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Ecology, Planning, and River Management in the United States: Some Historical Reflections

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ABSTRACT. River ecologists are also river-basin planners. However, their role in planning has developed slowly over the decades since the beginning of the 20th century. Three major factors explain this phenomenon. First, ecologists focused on plant and animal communities rather than on broader policy issues related to land settlement and water development. Second, the federal government, and most state and local governments as well, used mainly economic criteria to justify projects. Intangible benefits, including the value of species or an aesthetically pleasing landscape, drew relatively little attention. Third, the public generally favored development, especially during the Great Depression of the 1930s. Only after World War II did the public's position shift in favor of more preservation, as ecologists developed the concept of the ecosystem, large dam projects forced basin inhabitants from their homes, and chemical and nuclear pollutants threatened the environment. Also, urbanization increased support for the preservation of recreation sites and of streams undisturbed by human intervention. Meanwhile, partly through important advances in geomorphology and hydrology, ecologists acquired new tools to understand the land-water relationship within river basins. Neverthless, benefit-cost analysis continued to dominate federal water-resources planning, and organizational culture and competing or overlapping bureaucracies hampered rational water resources administration. Environmental groups and physical, natural, and even social scientists began to promote alternative ways to develop rivers. Today, the ideas of integrated water resources management, sustainable development, and comprehensive river-basin management dominate much of the thinking about the future course of river planning in the United States. Any future planning must include ecologists who can help their planning colleagues choose from among rational choices that balance ecological and human demands, provide advice when planning guidance is drafted, assist engineers in designing projects that lead to ecologically responsible solutions, and help monitor results.

Key Words: *history; ecology; river basins; water management; planning; benefit-cost analysis; multiobjective planning; river restoration; geomorphology*

INTRODUCTION

Ecology is as much, and perhaps more, social science than physical science, because it deals with relationships among all living creatures, including human beings, and their connection with the nonliving world. For ecologists engaged in the restoration of natural systems such as floodplains, the relationship with social science is particularly close. Even the most reductive and mathematical presentations at the Second International Symposium on Riverine Landscapes in Storforsen, Sweden, could not totally ignore issues dealing with social dynamics. Other presentations focused more explicitly on production and consumption and on reconciling human needs with sound ecological science. The common denominator was the implicit insistence that ecological science could help resolve the problems visited upon the world by applied science and engineering. The truth was that nearly all the presenters showed that river restoration was an exercise in planning as much as science, and that the best river restoration ecologists share some of the social science skills and much of the aptitude of professional planners.

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This essay attempts to put ecology as a planning tool in some historical context, but first we need to understand the important ways in which ecology departs from many other sciences. Perhaps most significantly, rather than extending mankind's technological control of nature, ecologists often constrain technological applications. Trade-offs are required, and in the process ecologists essentially become nature's advocates. Moreover, ecologists and other scientists may spend a very long time, and often a substantial amount of money, obtaining and accurately measuring objectives, and some results may not even occur in the area being restored. Success often requires adaptive management techniques.

Finally, and most important, ecology, and perhaps especially ecological restoration, threatens the way mankind, at least Western civilization, has historically arranged its affairs. Ecologists do not fear technology but have suggested that technology by itself is rarely the complete answer and may even provoke disaster. Periodic floods and droughts support this view. Added to this technological uncertainty is the question of mankind's role in the divine order. Former U.S. Secretary of the Interior James Watt made reference to this question when he observed that the Bible advises us "to occupy the land until Jesus returns" and that environmentalists are "the greatest threat to the ecology of the West [i.e., of the western United States]" (Reuss 1992). Whether one agrees with Watt or not, ecological restoration may affect not only the geography of the Earth but also the landscape of the mind.

ECOLOGISTS ON THE MARGINS: EARLY 20TH CENTURY RIVER-BASIN PLANNING

Riverine ecologists deplore the human alterations that have degraded and depleted water, contributed to disease and species loss, increased invasive species, and affected the natural movement of material between ecosystems. Through river restoration and the modification of human behavior, they hope to salvage the advantages of natural systems, such as clean water, species restoration, increased biodiversity, improved public health, and even the economic benefits resulting from a restored commercial fish and wildlife population. These ecologists transcend the boundary between pure science and applied resource management, whether the latter is called "ecosystem management" or something else, i.e., between the science that seeks to understand and the science that seeks to direct. Their rivers are "natural laboratories" to be preserved for science and protected from human disturbances.

