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RESEARCH ON NATURAL RESOURCES: A REVIEW AND COMMENTARY

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In the vigorous debate about the role of science in the formation of national policies, a current issue is the responsibility of the federal government for research on natural resources. Various groups—including several federal commissions and congressional study committees—have warned that the time is fast approaching in the United States when a substantial portion of natural resources needed to sustain living standards, stimulate growth, and build our defenses will no longer be obtainable from within our own boundaries.[1]

Under the assumption of expanding international trade, many economists urge that United States resource policy recognize the entire world as a potential resources system from which the United States economy may draw.[2] Certain engineers, on the other hand, assure us that our own growth in technical skills and inventiveness can provide new resources or suitable substitutes, when urgently needed, and that economic growth is, in fact, stimulating requisite technologic innovations.[3] Others claim that the rising expectations and demands of an ever-mounting population here and abroad and urban growth will eventually cause severe modifications of natural environments.[4] In the process, many of the natural values that satisfy man's less material needs will be diminished.

To what extent, and by whom, can federal research programs be formulated and carried out to provide illumination for resource policy decisions and action?

Two recent events involving federal science programs and policies have bearing on this vital question. The first is the establishment of the President's Science Advisor, and under him, the Federal

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1. A lively discussion and interpretation of information relating to this topic is contained in Brown, Bonner & Weir, The Next Hundred Years (1957).

2. See Landsberg, Fischman & Fisher, Resources in America's Future (1963).

3. See Nolan, *The Inexhaustible Resource of Technology*, Perspectives on Conservation (Jarret ed. 1958).

4. See Leopold, A Sand County Almanac (1949); Ekirch, Man and Nature in America (1963).

Council for Science and Technology (FCST). This is considered by some scientists and public administrators to be a most significant step to advance science research and policy in government. The Federal Council has been assigned the function of comparing and coordinating research endeavors on a government-wide basis, and it has also been authorized to establish coordinated interagency science programs.

A second significant development has been the enlarged role, partly due to requests from the Office of the President, which the National Academy of Science-National Research Council (NAS-NRC) has assumed in providing scientific and technical advice to the Executive Department. This quasi-governmental organization has contributed substantially during the last few years, in a variety of ways, to the formulation of federal science programs. Outside of government, the Academy-Research Council is possibly in a more independent position to examine scientific-technical problems in a detached way than can government agencies and personnel. There have been claims that some federal agencies and interagency groups select their own advisory committees to approve, dignify, and support their scientific programs.

On February 23, 1961, the President informed Congress that he was asking the Academy-Research Council to prepare a thorough report on "the present state of research underlying the conservation, development, and use of natural resources . . . and giving particular attention to needs for basic research and to projects that will provide a better basis for natural resources planning and policy formulation."[5] Pending the recommendations of the Academy-Research Council, he also directed his Science Advisor and the Federal Council to review ongoing federal research activities in the field of natural resources and "to determine ways to strengthen the total government research effort relating to natural resources."[6]

These two reports were received in December, 1962 and May, 1963. The Academy-Research Council's report, following several previous less extensive efforts in the same endeavor, urges interdisciplinary studies as a basis for policy determination. The Federal Council's report, including detailed tables of current and prospective agency research, useful to the Chief Executive, the Bureau of the Budget, and Congress, urges, in effect, policy formulation by an interagency committee.

5. 107 Cong. Rec. 2584 (1961) (address by President Kennedy).
6. *Ibid.*

Our purpose here is to summarize and comment on some of the important findings of the two committees; then restate and lend support to what we consider the major recommendation, gleaned from both reports, for more integrated research on the resources environment. In conclusion we shall offer observations on other current conservation trends, about which the studies of the two committees are indicative.

I

THE NAS-NRC COMMITTEE ON NATURAL RESOURCES

Six supporting studies were prepared by members of the Committee on Natural Resources, which was appointed by the National Academy of Sciences-National Research Council: *Renewable Resources*,[7] *Water Resources*,[8] *Mineral Resources*,[9] *Energy Resources*,[10] *Marine Resources*,[11] and *Social and Economic Aspects of Natural Resources*.[12] They became the basis of final deliberations and the recommendations in the Committee's summary report, *Natural Resources*.[13]

A. The Summary Report

The summary report, *Natural Resources*, is an extraordinary document, far broader in view and yet more incisive than any previous marshalling of scientific thought on *problems*, *principles*, and *research areas* related to the formulation of policy on resources development. This fact befits the importance of the first report on this subject ever requested directly by the President from the Academy-Research Council. This report should enhance the influence of the Council in public affairs.

7. Weiss, *Renewable Resources, A Report to the Committee on Natural Resources of the NAS-NRC* (NAS-NRC Publication No. 1000-A, 1962).

8. Wolman, *Water Resources, A Report to the Committee on Natural Resources of the NAS-NRC* (NAS-NRC Publication No. 1000-B, 1962).

9. Frasché, *Mineral Resources, A Report to the Committee on Natural Resources of the NAS-NRC* (NAS-NRC Publication No. 1000-C, 1962).

10. Hubbert, *Energy Resources, A Report of the Committee on Natural Resources of the NAS-NRC* (NAS-NRC Publication No. 1000-D, 1962).

11. Pike & Spilhaus, *Marine Resources, A Report to the Committee on Natural Resources of the NAS-NRC* (NAS-NRC Publication No. 1000-E, 1962).

12. White, *Social and Economic Aspects of Natural Resources, A Report to the Committee on Natural Resources of the NAS-NRC* (NAS-NRC Publication No. 1000-G, 1962).

