	100.61[b]

[a]Others includes: operations research (.047%), urban planning (.029%), and health personnel (.369%).

[b]Due to rounding off, total is not exactly 100.00.

TABLE 12

DISCIPLINE COMPONENTS OF WATER-RESOURCES MANPOWER DEMAND 1980

DISCIPLINE	PERCENTAGE OF MANPOWER DEMAND	
	TOTAL WATER RESOURCES	WATER-RESOURCES RESEARCH
Agronomy	1.7%	1.5%
Biology	4.5	5.6
Botany	0.6	1.5
Chemistry	1.7	3.6
Ecology	2.8	3.0
Economics	11.8	8.7
Engineering	28.2	28.7
Fish and Wildlife	1.7	1.5
Forestry	1.1	1.0
Geography	2.6	1.8
Geology	10.0	9.1
Hydrology	5.6	5.1
Law	3.5	2.0
Limnology	1.1	1.0
Meteorology	1.7	2.0
Physics	0.6	2.0
Planning	1.5	1.0
Political Science	0.6	1.5
Recreation	1.2	0.7
Sociology	0.6	1.0
Soil Science	1.1	1.0
Statistics	.6	0.5
Systems Analysis & Computer Applications	3.4	3.0
Water Quality	2.3	2.0
Water Resources	4.5	4.1
Watershed Management	3.4	3.0
Zoology	2.8	3.6
TOTALS	101.2*	99.5*

*Due to rounding off, actual total is not exactly 100.0.

CHAPTER VII

THE POTENTIAL SUPPLY OF WATER-RESOURCES MANPOWER

EXISTING SUPPLY

The current supply of water-resources personnel, even on an estimated basis, is not known at present. Thus, there exists no benchmark upon which projections of the potential supply can be based. The first item, then, is an estimation of the existing (1966) supply, and the second, the projection of the existing supply t 1980. Projections have been made according to occupation for total water-resources manpower and water-resources research manpower. An attempt will also be made to analyze the projected supply by disciplines.

The estimating of the existing supply of water-resources manpower involves broad assumptions about science personnel that may or may not be fully correct, but which are necessary for computations. As an example of these assumptions, the independent projections of science-manpower supply are accepted as correct not only in the final total, but also in the year-by-year and occupational bases.

The 1966 edition of "American Science Manpower" reported that 101,000 scientists out of 243,000 questionnaire respondents had received government support [National Science Foundation, 1967]. Government support had been given 11,000 scientists in the Natural Resources and Public Works program areas.

For computing the total of scientific personnel engaged in these two program areas, the number of respondents (11,000) was expanded in direct ratio to the 1966 supply calculated earlier. The computation yielded a total of 179,300 (107,900 engineers and 71,400 scientists). The latter figures, after being multiplied by the estimated percentages of national expenditures used for water-resources development and research (Table 13), yielded an estimated 1966 water-resource manpower total of 98,300, with 20,100 being engaged in water resources research. The latter number was substantiated by relating per-scientist research costs to the estimated 1966 water-resources research expenditures.

PROJECTED SUPPLY

The supply of water-resources personnel (the total and research only) was obtained in the same manner for the years 1970, 1975, and 1980 (Table 14) on the basis of the science manpower supply given by the independent projections (Chapter IV) and the discipline-component percentages (Table 12).

In Table 14, it is apparent that the supply of total water-resources manpower will have a net increase of 57 percent by 1980 and the supply of research personnel, 173 percent.

For the total supply, the supply of engineers will hold nearly steady after a drop of 3,300 by 1970. However, the number of natural scientists will be more than doubled by 1980; the supply of social scientists will be about 480 percent of the 1966 level.

For research personnel, the change is somewhat different, with a nearly 240 percent increase in the number of engineers and three-fold increases in the supply of natural and social scientists.