This ecological perception goes back a century or so. Barrington Moore, former president of the Ecological Society of America (ESA), which was established in 1915, provided one example. He came before the House of Representatives Agriculture Committee in 1923 to protest the draining of bottomlands along the Upper Mississippi River for agricultural use. He represented 26 different organizations, including the ESA, the Sierra Club, the National Geographic Society, and the American Automobile Association. The ESA, he pointed out, had been working to develop reserves as outdoor laboratories, but drainage activities threatened to destroy the opportunity to learn more about natural processes and functions. Focusing on one stretch of wetlands along the Upper Mississippi, the Winneshiek Bottoms, Moore argued that it had a "remarkable assemblage of plants, fishes, birds, and other animals ... To drain that area, even though it were valuable for agriculture, which it is not, would be the same as destroying a library which contained manuscripts of which there were no other copies" (Anfinson 2003).

Moore's argument probably availed him little in political circles. Former Secretary of the Interior Franklin K. Lane, an attorney by training, exemplified the prevailing climate when he declared in a commencement address at Brown University in 1916, "The mountains are our enemies. We must pierce them and make them serve. The sinful rivers we must curb" (Pisani 2002). For Lane, conservation meant reigning in capricious and wasteful natural forces and managing the environment for the betterment of the human population. His statement seems today both arrogant and subversive, but in fact it mirrored a conservation ethic that typified the Progressive Era (ca. 1900–1920) in the United States and the Age of Positivism in Europe, although no doubt many would have questioned the ability of rivers to sin. Rather than preserving stretches of river bottomland, "nature's libraries" according to Moore, for study and enjoyment, conservationists urged the maximum exploitation of the nation's freshwater; the less water "wasted," the better.

For many conservationists, the way to reduce "wasted" water was through multipurpose river development. They championed the harnessing of rivers to satisfy a multitude of human needs, including hydropower, navigation, water supply, flood control, and irrigation, although some engineers questioned whether all these needs could be technologically reconciled. For instance, hydropower favors relatively full reservoirs, whereas flood control requires reservoirs to have reserve capacity to handle floods from upstream. In all cases, the emphasis was on production and consumption, i.e., the maximum use of the water resource consistent with its replenishment. The idea grew out of increasing demands for irrigation water in the western United States and for hydropower throughout the country.

Even though multipurpose development clearly subordinated natural processes to human requirements, there is little evidence that ecologists attacked the concept as a whole. Rather, like Moore's argument about the Upper Mississippi wetlands, protests were directed against the destruction of particular regions. Given the dominant ecological focus of the time, this can hardly be surprising. As editor of the journal *Ecology,* Moore had suggested in 1915 that ecology was an integrating science, but his peers generally stayed closer to the ground and limited their studies to individual plant and animal communities. Indeed, another distinguished ecologist, Victor Shelford, in 1919 defined ecology as "the science of communities" (Worster 1977). Highly empirical research in these communities, accurate description, mathematical analysis, and inductive reasoning would lead to new insights about the laws of nature (Kingsland 2004). This approach honored its 19th century forbears, Alexander von Humboldt and Charles Darwin.

The "science of communities" appeared tailor-made to fit regional planning efforts during the New Deal of President Franklin D. Roosevelt in the 1930s. New Deal planners believed that regional administration, as exemplified by the Tennessee Valley Authority (TVA), resulted in better integrated and more economical plans. They envisioned flexible administrations capable of responding to social shifts. Often under the umbrella of the Social Science Research Council, numerous social and natural scientists, ecologists among them, became involved. Questions emerged that crossed disciplinary boundaries. Were engineering solutions economically efficient and socially beneficial? How should regions be defined, i.e., culturally, economically, common natural resources, drainage basin, etc.? What should be the objectives of regional planning, and did these objectives threaten traditional institutions and life-styles? Hypotheses about social and administrative behavior abounded, with the TVA serving as a prototype (Reuss 1992).