13. National Academy of Sciences-Nat'l Research Council, Committee on Natural Resources, *Natural Resources, A Summary Report to the President of the United States* (NAS-NRC Publication No. 1000, 1962).

Perhaps the outstanding feature of the summary report is its emphasis on the need for more profound understanding of the interplay between the social and the natural sciences to meet the requirements of productivity "without lasting damage to our natural endowment."[14] There is a tendency among economic groups to rely upon technology to discover, synthesize, and produce new materials and find ways of utilizing economically degraded materials of nature to sustain our economy and human prosperity everywhere. The summary report, optimistic in many regards, focuses new attention on the neglected importance and essentiality of the life sciences, and the fundamental need to understand and nurture the complex environment that is an ecological unity, of which man is only one of many interdependent parts.

The summary report is successful in synthesizing the basic findings of the Committee into a brief and forceful statement. It presents eleven specific recommendations on the nature and uses of resource research and the development of techniques for planning and management of resources. However, the roots of the analysis and progressive thinking are found in the six supporting studies.

B. The Renewable Resources Report

The study group on renewable resources was chaired by Paul Weiss. The report sets forth seven propositions which are here summarized for brevity's sake, at the risk of corruption. (The propositions stated at length in the report are so precisely expressed that they should long remain required reading in their original form.)

Proposition I states that nationwide in the United States most of our renewable resources will not be quantitatively in short supply over the next fifty to one hundred years; even though supply and demand over that time are not precisely measurable.

Qualifying this proposition, the report states that total availability means little in view of specific imbalance at times and places that now exist and may well become more frequent in the light of rapid economic, social, political, and technologic change, often referred to as progress. The problem is viewed as one of "incongruous and highly specific patterns of differential distribution."[15]

Since divergent lines of progress create stresses and strains "too fast to be resolved *after* they have arisen," we should learn "to an-

14. *Id.* at i.
15. Weiss, *op. cit. supra* note 7, at 3.

ticipate . . . untoward developments *before* they arise."[16] The report concludes that there is no adequate machinery for this task in existence at present.

Lack of anticipation may be questioned. It seems to us that over the past fifteen years a number of specific problems have been postulated through institutional propaganda in the resources field. The challenge is that existing institutional machinery has not minimized the problems predicted. The democratic process, meaning the combined action of government, industry, and civic leadership, is a ponderous machine—preferable for us to dictatorship—able to act most effectively in emergency, but not yet capable of forestalling emergency (*e.g.*, our inadequate policy and war plans before Pearl Harbor).

What are some of the problems postulated?

1. Population growth will increase consumption so that in time there will be shortages of many native supplies of food and fiber, not only locally, but nationally.

2. Our economic and technologic assistance to underdeveloped nations will so increase industrialization abroad that those nations will require for their progress much of the raw materials that we now import and depend upon to maintain economic growth.

3. Urbanization and mechanization will so remove us as a people from nature and from comprehension of the interdependence of renewable resources, that we will not be aware of the deterioration of the resource base and thus will be incapable of coping with it.

4. A growing faith in our cornucopian technology, the never-ending storehouse concept, is also reducing recognition of our inevitable dependence on nature for life support.

What machinery, if any, may be added to our existing political and social structure to cope effectively with such changes as they materialize? This question is dealt with hereafter in the discussion of recommendations.

Proposition II is that organic nature is such a complex, dynamic, interacting, balanced, and interrelated system that change in one component entails change in the rest of the system. Isolated analytical study of separate components cannot yield desired insight. To find solutions to separate problems of hydrology, waste disposal, soil depletion, pest control, etc., is not adequate to achieve the optimization of resources generally; all factors and their cohesive impact on each other need to be simultaneously considered. This is difficult due

16. *Id.* at 5.

to "unequal distribution in space and time of biological requirements."[17]

The report makes it clear that ecological studies have not yet met this fundamental requirement—although it is conceded that valuable corrective controls and measures have resulted from such separate studies which do increase yields and reduce waste. It follows that "serious attention ought to be focused on the development of public understanding and acceptance of the underlying principle of interrelatedness and interdependence, and the consequent impossibility of reaching decisions by confining considerations to limited aspects or sectors of ecological systems."[18]

It is doubtful that any such forceful statement of the ecological imperative would have been made ten years ago. We hope it will be taken to heart and mind by those who measure resources in quantitative terms only, and those who send only technicians, engineers, and economists to provide technical assistance in less developed lands.

Ecological advice may well modify some of the more destructive piecemeal efforts to increase production in rapidly changing environments. In all probability we cannot avoid some damage in these endeavors, but it should be possible to encourage greater ecological consideration in planning, so that the long range deteriorative impact may be minimized.

Proposition III deals with the fallacy of a tendency to concentrate on uniformity and single-track standardization in application of isolated measures and practices. The significance or insignificance of mixtures of components and environmental conditions cannot be judged from sheer data on bulk or averages. This fallacy is a pitfall ignored today by some planners, developers, builders, and other practicing resource manipulators. As a people we are not educated to know the danger of our most potent acts in furthering what we believe to be the greatest good for the greatest number at the present time.

Granted that existing equilibria are not necessarily optimal, our present drive to maximize a specific change or result too often sacrifices other interrelated parts without optimizing the total result. This part of the report on renewable resources, therefore, is a plea for a knowledge and sense of proportions.

Proposition IV suggests that the concept of single, rigid, linear cause-to-effect chains of natural events has given rise to organically

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17. *Id.* at 6.
18. *Ibid.*

unreal and practically untenable conclusions; and more attention should be given to the network type of causal relations in an integrated system that establishes a multiplicity of alternative routes to such a goal as optimization. It is now incumbent on us to lay out patterns of alternative and substitutive practice *in advance* of an emergency, in order to have feasible devices and schemes ready for use when necessary.