TABLE 13

EXPENOITURES FOR WATER RESOURCES
1962-1980

Year	Water-Resource Expenditures (in Relation to Total Natural Resources)	Water-Resources Research Expenditures (in Relation to Total Natural-Resources Research)
1962	63.25%	9.38%
1966[a]	54.80%	11.20%
1970	46.02%	13.02%
1975	44.44%	14.39%
1980[b]	42.86%	15.76%

[a]Interpolation of 1962 and 1970 figures.

[b]Projected at 1970-1975 growth rate.

Source: Leonard A. Lecht, Goals, Priorities, and Dollars: The Next Decade (New York: The Free Press, 1966), 248.

TABLE 14

SUPPLY OF WATER-RESOURCES MANPOWER
1966-1980

Year	Total	Engineers	Scientists	Natural Scientists	Social Scientists
			Total Water Resources		
1966	98,300	59,200	39,100	34,200	4,900
1970	101,700	55,900	45,800	40,800	5,000
1975	126,200	60,600	65,600	53,000	12,600
1980	154,100	61,600	92,500	69,300	23,200
			Water-Resources Research		
1966	20,100	7,000	13,100	10,100	3,000
1970	28,800	9,800	19,000	14,700	4,300
1975	40,900	13,100	27,800	21,300	6,500
1980	54,900	16,500	38,400	29,400	9,000

ANALYSIS OF SUPPLY BY ACADEMIC DISCIPLINES

As projections are dissected into smaller and smaller categories, the reliability decreases proportionately, at least. Nevertheless, a meaningful discussion of water-resources manpower requires such an attempt. The analysis by disciplines for the supply of total water resources and water-resources research manpower, projected for the 1966-1980 period, consisted simply of applying the probable disciplinary mix (Table 12) developed in Chapter VI to the net increase in supply.

For several disciplines, the projections are exceedingly optimistic. In some cases, meeting the projected supply of water resources personnel would require the entire projected 1966-1980 net increase in a given discipline. In other cases--ecology, for example--the net increase in supply is estimated at 1,900; however, projection of degrees granted by discipline indicates that the net increase in the number of ecologists will be on the order of 75 in the 1966-1980 period. Because several of the disciplines relevant to water resources, in addition to ecology--such as fish and wildlife management, geology, hydrology, limnology, planning, systems analysis and computer applications, water quality, water resources, and watershed management--exhibit similar supply patterns, the overall estimates of net increases in the supply of water-resources manpower may be as much as 10 to 15 percent high.

Water-resources research manpower was treated separately, but in an identical manner with the percentages developed in Chapter VI for research manpower (See Table 17, Chapter IX).

CHAPTER VIII

THE POTENTIAL DEMAND FOR WATER-RESOURCES MANPOWER

CURRENT DEMAND

Lacking concrete data on the current demand for water resources personnel, we must assume for this study that, in 1966, demand and supply were in equilibrium. Superficially, this assumption may appear patently false. However, the earlier discussion of demand and supply (Chapter III) provides the reasonable interpretation that although the need for water-resources personnel in 1966 may have exceeded the supply, the demand, as measured by willingness to pay, was being met. In any case, projections must be made from a stable benchmark, and because the assumption concerning the 1966 demand is the most reasonable one available, it is used here. If it is faulty, the future demand for water-resources manpower has probably been underestimated.

As in the preceding chapter on potential supply, the potential demand for water-resources manpower and water-resources research manpower will be projected by occupation to the year 1980. These future demands will then be broken down into academic disciplines.

PROJECTED DEMAND

The demand projections are based on existing relationships between water-resource research expenditures and the number of researchers supported. The Presidential Goals Commission foresaw $250 and $400 million (in 1962 dollars) being spent for water resources research in 1970 and 1975 respectively [Lecht, 1966, p. 243]. These amounts were based on a 20-percent annual increase in expenditures--double the rate of recent years. This same rate of increase, carried forward to 1980, yields a research expenditure goal of $645 million for that year.