The TVA itself funded many regional studies. Perhaps this helps explain why so much planning attention centered on river basins. Other reasons include the ongoing interest in multipurpose river planning and the ability to define a drainage basin unambiguously. Nevertheless, nature's topographic boundaries, no matter how well defined by elevation and water flow, do not necessarily coincide with the boundaries set by technology and economics, not to mention politics. As long as planners focused on navigation and flood control, on the control of the water in short, river basins worked well. However, when they considered hydropower, transportation, agriculture, industry, and land use, the drainage basin worked less satisfactorily, because these activities touched areas that often crossed drainage-basin boundary lines. Geographers in particular became quite enthusiastic about multipurpose river-basin planning, although some political scientists doubted that river basins could serve as "decision arenas" because of congressional resistance and doubts about their economic efficiency (Reuss 1992).

The study of specific plant and animal populations definitely complemented regional planning efforts. Nevertheless, although the data gathered certainly led to a greater understanding of the interdependence within the natural world, ecologists still remained uncertain of the dynamics at work. Some emphasized competition theory in a Darwinian framework; others saw cooperation as the dominant motif even though the tide of fascism and militarism encircling the globe contradicted such optimism. In short, ecological investigations did not always lead to greater theoretical understanding.

By the late 1930s, however, far more intellectually exciting ideas from the UK attracted growing attention in the United States. In 1927, Cambridge zoologist Charles Elton had published his major work, *Animal Ecology,* which set forth the concept of a food chain linking the smallest to the largest animals. This was an integrated vision of producers and consumers with a place, i.e., a "niche," reserved for every organism in the chain. In this way, Elton defined a species by what it did rather than by its structure. Then, in a 1935 essay, Oxford botanist A. G. Tansley took Elton's insight a significant step forward, when he dismissed the ideas of both a food chain and separate plant and animal communities. Instead, he proposed the "ecosystem," a concept that integrated living and nonliving substances. Not food but energy flow, i.e., the exchange of energy and of chemical substances such as water and nitrogen, defined an ecosystem. The young American scientist Raymond Lindeman produced a scientific paper in 1942, "The Trophic-Dynamic Aspect of Ecology," that merged Tansley's and Elton's concepts. He suggested that organisms could, in fact, be divided into consumers and producers that are further divided into different levels. Energy is transferred from one level to another, with some energy being lost with each transfer (Worster 1977).

No matter how exciting, the idea of the ecosystem arrived too late in the United States to have any impact on New Deal regional planning studies. Ecology supplied few theoretical tools to the natural resources planner of the 1930s. Ecologists remained marginal players who provided data and interpretation, but not a coherent conceptual framework with which to view river basins. Their impact on river basin planning would come only after the middle of the 20th century.

SCIENCE AND SCIENTIFIC MANAGEMENT

In looking back at the development of river basins in the United States, it is easy to exaggerate the influence of the Tennessee Valley Authority (TVA) and other regional planning efforts. The fact is that, until the 1960s, Congress opposed most regional planning efforts and prevented the development of other regional basin commissions based on the TVA model. Neither President Roosevelt nor President Harry S. Truman, for instance, prevailed in arguing for a Missouri River Basin Commission. Nevertheless, although Congress opposed political innovation, it embraced with some enthusiasm the idea of scientific management, an idea that had emerged during the Progressive Era. In the aftermath of the catastrophic Dust Bowl of the 1930s, Congress was especially eager to encourage investigations of the relationship between land and water. In 1935, it authorized the creation of a Soil Conservation Service within the Department of Agriculture to help farmers. Then in December 1936, a distinguished group of civil servants, constituted as the Great Plains Committee and chaired by Morris Cooke, head of the Rural Electrification Administration, issued a unanimous report that concluded that the Dust Bowl was caused entirely by misguided agricultural practices reaching back three-quarters of a century. Members embroidered their analysis with a kind of pop ecology: "Nature has established a balance in the Great Plains by what in human terms would be called the method of trial and error. The white man has disturbed this balance; he must restore it or devise a new one of his own" (Worster 1977). If their warning were ignored, the result would be a perennial desert in America's heartland. Scientific management was the key to success.