Proposition V states that marginal resources should be valued in the light of multiple, alternative pathways and equivalence considerations. Small substitutions and gains in productive use, even in limited areas, may be as significant to network conservation as gross bulk considerations. Examples given are desalination of water for local usage and solar energy for refrigeration in some areas.

Here, apparently, the words "marginal resources" are not used in the sense alone of "scarce or brittle resources," but the latter also, even though substitutes may be found, require care and nurture as significant and sometimes essential elements in the network of interdependence.

Proposition VI is that acceptance and implementation of the "systems concept require major and profound reorientation of public thinking, for which the foundation must be laid in the educational process."[19]

This is a plea for public understanding and acceptance of basic ecological relationships and man's responsibility for nurturing them. Scientific planning and decisions in resource management need increasing citizen support. High school and college work to promote "awareness and even appreciation of the 'system' character of man's universe"[20] are commended.

Surely teachers would go further than this and insist on exposure of students to ecology in field laboratories as well as in classrooms. Each day more and more of our citizens become less and less familiar with life and its environment.

The report's recommendation of more adult education, through increased discussion in the press and in adult groups, is also important though perhaps inadequately developed. Finally, the call for more adequately trained "expositors" and technicians is timely.

Proposition VII states that optimization of natural resources for human benefit requires a permanent, continuous, and systematic—not fragmentary or isolated—process of investigation, recording,

19. *Id.* at 13.
20. *Id.* at 14.

and evaluating in reference to the total perspective. An independent organization for this task seems mandatory.

The ensuing prescription for such an organization is visionary in the better sense of the word. An intelligence agency is proposed: (1) to keep us informed of all physical, biological, sociological, geographic, and economic events and developments of potential bearing on man's optimal adjustment to his environment, and (2) to attempt to "evaluate in scientific terms the probable net effect of their mutual interactions on man's future—short-range and long-range—in national, regional and global respects."[21] The full prescription should be read carefully in detail. A warning against endowing the agency with powers of decision, or enforcement, so that it may steer clear of the political arena, is noteworthy.

C. The Water Resources Report

Abel Wolman's report is a compilation of present and prospective water problems—an analysis of the complicated nature of the factors affecting supply and demand and general considerations in water resource development. The report lays a comprehensive groundwork for the subsequent definition of areas of needed research—arid, semi-arid, and humid, followed by five specific subject research recommendations which are applicable to all areas. The report concludes with a summary of proposed priorities in water research; it speaks for itself and is so much more detailed and explicit than the summary report that it should be a landmark in water research considerations for some years to come.

Wolman does not minimize the nature of the problem despite overall statistical evidence of underuse of total water supplies. He states that within about twenty years the full potential development of some of our big river basins will have been reached. There will be no more water attainable in those areas.

While recognizing the high cost of desalination and the prohibitive cost (under present economic usage) of distant transportation of water, the report does not discuss the possibility that more water in a particular fully developed basin (while not attainable) may become *available* locally if the needs of seacoast cities are supplied by desalination rather than by use of upland supplies.

Since many of the nation's rivers and streams are becoming seriously polluted and since this problem is likely to grow, the first most urgent research recommendation in humid areas is aimed at develop-

21. *Id.* at 15.

ing water purification methods (improved means of separating a wide variety of substances from water). Also high in priority is research to discover the means of forecasting the effect of wastes on receiving water and toward quantifying pollution damages. Research of another kind would seem perhaps as beneficial—discovering social, political, economic, and physical ways to obviate pollution before it occurs. Waste disposal by means other than dumping into streams and rivers might be less costly and more desirable in the long run.

The report emphasizes again the need for more basic knowledge of the physics, chemistry, and biology of ground water behavior, and of ground water management, use, and storage. There is urgency in finding new processes to slow down transpiration and evaporation from soils, plants, streams, and lakes, and new techniques of water management including hydrologic forecasting and weather analysis, along with increased scientific understanding and increased production of skilled professionals in the hydro-sciences.

In reading the discussions of evapotranspiration in arid areas, an ecologist might question the reference to phraetophytic plants as "useless"; and the more sentimental conservationists will rejoice in references (too seldom seen in learned reports) to the values of recreational and aesthetic amenities.

The water resources report, for all its conciseness, is comprehensive, constructive, and practical.

D. Mineral Resources Report

Dean F. Frasché of Union Carbide Ore Company was responsible for preparing the study report on mineral resources. Perhaps in no other resource area should the United States be more concerned about coordinating as closely as possible the combined conservation policies of industry and government.

Extensive inventory work has shown for quite some time that known economic reserves of most metals are unevenly distributed among nations. Although the United States is believed to be more fortunately endowed with mineral resources than most nations, we are by no means self-sufficient. During the period 1953-1957, the United States ranked first in importing fourteen out of sixteen major metals or their ores, was the second and third largest importer of the other two, and was a major exporter of only two major metals. A national stockpiling program has been carried out for a number of years in recognition of the United States' deficiencies and dependencies on foreign imports.

Considering the short-term as ten years, the Frasché report states that the United States will "not be plagued by mineral shortages unless war or other foreign political developments curtail imports of critical mineral commodities."[22] In connection with the latter, the economic importance of minerals to developing nations is acknowledged: "Today, the tendency is for greater and greater increases in the percentage of primary mineral processing to be done in the country of origin."[23] Furthermore, as emerging nations build up the industrial sectors of their economies, there is less desire to export raw materials except where surpluses exist and can be used to advantage for trade and barter.