In 1968, the Office of Water Resources Research spent $8.1 million to support the work of 965 principal investigators in its cooperative research program. The cost per researcher was about $8500 in 1968 dollars. Deflating this cost to 1962 values, for comparison with the earlier expenditure goals, gives about $6800 per investigator. The 1970, 1975, and 1980 research expenditure goals, divided by the cost per researcher (all amounts are in 1962 dollars) yield the following demands for water-resources researchers: 1970, 36,800; 1975, 58,800; and 1980, 94,900 (see Table 15).

The total demand for water-resources manpower (Table 15) was computed by multiplying the projected number of research workers by the ratio of total manpower to research manpower developed in the supply projections (Table 14).

The demand for supportive personnel--secretaries, aides, technicians--is estimated to be 3 times the number of water-resources professionals. This ratio approaches that of the California Department of Water Resources, as well as that of the OWRR-supported principal investigators, when the reported number of assistants is reduced to account for part-time workers. The supportive manpower requirement is estimated at 389,000 for 1970, 545,000 for 1975, and 800,000 for 1980. Of course, these estimates will vary proportionally with the actual supply of water-resources manpower.

TABLE 15

DEMAND FOR WATER-RESOURCES MANPOWER
1966-1980

Year	Total	Engineers	Scientists	Natural Scientists	Social Scientists
			Water Resources Manpower		
1966	98,300	59,200	39,100	34,200	4,900
1970	129,900	71,400	58,500	49,200	9,100
1975	181,700	87,200	94,500	76,300	18,200
1980	266,700	106,700	160,000	120,000	40,000
			Water Resources Research Manpower		
1966	20,100	7,000	13,100	10,100	3,000
1970	36,800	12,500	24,300	18,800	5,500
1975	58,800	18,800	40,000	30,600	9,400
1980	94,900	28,500	66,400	50,800	15,600

ANALYSIS OF DEMAND BY ACADEMIC DISCIPLINES

The same disclaimer concerning the analysis of water-resources manpower supply also applies to the analysis of demand: the smaller the projection base, the less accurate the projection. As in the case with supply, the breakdown by academic disciplines is made of the net increase in projected demands for total water-resources manpower and for water-resources research manpower. These increases were allocated to the several disciplines according to the component factors developed in Chapter VI (Table 12).

There are several disciplines for which water resources will constitute almost the entire net increase in demand during the projection period. For hydrology, as an example, the normal demand pattern indicates a net demand increase of 30 trained hydrologists. If water resources development and research are carried out at the proposed goals level, however, the demand for hydrologists will reach 9,400. Several other disciplines besides hydrology show similar demand patterns--agronomy, ecology, fish and wildlife management, limnology, meteorology, planning, soil science, systems analysis and computer applications, water quality, water resources, and watershed management. Nevertheless, it is felt that the demand projections for each discipline are statistically reliable.

CHAPTER IX

INTERRELATIONSHIPS OF MANPOWER SUPPLY AND DEMAND IN WATER RESOURCES

INTRODUCTION

Although a separate analysis of either the supply or demand patterns may be intrinsically interesting, our major objective is to discover their relationship in water-resources manpower, and secondarily, their relationship to science manpower. The outlook is still no brighter than it was at the beginning of this study, but at least we now have quantitative information for basing some opinions. To begin this chapter, we will examine the supply-demand relationships in water-resources manpower. Secondly, we will look at them in the larger context of science manpower. In Chapter X, we will conclude the study with recommendations for national policies that will increase both the supply and the effectiveness of water-resources manpower.

FUTURE DEFICITS IN WATER-RESOURCES MANPOWER

In Table 16, not one occupational category in water-resources manpower--engineers, natural scientists, or social scientists--shows a surplus of supply over demand throughout the 1970-1980 projection period. If the assumption is correct that the supply and demand actually were in equilibrium in 1966, the crux is yet to come. With the time for education and training considered, the crux is here already. At this late date, the diversion of 28,000 undergraduate and graduate students from their present educational course to meet the 1970 deficit is an impossibility. Especially is this true in light of the OWRR reports on career selection by students supported or assisted through the cooperative research program. Only about 50 percent of the graduating students choose a career in a water-related field [U.S. Dept. of the Interior, 1968, p. 82]. In other words, 56,000 students would have to be re-oriented to meet the 1970 deficit. Furthermore, the deficit does not level off; it doubles for each 5-year period to 1980. Thus it is almost hopeless that the manpower demands of 1975 can be met. But, if recognition of the problem is the first step toward its solution, we may begin now to establish policies and programs to help alleviate the projected deficits in the latter half of the 1970's.