Government research laboratories took the lead. Gifted scientists and research engineers, some of whom had looked in vain for university positions during the Depression, studied sediment transport, bed movement, and turbulence in rivers. Academic laboratories, some built with New Deal government funding, became allies in this effort. New government flood-control projects put a premium on understanding river behavior. At the Corps of Engineers Waterways Experiment Station in Vicksburg, Mississippi, engineers gained insights into the river meandering process. At a Soil Conservation Service experimental station in Greenville, South Carolina, Hans Albert Einstein, the son of the physicist, and others began to develop a statistical explanation of sediment transport. Across the continent, at another Soil Conservation Service laboratory at the California Institute of Technology, hydrologist Hunter Rouse formulated a groundbreaking equation to describe the distribution of suspended sediment in open-channel flows. All these efforts contributed to a better understanding of the ways in which water and sediment interacted. They all also responded to engineering problems, often resulting from specific project designs or operational challenges, rather than to scientific theory.

At the same time, major advances in geomorphology contributed to the scientific understanding of the drainage basin as an integrated unit. Here, too, the federal government made important contributions. Going back to the 19th century, John Wesley Powell's government-sponsored western explorations had given him the idea that the physical history of a region could be read from a study of its drainage system in relation to its rock and mountain structures (Chorley et al. 1964). Powell's colleague Grove Karl Gilbert saw the Earth's landforms working toward a state of "dynamic equilibrium" in which the forces of erosion, including water, would equal the forces of resistance. Gilbert observed the inverse relationship between amount of water and the slope of the land from a river's mouth to its source. He molded his observation into what he called the "law of divides" and concluded that, in accordance with this law, mountains are steepest at their crests. Indeed, Gilbert maintained, the Earth's topography can be explained solely in terms of the laws he advanced (Gilbert 1877, Chorley et al. 1964).

Gilbert influenced geographer William Morris Davis's concept of a "geographical cycle," an idea that in its emphasis on evolution may have also reflected Darwin's profound impact on late 19th century science. For Davis, the river dominates the landscape, passing through successive states of youth, maturity, and old age. He spoke of a "geographical cycle" that melded geological structure and erosive processes into an ever-changing landscape. If you can identify the landscape, you will know its age (Chorley et al. 1964). Gilbert and Davis provided descriptive and theoretical tools that profoundly changed hydrology. Equally important, in linking land and water, they compelled hydrologists to appreciate the entire river basin, not just the water running through it. Their influence was so pervasive and their writing so compelling that their descriptive approach held sway in hydrology for more than 50 years.

Only in the mid-20th century did engineers, hydrologists, and geomorphologists successfully introduce quantitative analysis into geomorphology. This transformation produced a much more useful tool for understanding the development of drainage basins and stimulated important conceptual advances in both hydrology and ecology. Indeed, it helped render hydrology an acceptable science in the classical sense by illuminating fundamental natural laws and relationships, rather than simply functioning as an adjunct of engineering more narrowly focused on the accumulation, interpretation, and application of data for water projects. Hydrologist Robert Horton initiated this transformation in 1945, when he published a 95-page article with 40 figures in which he proposed a new "law of stream lengths" that showed a constant relationship between the number of streams of different orders, from main stem to subtributaries, within a basin (Horton 1945).