The significance of these observations can be underscored by mentioning a few statistics by way of illustration. The United States, with approximately six per cent of the world's population and about eight per cent of the land area, presently consumes about one-half of the world's yearly production of antimony, asbestos, molybdenum, and nickel. All of these, and others consumed in lesser proportions, are vital to United States industry, just as they eventually will be to industries of the emerging nations from which the United States obtains its imports. The pattern of long-term availability is obscure; nevertheless, Frasché reported one serious trend. Consumption in the latest ten year period has generally increased in the United States, but domestic mineral production relatively has seldom kept pace.

An urgent and immediate problem exists in the conservation of adequate helium reserves. Helium is considered indispensable for an ever increasing number of important industrial and research uses, including the application in low-noise maser amplifers for radar and radio-astronomy and cryotrons for computers. The summary report stresses the importance of this problem as follows: "Present failure to extract helium from much of the natural gas produced from the Texas Panhandle gas field, and the further dissipation of 85 per cent of the helium which is extracted, represents an unnecessary wastage of a vital and non-replaceable resource."[24]

The mineral resources report concludes that the answer to the United States minerals problem is not to be found in improved bene-

22. Frasché, *op. cit. supra* note 9, at 12.
23. *Id.* at 10.
24. National Academy of Sciences-Nat'l Research Council, *op. cit. supra* note 13, at 11.

ficiation of ores or increased use of scrap metals alone. Our success in the minerals field will depend "upon the vigor with which we find and appraise new geologic resources, devise efficient systems of handling new types of rock and ore, and work out methods of separating the desired constitutents from waste."[25] A forthright plea is made for greater cohesiveness in industrial research on minerals and much closer cooperation between industry, universities, and federal agencies. Mining companies, with few exceptions, are unable to match other segments of the United States industrial community in making investments on a major scale in research and development which, today, require continuous multi-disciplinary programs. "The mining industry has been extending its research and development about as far as its response to conditions in the market place will permit; our economic system inhibits private investment which is not likely to pay off for more than 10 to 30 years, even if successful."[26]

The implication of this conclusion is that the federal government should reorient its research activities to look beyond temporary surpluses and stockpiles.

The eight recommendations for federal action presented in the final pages of the report appear to reflect some coordination with concurrent program analysis of minerals research undertaken by the Federal Council for Science and Technology. They also appear to be sufficient to serve as generalizations for intensifying federal research and development on minerals in response to industry needs.

E. The Energy Resources Report

Marion King Hubbert, representing Shell Oil Company, chaired the energy resources study and was responsible for preparing the energy report. His simplified description of the energy flux of the earth provides a comprehensible framework for ensuing, more complex discussions of the sources and degradation of energy supplies.

Man is viewed as a unique interloper in the energy system, "able to do what no other animal has ever achieved; he has learned to tap other channels of the energy flow-sheet; and he has managed to divert the energy flow from its customary path into other channels appropriate to his own uses."[27]

Hubbert illustrates how history can be interpreted in terms of energy flux. Early man increased the fraction of energy available to

25. Frasché, *op. cit. supra* note 9, at 14.
26. *Id.* at 25.
27. Hubbert, *op. cit. supra* note 10, at 8.

him through invention of clothing, use of tools and weapons, controlling fire, and domesticating animals and plants. Later, the nonbiological sources of energy—winds and the hydrologic cycle—were tapped; thereafter, supplements to solar energy became available with the discovery and use of fossil fuels, introducing a "crescendo stage of history"; finally, within the last two decades, ways have been found to tap the most highly concentrated reservoir of potential energy—the atomic nucleus. With each successive tapping of a larger fraction of the total energy flux, there have been spectacular increases in human numbers accompanied by increased interference with natural ecosystems. Here, we recommend the reader to a comparison of this section of the report with F. Fraser Darling's excellent interpretation of English history, considered in ecological terms.[28]

The body of Hubbert's report is a summary and projection of energy production data, known reserves, and ultimate United States and world production potentials for crude oil, natural gas, liquid hydrocarbons, and natural-gas liquids. The reader will want to compare this valuable information with an analysis of energy needs in the United States' economy, in a recent study published for Resources for the Future, Inc.[29]

The peak in coal production for both the world and the United States is expected to occur in about 200 years. Reserves of petroleum and natural gas are much smaller than those of coal. The report concludes that these fuels will be much more short-lived than coal: "In fact, the culmination in the world production of petroleum is expected to occur by about the end of the present century. In the United States, the culmination in the production of crude oil is expected to occur before 1970, and that of natural gas before 1980."[30] There are still reserves of oil shale and coal from which such fuels can be produced, if necessary.

Section five of the report turns to more stable sources of power. Solar energy is available through the biologic channel (photosynthetic capture) and the heat-engine channel (atmospheric and oceanic circulations and the hydrologic cycle important to wind and water power sources). Less important, so far, are direct conversion of solar energy (used primarily in cooking and water heating), tidal power, and geothermal energy.

28. *The Unity of Ecology*, Address by F. Fraser Darling before the British Ass'n for the Advancement of Science, 1963.