CHANGES IN FUTURE DEFICITS

There are occupational differences in the demand patterns for resources manpower that might interest policy-makers in water resources agencies. Overall, the steepest growth rates in the deficits are in the natural sciences throughout the projection period and in the social sciences in the latter half of the period. The deficits for engineers, although important, do not increase nearly as rapidly as do those for the scientists. This pattern is particularly obvious for research manpower. Thus, it would appear that a conscious de-emphasis of engineering, accompanied by greater emphasis on the natural and social science contributions to water-resources development and research, might alleviate some of the manpower deficit later in the 1970 decade.

The solution to problems in water-resources development will require improved resource allocation and management, better institutional relationships, and hard work in similar areas.

By itself, water-resources engineering, because of its tendency toward structural solutions, often creates worse problems than it solves.

TABLE 16

DEFICITS IN WATER-RESOURCES MANPOWER
1966-1980

Year	Total	Engineers	Scientists	Natural Scientists	Social Scientists
		Water-Resources Manpower			
1966*	0	0	0	0	0
1970	28,200	15,500	12,700	8,600	4,100
1975	55,500	26,600	28,900	23,300	5,600
1980	112,600	45,100	67,500	50,700	16,800
		Water-Resources Research Manpower			
1966*	0	0	0	0	0
1970	7,300	2,700	5,300	4,100	1,200
1975	17,900	5,700	12,200	9,300	2,900
1980	40,000	12,000	28,000	21,400	6,600

*Supply and demand assumed to be in equilibrium.

The analyses by disciplines of the net increases in water-resources manpower supply and demand were discussed only briefly in previous chapters. More remains to be said, however, for only deficits are shown in Table 17. Indeed, the projected net increase in demand for most of the water-resources disciplines would absorb the greater portion of the projected net increases in supply in the same areas (Table 18). Even in the larger disciplines (economics and engineering, for example) the net increase in water-resources demand would require 67 and 41 percent, respectively, of the net increase in production. Hence, it is unrealistic to believe that these demands can be met.

For other disciplines--hydrology, water quality, water resources, watershed management--the net increase in supply would have to be several thousand percent larger to meet the projected water-resources demand alone. What this means, of course, is that some scientists, and perhaps engineers, will be drawn into these high-demand fields as transfers. It is very unlikely, however, that such transfers will be in sufficient numbers to satisfy any significant portion of the demand.

The analysis by disciplines in Table 17 points up other problems. The starred items identify a research manpower supply or demand that exceeds the total water-resources manpower supply or demand. In such cases, the discipline and occupational category percentages have failed to account, on a total basis, for the special manpower requirements of research. In actuality, these demand levels, if attained, could be met from the science manpower supply because, with the exception of engineering, water resources draws less on the supply of the affected disciplines--botany, chemistry, and physics.

It should be recalled, too, that the supply and demand figures are based on proposed national goals. Without a coherent system for establishing such goals and their priorities, the supply and demand values may well be lowered or possibly raised. For water-resources research, the goals exceed straight-line projections by the Federal Council on Science and Technology in its long-range plans for water-resources research expenditures--by 32 percent in 1970, 20 percent in 1975 (Table 19). By 1980, expenditures and goals are even. Thus the projected manpower requirements could be 20 to 30 percent too high for 1970 and 1975. And if so, the rapid climb from the 1970-1975 levels to the 1980 level will draw even more severely on science manpower. The effect of the pressure possibly will be to increase the deficits. Probably, however, additional "swing-group" professionals would be attracted into water resources by what would almost have to be inordinately large salaries and heightened accessibility to research funds.