Horton's article initiated a general reevaluation of Davis's historical and qualitative geomorphology. The influential American geomorphologist Arthur N. Strahler decried Davis's methodology as "a superficial cultural pursuit of geographers that is completely inadequate as a natural science" in a rather courageous speech in 1950 before the Association of American Geographers (Strahler 1950). He later observed that "Davis himself maintained that the aims of his method were geographic; that the consideration of process was introduced merely to permit an orderly genetic system of landform classification." However, if geomorphology were ever to achieve full stature as a branch of geology, "it must turn to the physical and engineering sciences and mathematics for the vitality which it now lacks." According to Strahler, the successful geomorphologist will be "trained as a geologist, [who] has built up a life-time store of information and experience, much of it relating to theoretical and historical aspects of geology." Geomorphologists, Strahler proposed, should study processes and landforms "as various kinds of responses to gravitational and molecular shear stresses," develop quantitative determinations of landform characteristics and causative factors, formulate empirical equations using mathematical statistics, build on the concept of open dynamic systems, and, finally, "deduce general mathematical models to serve as quantitative natural laws" (Strahler 1952, Sack 1992).

Luna Leopold carried Strahler's battle to the hallways of the U.S. Geological Survey, where he began work in 1950 just as he was completing his doctorate at Harvard. He soon found himself out in Wyoming with his friend, John Miller, another Harvard Ph.D. Together, decades before such investigations became common, they studied the impact of climate change on river valleys. Along the way, Leopold became intrigued with the question of why rivers have particular widths. He and another colleague, Thomas Maddock, Jr., completed a paper on "The Hydraulic Geometry of Stream Channels and Some Physiographic Implications" in 1953 that was published by the Geological Survey. In this paper, Leopold and Maddock showed a mathematical relationship between river width and discharge. The paper initiated a new approach to fluvial geomorphology called "hydraulic geometry." In 1964, the book

Fluvial Processes in Geomorphology was published, co-authored by Leopold, M. Gordon Wolman, and Miller, who died before the book went to press. The book quickly established itself as a basic work on the subject, and Leopold's integration of geomorphology into hydrology helped put hydrology on a sound scientific footing within the federal government (Leopold and Maddock, Jr. 1953, Leopold et al. 1964).

By the middle of the 1950s, new and exciting concepts and research had energized the ecological community. Developments in geomorphology and hydrology contributed a much more sophisticated understanding of the natural operation of the drainage basin, and the idea of the "ecosystem" provided a holistic explanation of the interdependency of living and nonliving substances. However, unlike economists and geographers, ecologists did not appear eager to translate new concepts and theories into government policy. The nation's stewardship of its natural resources deferred more to economics, engineering, and politics than to science.

BENEFIT-COST ANALYSIS AND MULTIOBJECTIVE PLANNING

In 1933, Luna Leopold's father, Aldo, wrote an essay on "The Conservation Ethic" that criticized those who valued land strictly in economic terms. Subsequently, the renowned forester and game management expert, and later president of the Ecological Society of America, increasingly viewed scientific management with suspicion because of its emphasis on economic rather than ecological benefits (Worster 1977). He also implicitly insisted that mankind was part of nature and not outside of it. At the time, even some of Leopold's ecological colleagues casually wrote of human impacts on ecosystems as though natural ecosystems excluded humans; conversely, any human intervention rendered ecosystems artificial. In the two decades following World War II, Rachel Carson's *Silent Spring* (1962), fears of nuclear devastation, and real and imagined chemical threats to land and water strengthened this perception. It appeared that humans were incapable of improving the natural world; they could only degrade or destroy it. Indeed, some would go further and argue that any change to the natural world degraded both the world and its corrupters. That position influenced both ethics and science, and only during the environmental era that began around 1970 did that perception change. Today, most ecologists accept humans as an integral part of ecosystems, for good or ill.

Nevertheless, economics, not ethics, has justified water projects in the United States since the origins of the Republic. As Leopold observed, nature had become commodified, and the value of flora and fauna, water and land, was reduced to dollars. Congress completely embraced the concept in the Flood Control Act of 1936, which for the first time stipulated that flood control "was a proper activity of the Federal Government in cooperation with States, their political subdivisions, and localities thereof." The act required that no flood control project should be built if the benefits "to whomsoever they may accrue" did not exceed costs. Although born of a need to rationalize the planning process in some way, benefit-cost analysis proved devilishly hard to implement in practice. The planning community faced fundamental problems in developing rational and equitable procedures. Questions ranged from definitions of national interest or flood "damage" to what constituted tangible and intangible benefits. Intangible benefits might include the value of a deer, woodlot, or wetland; the value of recreation or of a positive aesthetic experience; or even the value of a human life. In all cases, value was to be transformed into market price. Subsequent amendments and modifications to the Flood Control Act eventually extended benefit-cost analysis to all federal water resources projects, including large multipurpose dams (Arnold 1988, Reuss 1991, 1992).