29. Schurr & Netschert, Energy in the American Economy, 1850-1975 (1960).

30. Hubbert, *op. cit. supra* note 10, at 90.

The problem of developing large-scale power from nuclear sources is discussed in three fundamental aspects: (1) development of breeder reactors, (2) an adequate supply of uranium and thorium, and (3) proper disposal of the extremely dangerous fission products. If breeding becomes the established practice, "we shall have achieved almost unlimited supplies of energy from the fissionable and fertile isotopes of uranium and thorium."[31] The principal remaining problem is to achieve safe disposal of radioactive waste products. The report refers to an earlier Academy-Research Council study which concluded that the two likely means of waste disposal are in the salt mines, or domes, and in the form of heavy liquids in permeable sedimentary rocks in the "bottoms of synclinal basins."[32] None of the existing Atomic Energy Commission's installations, and few of its proposed power plants, have suitable waste-disposal sites.

After reading such detailed, tabular, and complex technical material, it was refreshing to come upon the thoughtful observations of the concluding section. We believe this is the first instance that we have read a predominantly statistical report on energy resources in which the material is summed up with an ecological perspective:

> [T]he whole biological complex of the earth is at present in the midst of one of the greatest ecological upheavals known in geological history. The various biological populations are about mid-range in their transitions from their earlier near-equilibrium states to new equilibria at markedly different levels. In this transition some populations, notably that of man, are increasing; others, including most of the familiar wild animals and most native plants, are decreasing; some have already become extinct. Because the earth is of finite magnitude, it is unavoidable that the present abnormal rate of increase in the human population must eventually slow down and ultimately become zero or even negative. The population itself may level off asymptotic to some maximum number, or it may overshoot and stabilize at a lower, more nearly optimum figure. Or, in the event of a general cultural degeneration, it may be forced back to some level that could be sustained by the industry of a more primitive culture . . . . [I]f we disallow imminent annihilation by nuclear warfare, three distinct possibilities appear to exist . . . . One possibility . . . is that we may be able to maintain our present scientific and technological culture, using the fossil fuels as an essential intermediate step in the transition to ultimate dependence upon the large-scale use of

31. *Id.* at 114
32. *Id.* at 116.

> nuclear energy . . . . There is also a possibility . . . that we may not succeed in overcoming the cultural lag between our inherited folkways and our present requirements in time to prevent a serious overshooting of the world population above a manageable magnitude. . . . Finally, there is the possibility . . . that we could go into a state of confusion and chaos, including nuclear warfare, from which we might never be able to recover . . . . [W]e could suffer a cultural decline and return to our former agrarian and handicraft level of culture.[33]

This is a plea for foresight in relating resources policy and planning, including energy resources, to the more fundamental ecological problems involved in guiding human affairs.

F. The Marine Resources Report

This study report, prepared by Sumner Pike and Athlestan Spilhaus, is brief and pithy. Resources of the sea are multitudinous. Most of them are not exploited at all. A few are in danger of depletion to the point of commercial exhaustion. The littoral estuaries and salt-water marshes are subject to increasing modifications and pollution with devastating effects on anadromous fish and the many species which spawn or depend on these shallows.

It is interesting to note that in the colloquium, summarized in the renewable resources report, Frits Went referred to most of the ocean as lacking nutrients, especially P and N, and therefore very limited in photosynthetic production. In spite of these limitations, sea fish form a substantial portion of the world's food. Yet people in countries surrounding the Indian Ocean (estimated at 500 million) lack "a reasonable amount" of protein in their diet. One problem is that of preservation of fish which deteriorate rapidly. Refrigeration cannot be relied on as an answer because of its prohibitive cost. The authors do not mention the suggested use of solar energy for refrigeration. They believe that reducing the catch to whole fish flour with a protein content of around eighty per cent is probably the most practical solution if this product can be made acceptable "to people hagridden with various taboos."[34]

Important areas of research opportunity include the need for systematic ecological mapping of the sea; comprehensive studies of marine communities; studies of life cycles and behavior of fishes; new types of research equipment and facilities; and studies in estuarine ecology to make known the need for ameliorating pollution

33. *Id.* at 127, 135.
34. Pike & Spilhaus, *op. cit. supra* note 11, at 3.

and other intervention by men. It may be that research will reveal better methods of exploiting renewable resources of the sea with less damage to productivity.

The report recommends early endeavor to arrive at new international agreements as to future use of resources of the sea before increasing competition leads to serious and perhaps intolerable strains.

While in preliminary discussion the authors say that minerals dissolved in sea water are, with minor exceptions, not susceptible to commercial recovery, they do recommend mineralogical studies and surveys of deposits, particularly phosphorus, and note that the rate of formation of manganese, nickel, cobalt, and zirconium is much greater than the present rate of world consumption.

Both this report and the summary report which largely endorses it refer to the earlier report of the NAS-NRC Committee on Oceanography for further recommendations. Lionel Walford's study,[35] sponsored by the Conservation Foundation, presents in much greater detail a sound account of what is and is not known about the sea's resources and lists additional areas of study and research to meet some predicted resource deficiencies in the future.

G. The Report on Social and Economic Aspects

Gilbert White's report on the social and economic aspects of natural resources applies in a fashion—and an excellent fashion it is—the interrelated and interdependent approaches of each of the preceding study reports. It is a kind of summary of the total effort and deals at the end with needed economic and social research and with attitudes and organization to implement an effective research program for natural resources.

An introduction exemplifies the clarity and coverage of the overall approach. The world is experiencing an unprecedented growth of population; future requirements for food, water, energy, and minerals can be expected to increase greatly. Each natural resource has finite limitations and a unique pattern of distribution. The economy has already been inhibited in some areas by resource shortages or exhaustion. Advancing technology has enhanced greatly the development of resources and has altered ideas of what constitutes a resource. It is becoming progressively more meaningful to think in terms of satisfying broad categories of need, such as the need for energy, rather than in terms of simply conserving a particular resource, such as coal.