TABLE 17

NET INCREASE IN WATER-RESOURCES MANPOWER
(BREAKDOWN BY ACADEMIC DISCIPLINES)
1966-1980

Discipline	Total Water-Resources			Water-Resources Research		
	Supply	Demand	Deficit	Supply	Demand	Deficit
Agronomy	1,160	2,830	1,670	540	1,140	600
Biology	3,080	7,550	3,470	1,980	4,180	2,200
Botany	390	940	550	540*	1,140*	600*
Chemistry	1,160	2,830	1,670	1,270*	2,670	1,400
Ecology	1,930	4,720	2,790	1,080	2,280	1,200
Economics	9,750	19,790	9,940	3,270	6,490	3,220
Engineering	2,400	47,500	45,100	9,500*	21,500	12,000
Fish & Wildlife	1,160	2,830	1,670	540	1,140	600
Forestry	770	1,880	1,110	360	760	400
Geography	2,190	4,450	2,260	700	1,380	680
Geology	6,930	16,980	10,050	3,240	6,840	3,600
Hydrology	3,850	9,430	5,580	1,800	3,800	2,000
Law	2,930	5,930	3,000	770	1,530	760
Limnology	770	1,880	1,110	360	760	400
Meteorology	1,160	2,830	1,670	730	1,520	790
Physics	350	940	550	730*	1,520*	790
Planning	1,220	2,470	1,250	390	770	380
Political Science	610	940	330	570	1,120	550
Recreation	1,000	1,980	980	270	530	260
Sociology	610	940	330	390	770	380
Soil Science	770	1,880	1,110	360	760	400
Statistics	390	940	550	180	390	210
Systems Analysis & Computer Applications	2,320	5,660	3,340	1,080	2,280	1,200
Water Quality	1,550	3,770	2,220	730	1,520	790
Water Resources	3,080	7,550	3,470	1,440	3,040	1,600
Watershed Management	2,320	5,660	3,340	1,080	2,280	1,200
Zoology	1,930	4,720	2,790	1,270	2,670	1,400

*Demand or supply in research exceeds demand or supply in total water-resources column.

WATER-RESOURCES MANPOWER AS A PART OF SCIENTIFIC MANPOWER

A measurement of the effects of competing demands for science manpower is difficult without a detailed analysis of each mission orientation and of the nonoriented sources of demand. In Table 20, the proportions of science-manpower supply and demand that would be accounted for by the national-goals supply and demand for water-resources manpower are shown. These ratios do not appear to be out of line either with what might be reasonably expected or with what is feasible, under appropriate scientific manpower policy.

The ratios of water-resources demand to science supply, shown in Table 21, are probably higher than those that could be met without a conscious program for water-resources manpower. The field of water resources competes with health, oceanography, and several other mission orientations for personnel from the same pool of scientific manpower. Whether it can actually attract more than 6 percent of the science manpower total in 1970 and 8 percent in 1980 is beyond the scope of this study.

TABLE 18

WATER-RESOURCES MANPOWER DEMAND-SUPPLY RATIO
(BREAKDOWN BY ACADEMIC DISCIPLINES)
1966-1980

Discipline	Demand-Supply Ratio (Percent)
Agronomy	136.6
Biology	20.0
Botany	42.8
Chemistry	36.5
Ecology	646.57
Economics	67.0
Engineering	40.0
Fish & Wildlife	215.0
Forestry	50.7
Geography	81.1
Geology	396.1
Hydrology	3626.9
Law	20.1
Limnology	470.0
Meteorology	325.4
Physics	5.9
Planning	894.7
Political Science	2.7
Recreation	97.2
Sociology	2.8
Soil Science	321.9
Statistics	67.8
Systems Analysis and Computer Applications	436.39
Water Quality	3770.0
Water Resources	2516.6
Watershed Management	566.0
Zoology	44.1

TABLE 19

PROPOSED EXPENDITURES FOR WATER-RESOURCES RESEARCH
1970-1980
(Millions of Dollars)

	1970	1975	1980
Presidential Goals Commission[1]	250	400	645
Fed. Council on Science and Technology[2]	170	330	645
FCST-Goals Ratio	68%	80%	100%

[1]Lecht, Leonard A., 1966, Goals, Priorities, and Dollars: The Next Decade, The Free Press, New York, p. 243.