Benefit-cost analysis essentially marries market principles to the utilitarian philosophy of Jeremy Bentham. It suggests that obtaining "the greatest happiness for the greatest number" is a matter of using available resources to optimize social welfare benefits. In the 1930s, a popular economic idea was "Pareto Efficiency," in which no individual could be made better off without leaving someone else worse off, but it was basically naïve, because few policy changes involve situations in which literally no one loses. The major advantage of benefit-cost analysis is that it imposes discipline on public choice so that scarce resources are rationally allocated in ways that ensure their highest possible value. It also provides a means for addressing social problems systematically. In fact, benefit-cost analysis in the abstract negates the necessity for any public input.

The problem is that, in democratic countries, public interests and pressure groups distort this process, for better or worse. The economists' rule of reason is transformed into the rule of consent. The rule of reason is further imperiled when normative beliefs impinge on a process that is supposedly non-normative, i.e., based on market price. Any decision on the value of human life or of a particular habitat, for instance, must be based on some normative calculation. One can go still further and argue that non-normative calculations based on actuarial standards and economic data will still result in normative solutions. For example, the use of historical data on farm production or the wealth of different populations would tend to ensure that the future would replicate the past; higher net project benefits would be assigned to higher net worth, whether of land or people. None of these methodological obstacles would in themselves doom benefit-cost analysis if the calculations were used only as a guide and framework for addressing social concerns. The methodology might then be considered simply a pragmatic and even morally responsible approach. Instead, benefit-cost analysis became the basis for establishing formal federal decision-making criteria. Against a background of changing values, new technology, and new science, experts and policy makers hammered out these criteria over the two or three decades following passage of the Flood Control Act of 1936 (Byrne 1987). Despite changes in the criteria to embrace, or at least acknowledge, emerging environmental values, benefit-cost analysis, with its heavy emphasis on market price, became a red flag teasing a confused and angry public.

As practiced, benefit-cost analysis raised substantial ethical issues almost from the time the Flood Control Act enshrined the practice. Economists insisted that the social value of income generated by a project remained the same whether the project benefited poor or wealthy people. The ethics of such a position even bothered some of its proponents. Do, for instance, benefits "to whomsoever they may accrue" require that the protection of a millionaire's property on one side of the river be considered more beneficial than saving 10 poor hovels worth far less money on the opposite bank? This may be sound economics, but it is usually bad public policy. Benefit-cost calculations also require that social problems be treated independently to derive their "cost," when more often than not they are interdependent, e.g., disease, poor quality water, and inadequate education. Also, alternative solutions to social problems need to be commensurable and finite to make comparisons, a stricture that, among other things, leads to a bias in favor of structural vs. nonstructural, e.g., restrictions on land and water use and on types and number of buildings, flood-control solutions.

Nevertheless, probably the most fundamental objection to benefit-cost calculation is the inappropriate application of market prices. Other considerations aside, benefit-cost analysts would inevitably conclude that rich farmland should be protected before poor agricultural land or that urban areas should receive pollution protection before rural areas. However, public input and interest groups can change the calculus. Implicit recognition is given to the fact that social problems and objectives, including those associated with river control, are not only interdependent, but at least partially subjective. Given this, benefit-cost analysis, i.e., the rule of reason, is a poor decision-making tool. It often favors the status quo, fails to answer questions about equity and environmental justice, and assumes an economic climate at variance with reality.

A group of academicians at Harvard University thought that the innovative use of a new machine, the electronic computer, might resolve some of these problems. In 1955, they formed the Harvard Water Program, a multidisciplinary research and training program to develop new methodological techniques for water resources planning. The professors and their students used computers to develop physical and economic simulations of water systems. They also developed something that eventually was called "synthetic hydrology": computer-generated predictions of future hydrologic activity and impacts. This approach reduced reliance on historical data and integrated physical, social, and economic data into the programs. Finally, they developed a new approach to economic evaluation known as "multiobjective analysis."