35. Walford, The Living Resources of the Sea (1958).

This report summarizes the importance of the new emphasis on "systems analysis" and "systems research" in the complex economy of the United States and underdeveloped countries which share in the production and consumption of the world's wealth.

White decries the established and widespread tendency to view the problem of resources primarily as planning to avert shortages of fixed supplies (of timber, soil, or water) in the United States. The larger approach, he says, is more in harmony with the biological or physical view of the world than is the position of those who seek the largest dollar payoff for a business discount period, or those who condemn every move that disturbs the "balance" of nature. The larger view is concerned with optimum use and recognizes the world as an immensely complex set of *systems*. Action to alter these systems deserves appraisal in terms of effects on the rest of the system. Today these effects cannot be judged with wisdom. We are ignorant of precise relationships and of sound ways to measure or compare them. Research in human aspects of resource use can clarify some of these relationships and help sharpen the tools for weighing alternatives open to us in shifting the equilibrium.

But the research must be interdisciplinary. There are many forces that pull research into separate compartments. Strenuous effort must be made to marshal the contribution of competent investigators including anthropologists, geographers, psychologists, ecologists, and sociologists.

The Academy's summary report expresses its acceptance of this view. It says:

> A pivotal problem is how to combine and utilize knowledge of the physical, biological and social processes associated with resources to enhance productivity and extend flexibility of decision among alternative courses of action. Unless this ability is acquired through research, federal policy in resource management and the budgeting of federal research funds will continue to be set in the relatively narrow commitments of operating agencies. We must acquire competence in considering and planning for resource use in complex systems rather than considering only restricted segments of production or use for a single resource.[36]

36. National Academy of Sciences-Nat'l Research Council, *op. cit. supra* note 13, at 26.

II

THE FEDERAL COUNCIL FOR SCIENCE AND TECHNOLOGY

Let us turn now to the resources report of the Federal Council, *Research and Development on Natural Resources.*[37]

Formerly headed by Jerome Wiesner, the director of the President's Office of Science and Technology, the Council is made up of scientific representatives of federal departments and agencies concerned with science, and the Director of the National Science Foundation.

Observers from the State Department, the Bureau of the Budget, and the Federal Aviation Agency participate in the Council. Roger Revelle, former Science Advisor to the Secretary of the Interior, chaired the Committee on Natural Resources which prepared the report to the President on federal agency research and development in natural resources.

The body of this report is contained in a twenty-nine page summary, based on seven short subcommittee reports which include detailed surveys of federal research and development programs. These reports identify problems requiring scientific effort, evaluate the adequacy and balance of the federal scientific effort, and recommend a ten year interagency research program in the following areas: energy, biological resources, water, land resources, minerals, air, and the economics of resources. The two summary reports to the President contain many points of similarity in approach and some apparent differences in emphasis. What do the scientists of the executive branch think and say that differs from the thought and experience of those scientists not on the Executive payrolls? What is the significance, if any, in their different approaches for current evolution of policy, and for future impact on policy formation and execution?

The Federal Council's report contains a thorough-going record and analysis of federal research projects relating to natural resources. The scope as well as the cost of this research will doubtless surprise many individuals who constantly hear that research on natural resources is totally inadequate. However, compared to other budget items, and in the light of new recommendations for substantial and increased studies, there can be little doubt of present

37. Federal Council for Science and Technology, Committee on National Resources, *Research and Development on Natural Resources, A Report to the President of the United States* (1963).

inadequacy in the face of mounting resource demands and growing populations.

Tables on present and prospective research are both comprehensive and detailed. However, it is the commentary on the state of natural resources in the United States, the analysis of outlook for certain classes of resources, and the position of the federal government as manager, user, and policy former that contrast the Federal Council's and the Academy-Research Council's presentations.

Jerome Wiesner's memorandum of transmittal of the report to the President states—that it, "taken with the Academy-Research Council's report," provides a common framework for policy and planning guidance to the Executive enterprise. He adds that the two reports stress the need for additional research and recommend that future studies be devoted specifically to establishing a new type of "capability for resources analysis." He does not add that on this latter point the two reports imply an important conflict or competition for influence in the future shaping of national resource policy. Shall the White House's Office of Science and Technology and the Federal Council, made up of government scientists, be the source of Executive policy, or shall the Academy-Research Council, with its increasingly powerful private specialists beyond Executive control, influence the establishment of the new type of capability?

The underlying sense of the two reports is different. The Federal Council's approach is primarily economic and technological; the Academy-Research Council's approach is primarily ecological. The former seems to be concerned with sustaining the growth of the gross national product; the latter with sustaining the resource base and a healthy total environment. It is useful that both approaches be stated at this time and that both be subjected to critical analysis.

The Federal Council acknowledges the need to live in harmony with the environment in an increasingly urbanized society. It holds that our ability to manipulate natural features and forces is impressive, and emphasizes that knowledge and ingenuity are now producing resources where none existed before. Scientific research and development are necessary to the solution of a host of resource problems—"problems which range from exclusively technical matters in the field of science and engineering to those which are primarily social, economic, and political problems . . . ."[38] The Academy-Research Council's reports are far more concerned with the

38. *Id.* at ii.

problems of environmental processes, resource systems, and living things.