[2]Federal Council for Science and Technology, 1967, Activities for 1965 and 1966, Washington, p. 36.

TABLE 20

WATER-RESOURCES PORTION OF
TOTAL SCIENCE-MANPOWER SUPPLY AND DEMAND
1970 AND 1980
(Independent Projections)

Occupation	1970		1980	
	Supply	Demand	Supply	Demand
Science Manpower	5.01%	5.71%	4.81%	7.59%
Engineers	4.76	5.76	3.52	5.73
Scientists	5.36	6.11	5.96	9.70
Natural Scientists	6.68	7.42	6.73	10.96
Social Scientists	1.81	3.09	4.45	7.21

TABLE 21

WATER-RESOURCES MANPOWER DEMAND
IN RELATION TO SCIENCE MANPOWER SUPPLY
1970 AND 1980
(Independent Projections)

Occupation	1970	1980
Science Manpower	6.4%	8.1%
Engineers	6.1	6.1
Scientists	6.8	10.3
Natural Scientists	8.5	11.7
Social Scientists	3.3	7.7

GEOGRAPHIC DISTRIBUTION OF MANPOWER

This report shares a fundamental flaw with nearly all other manpower studies--a lack of attention to the geographic peculiarities of supply and demand. "Where?" is equal in importance to "How Many?" We cannot answer the first question without collecting new data--without knowing the effect of state or regional characteristics on water-resources problems (demand) and on the production of manpower to solve these problems (supply). However, knowledge of such patterns does not mean that significant local deficits or surpluses could not occur.

The mobility of American labor is a hallmark of our economic system. Scientific persons, probably the most mobile of any occupational group, are neither homogeneous nor non-human in their desires for a satisfactory life-style. Consequently, we have had the marked outflow of trained scientists from the midwest to the eastern seaboard, especially to Boston, and to the West Coast, specifically to the San Francisco Bay area and the Los Angeles Basin. As in international movements of science manpower (the "brain drain"), there is probably little that any single agency can do to influence large-scale movements. But, if one agency knows the existence of such factors, subsequent policy deliberations will rest on a more factual base and, therefore, policy decisions will be strengthened. Obviously, any intensive study of water-resources manpower should include geographic distribution as a major element.

CHAPTER X

REDUCTION OF PROJECTED DEFICITS IN WATER-RESOURCES MANPOWER

RECOMMENDATIONS

The previous discussions would be incomplete without recommendations for alleviating the projected deficits in water-resources manpower. One common aspect--no additional appropriations needed--is shared by the following suggestions. This fact, in itself, deviates significantly from the time-honored war harse found in manpower studies: "Additional funds should be appropriated for ______________," in which one or more of the following words is inserted--training, grants, contracts, research.

Such recommendations have been and are still being made by various agencies in their budget requests. While there is no doubt that most follow careful deliberation, it is unfortunate that so little factual supporting information is prepared [Hanes, 1967, pp. 279-81; U.S. Senate, 1967]. The following recommendations contain the same philosophy as the entire study: Much can be gained from the examination of existing programs and policies.

WATER-RESOURCES CAREER INFORMATION

The cooperative water resources research institutes (funded by OWRR) could devote a small portion, say 2 to 3 percent, of their annual allotment for preparing brochures, exhibits, and seminars to publicize water resources as a career field. Seminars for undergraduate and uncommitted graduate students could be held to explain water resources as a career field with emphasis on the variety of needed disciplines. At a higher level, seminars could be held for professionals and technicians who may be interested in changing their work. Traveling exhibits could be developed for use in high-school career counseling.

The Oregon Water Resources Research Institute has made some effort in these areas. The effectiveness of its program should be evaluated for strengths and weaknesses [Ore. St. University, 1966].