The Federal Council's proposal for future service is expressed as follows:

> With regard to natural resources the Federal Council will continue to recommend policies and measures: (1) to provide more effective planning and administration of Federal scientific and technical programs; (2) to identify research needs, including areas of research requiring additional emphasis; (3) to achieve more effective utilization of the scientific and technologic resources and facilities of Federal agencies, including the elimination of unnecessary duplication; (4) to further international cooperation in science and technology.[39]

What is the nature of the Federal Council's attitude presented in its report? It is based on the economics of change everywhere: population growth merely concentrates and intensifies local demands on other segments of the economy; economic growth in less developed countries requires industrialized countries to evaluate resource policies in international terms; we are importing more and more of the raw materials needed in our economy. Despite world surpluses, less advanced countries need help in industrializing and in applying modern technology to reduce their costs of raw material production. Factors to be studied that will affect the future demand for specific resources are demographic, economic, technological, military, trade, regional migrations (urbanization), human habits, leisure and objectives, and the availability of resources themselves.

There is little emphasis given to the implications of ecological change and the relevance of the life sciences. Economic and social analyses need improvement. Dealing with specific resources, the Council says that in the United states we shall not be short of water, on the average, but regional shortages could arise in large areas. (Actually, they already exist.) "The principal problem . . . will be water reuse . . . ."[40] (Pollution is not emphasized.) Both reports concur that a better understanding of natural phenomena and the behavior of water can lead to large saving.

The Council finds that world supplies of most minerals exceed demand; accordingly, world prices have decreased to the point where a growing proportion of United States mineral deposits cannot be mined competitively. Many kinds of rock contain nearly all

39. *Id.* at iii.
40. *Id.* at 7.

the elements; new mineral supplies will be obtained as controllable energy becomes cheaper by separation of such rocks into their component parts. Large mining monopolies cannot afford to apply the latest advances in science and technology, and large companies account for approximately two-thirds of the minerals produced in this country. More publicly supported fundamental research in mineral explorations and extractive metallurgy is recommended.

The Council concurs in the oft-repeated recommendations for more research to improve the production of wood, water, wildlife, and recreation in our forests and on our ranges. Prediction of a four-fold increase in recreation use is not accompanied by a warning of the destructive nature of uncontrolled recreation activities. Federal research is essential to guide research development, improve fire protection, and rehabilitate depleted ranges and watersheds. The present and potential research investment of private ownership, and its relationship to federal programs, is not extensively discussed.

Because the government is the nation's "largest ultimate user of raw materials" [sic] it is directly concerned "that these materials shall be obtained at the lowest possible real cost and that they shall be used in the most effective manner . . . ."[41] One wonders whether the Council believes that the condition and health of the environment should enter into the computation of real costs. The importance of resources and public works upon national security are emphasized.

There follows consideration of the importance and scope of the government's role and leadership in resource conservation. It provides, protects, manages, and advances "long range technical developments in resource utilization . . . beyond the capacity or interest of the private sectors."[42] The Council points out: "Control of pollution of water and air, protection of public health and of wildlife against agricultural pesticides and livestock disease, and encouragement of wise use of flood plains are increasingly important Federal activities."[43]

Government's increasing support of university teaching and research to produce highly trained scientific and engineering manpower is covered in three lines in the report. The particular need today

41. *Id.* at 10.

42. *Id.* at 11.

We recommend examination of Cooley, Politics and Conservation (1963), for an example of the failure of both government and the private sector to conserve a resource—the Alaska salmon fishery.

43. Federal Council for Science and Technology, *op. cit. supra* note 37, at 13.

for more and better training in the life sciences is not specifically mentioned.

International activities in the resource field are described from the economic viewpoint without further reference to ecological influences or consequences.

The report turns then to federal research and development activities: to help make decisions, to carry out action programs, to increase knowledge and understanding for public use, and long range development. The Federal Council agrees with the Academy-Research Council on the need for development of new analytical methods and procedures "relevant for analysis of resource policy issues . . . and assessment of the implications of such analysis for existing programs and policies."[44]

In its final recommendations for future research and expenditures, the Federal Council recommends that biological resources research should increase over the next ten years from 219 million dollars proposed for 1964 to a level of about 500 million dollars. It points out that the total now spent on water resources research is still less than one-half of one per cent of the nation's annual investment in water facilities. Recommended expenditures for research in mineral resources, land resources, and the air as a resource and, finally, on the economics of resources are also significant in amounts and progressive in character.

The report concludes: "Those who guide and plan research on resources economics are urged to attempt to remedy the present fragmentation of resource economics research and consider ways to meet the need for expansion of professional training in resource economics."[45]

CONCLUSION

We have tried to present a fair taste of the flavor and some hint of the scope, value, and comprehensiveness of these two reports. Excerpts, paraphrases, and comment are intermingled without apology, and we believe without derogation of the sense and purpose of the reports of the two groups. An impelling urgency runs throughout both reports.

There is extraordinary breadth in the Academy-Research Council's interpretation of the ecological problems we face. The Academy-Research Council's report is a literate plea for new vistas, new

44. *Id.* at 16.
45. *Id.* at 29.

approaches, and more systematic study of the interdependencies of mankind and the resources, both natural and technological, by which the amenities of *all* life may be sustained despite inordinate pressures of human numbers and material progress. The list of consultants and participants in the Academy-Research Council's study effort is very impressive.

The Federal Council's report signals a new emphasis on natural resources research as one of the more important sectors of the growing science in government. It portrays strengths, and also weaknesses, in present federal government research and development efforts. Its lack of emphasis on ecological problems may be the result of failure to seek, as did the Academy-Research Council, opinions and counsel of industrial research groups, private institutions, private foundations, and learned societies promoting scientific and technical research on natural resources. One cannot help wonder, in reading both reports at one sitting, why more of the ecological thought in the Academy-Research Council's study did not carry over into the Federal Council's recommendations.

What is the lesson of these two reports? Should we not, under the aegis of the properly growing prestige, competence, and leadership of the NAS-NRC take first steps at once toward the earliest realization of the vision of an "intelligence organization" briefly discussed in the review of Weiss' report, *Renewable Resources*?[46] This is by far the most exciting and challenging recommendation of both committee studies. The summary report has boiled down this recommendation until it urges, in substance, only another "interagency research integrating committee." This is concurred in by the Federal Council which envisions its own committee on natural resources as the organ to assume this integrating function. However practical under existing administrative comprehensions another interagency committee may be, the recommendation wholly lacks the grand design envisioned to cultivate a requisite scientific overview and to assess incipient deteriorative developments in our natural resources endowment "before they reach critical dimensions."[47]

A Resource Science Clearing House, supported perhaps by National Science Foundation grants, should be established now, through the Academy-Research Council, to assemble information on environmental research in progress everywhere and on environmental research that ought to be initiated and supported, in all disciplines,

46. See note 21 *supra* and accompanying text.
47. Weiss, *op. cit. supra* note 7, at 15.

by government, private institutions, universities, and foundations—along with a special analytic unit on identification and warning of predictable disruptions in ecosystems. Simple as such a first step may appear, in comparison to the total prescription in the Weiss report, it should have the benediction of mankind. This would be an approach in far greater depth and potential than the quite bland and now stereotyped appointment of another federal interagency committee.

How practical is this recommendation? The scope of the required intelligence is enormous, and the cooperating disciplines are inclusive. The semantic problems present almost insurmountable difficulties at this time. Assuming such an agency could evolve and keep itself informed on all environmental and social aspects of present and anticipated events and developments relating to human welfare, how could its leaders restrain themselves from involvement in the action arena. To know so much, to foresee so much, and to arrive at informed interpretation is to "have to act," or else surrender the very vision they were selected to evolve and implement. Surely the objective of this ideal is devoutly to be sought. Nothing short of such continuous, interdisciplinary intelligence is likely to anticipate crises and identify in advance optimum means "to forestall, counteract or rectify predictable *future* disruptions and imbalances of the human ecosystems."[48] This ultimately imports intelligence of international scope—FAO, WHO, UNESCO, and the "Ecological Mind" united into a pictured organization greater by far in analytical acumen about the natural resources environment than anything the United States, or the world, has yet known.

Of what relevance and importance are the two reports to an interpretation of modern conservation trends? That there have been extensive changes in the conservation movement during the past six decades is obvious to all serious students of the movement. In the early era, the process involved the building of agencies of public administration and the training of technicians and scientists who could construct the system of conservation technology and controls then needed. The principal aim of the early conservation movement, according to historian Elmo Richardson, was one of destroying the evils of economic and political monopolies by enlarging the responsibility and power of government. Another historian, Samuel P. Hays, views the early era as, above all, a scientific movement, and its role in history as rising from the implications of science and technology

48. *Ibid.*

in modern society. Conservation leaders sprang from such fields as hydrology, forestry, agrosology, geology, and anthropology. Vigorously active in professional circles, these leaders brought the ideals and practices of their crafts into federal resources policy.

Today conservationists are not inclined to look back to the bustling laissez-faire era of the early twentieth century as the source of inspiration in isolating conservation problems; nor are they particularly troubled by the lack of aggressive government intervention and leadership in technical management of natural resources. The structure of the American economy has changed radically in recent decades; and, with the rapid development of federal interest in "resource planning," the control and management of natural resources by coteries of federal technicians has come to be recognized as one of the primary ingredients for ensuring the rational use of the nation's resource endowment.

The new conservation that has taken shape accepts the successes of the early conservation crusades. An essential problem in modern conservation is to improve the policies, programs, and approaches of the established institutions. Now a more sophisticated society of technology, public resource administration and management institutions, and professional planning is advancing. The emerging generation of professional, natural resource-oriented individuals is taught administrative science, policy formulation, cost-benefit analysis, planning techniques, underwater resource exploration, pollution chemistry, materials research, landscape design, and many other technical and scientific aspects of resource-conversion. Most of these disciplines are reflected in the reports of the NAS-NRC and FCST.

Present-day knowledge in these highly specialized resource areas is vast; so vast, in fact, that it is difficult to associate men and ideas, as was so easy in the earlier period of the conservation movement. Also, it is much more difficult to isolate specific resource issues and undertake dramatic conservation drives which are easily comprehended and supported by large segments of the lay public. Contributing to this problem is the professional's tendency to be concerned with only a part of the resources problem rather than the whole. Today we do not have many expositors of the ecological view.

In the years ahead, we shall probably find ourselves relying more and more on interdisciplinary committees instead of individual expositors as the source of guiding principles for resource research and underlying philosophical viewpoints. It is praiseworthy that the

NAS-NRC Committee on Natural Resources saw the fundamental resources problem so clearly:

> Perhaps the most critical and most often ignored resource is man's total environment . . . . The study of the interaction of all biologic species, among themselves and with the inanimate forces of nature, requires coordination of the contribution of all sciences, natural and social. The wisdom of examining environment in the totality of its interaction with man becomes increasingly apparent in view of the rapidity of environmental change in our country. We live in a period of social and technological revolution, in which man's ability to manipulate the processes of nature for his own economic and social purposes is increasing at a rate which his forebears would find frightening. . . . It would seem unwise to continue to tamper with environment without, concurrently, striving to determine the real and lasting effects of our actions. [49]

This is a sound, ecologic view of the contemporary resources situation—one we hope will become the philosophical base of future conservation effort.

49. National Academy of Sciences-Nat'l Research Council, *op. cit. supra* note 13, at 18, 21.