FEDERAL JOB-DEVELOPMENT PROGRAMS

Several Federal government programs--Manpower Development and Training, Vocational Education, and New Careers, for example--have as their primary goal the creation of jobs. Their strength lies in the determination to avoid training persons for dead-end positions and to push for projects in which training leads to jobs with clearly-defined opportunities for promotions and self-improvement--where the trainee can progress as far as he desires and as his capabilities allow. Technicians and operators in the water resources categories seem to be ideal for this type of program. Not only are such workers in short supply, but from a recruiting standpoint, these positions are more prestigious and open-ended than for cooks, janitors, dishwashers, groundskeepers, and other non-skilled workers.

The bringing of these possibilities to the attention of the appropriate administrators would be the first step in what could be a fruitful effort with many side benefits for water resources. One benefit would be the release of more highly-skilled personnel from routine tasks to more challenging and responsible work--thus alleviating a portion of the deficit in more highly-trained manpower.

MANPOWER REDUCTION THROUGH IMPROVED DATA COLLECTION AND PROCESSING

A qualitative shift in manpower requirements, if not a quantitative reduction, could be achieved through the encouragement by the OWRR and other agencies toward more intensive research in the application of remote-sensing systems (airborne sensors and satellites) to water resources. The geographic-applications program in the Department of the Interior is a major focus of the remote-sensing research being done in the United States.

The sensors now being developed and tested will make it possible for satellites to receive and transmit either images or code signals from earthbound monitors. The images and other signals read and processed by computers will thus provide timely data on water quality, temperature, and quantity, watershed conditions and changes, effects on water retention and movement by vegetation, and other phenomena. When ground truth has been established for the sensed data, the macroscale aspects of water-resources planning, development, and management can become truly effective--given that the institutional and allocative aspects of implementation inherent in our political system can be rationalized or, at least, that the irrationalities can be understood and turned toward positive goals.

INCREASED REPRESENTATION OF OTHER DISCIPLINES IN WATER-RESOURCES RESEARCH

Although the number of disciplines now participating in water-resources research is large, other fields capable of greater contribution are represented by only a small handful of professionals. The state water resource research institutes tend to be dominated by engineers and engineering-oriented activities, the latter often bordering more on development than on research. Some social and natural scientists find this an offensive situation; some believe it freezes them out of the research program; others do not realize that opportunities for water-resources research exist in their own field. The institute directors should be encouraged to: invite research proposals from beyond their own departments, colleges, or campuses; hold seminars for the purpose of identifying research interests and topics; and set aside a share of their annual allotment for small projects or start-up phases of larger projects in fields needing increased representation. The proposal review panels should represent a wide range of disciplines or, alternatively, consist of broad-gauge, experienced persons with an appreciation for the possible contributions by disciplines other than their own. The manpower benefits would then come from improved recognition of opportunities in water resources.

The institute directors should also be encouraged to seek research talent not found on their home campuses. Perhaps some limitation could be set on the use of annual allotment funds to support in-house principal investigators.

CONCLUSION

The foregoing recommendations cover only a few of the many possibilities for increasing the number of workers in, or what amounts to the same thing, improving the utilization of manpower presently engaged in water resources. They are enough, however, to emphasize that a mere increase in Federal expenditures will not necessarily alleviate manpower shortages, particularly those of scientific manpower. Although the status of water resources could be improved by increased expenditures, the primary effect would be the drawing of highly-trained personnel away from other mission orientations of equal, or perhaps higher, priority.

The ultimate challenge is the establishing of goals and priorities on a rational basis, a task that the United States has never really attempted except in times of extreme national emergency. Consequently manpower and other types of shortages will continue due to the misuse of the limited pool of talented and qualified persons. And, these shortages will be most keenly felt as long as priorities are determined on the basis of appropriations and glamour. Manpower shortages can be transferred to less critical areas when, and only when, appropriations come to be based on rationally-determined priorities of national goals.

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