Unlike benefit-cost analysis, which always seeks economic efficiency, multiobjective analysis designs water systems to address all the objectives sought by planners, including noneconomic values such as environmental quality or even the preservation of an ethnic neighborhood. While relying on computer simulations to identify the consequences of various options, it concedes that inevitably the decisions must be left up to the politicians or planners. Concerned groups must sit down, discuss the options, and determine trade-offs. This approach forces the various interests to develop priorities and negotiating positions. It demonstrates the need for interdisciplinary and intergovernmental cooperation in water resources planning (Reuss 1992).

However, this approach was expensive. Canvassing a broad range of options for the development of an entire river basin required considerable time and resources and often resulted in plans for projects that Congress refused either to authorize or to fund. In the late 1960s and early 1970s, the Bureau of the Budget, which after 1970 was known as the Office of Management and Budget, believed that multiobjective "framework" studies were grossly wasteful and refused to support them. Arguments that the studies would lead to better projects and more equitable solutions did not prevail. Given this situation, Congress, not the bureaucracy or technical experts, remained the great arbitrator. After 150 years of water resources development and a hodgepodge of statutes and executive orders, the United States still had no institutional framework for developing comprehensive water resources programs.

WATER RESOURCES PLANNING IN THE ENVIRONMENTAL ERA

Today, water planners in the United States and around the world are attempting to develop "comprehensive" water management plans. These plans are meant to apply to the entire watershed and are sometimes described as exercises in integrated water resources management (IWRM). The idea is to develop projects that contribute to economic development while respecting ecosystems and not degrading the environment for succeeding generations. This definition also applies to the concept of "sustainable development." Unquestionably, the two ideas have become linked in the public mind. Nevertheless, the conceptual allure of sustainable development has tarnished over time as it has become apparent that the term means different things to different people. Indeed, it can be manipulated in ways that may contribute more to political than ecological stability. Discussion often centers on the degree of allowable environmental degradation rather than the extent of necessary conservation practices.

Another imprecise term is "ecosystem management," which was popularized by Eugene P. and Howard T. Odum in the 1960s and early 1970s. In part, their work reflected the influence of their father, distinguished sociologist Howard W. Odum, and his groundbreaking studies on regionalism. Whereas the social science concept of regionalism recognized and attempted to preserve both cultural and natural regional characteristics, the Odums argued that ecosystem management holistically integrated physical and biological elements in the natural environment (Odum 1975). "Sustainability" is an objective of ecosystem management, just as it is for IWRM. Difficult questions remain concerning the priorities that should be given to various ecosystem functions and the degree to which they can actually be used to administer land and water.

Ecosystem restoration compounds the problems facing water resource planners. Restoration calls for a definition of a "natural system," but the term's imprecision leads to political consequences, matching agency against agency and interest against interest. Moreover, as science historian Sharon Kingsland has observed, it is not all that easy to reconstruct a significantly altered system. She notes that "nature will not automatically 'bounce back' and return to its former self" (Kingsland 2004). She might have added that it is not always possible to know what the "former self" was. Given the normal evolution of rivers basins, the proper term may, in fact, be "former selves." Is a "natural system" one that predates human intervention, one that has reached some sort of ecological balance, or something in between? In other words, what baseline data should be used? The answer could spell the difference between a $10 million or a $100 million project. Are stable systems composed of diverse species less vulnerable to outside interference than simpler systems or systems still not in balance? Finally, what assumptions should be made about mankind's future relationship with land and water, and what role will new technology or even new political arrangements play? Engineers occupy the central role in the design of water projects, but ecological input is critical in decisions regarding the type and degree of intervention to restore a system.

The challenges facing ecologists should not be understated. Despite the strides in integrating ecological concepts into river basin planning, the reality is that the technical literature inevitably favors hard engineering data. This may be especially true of flood control projects. In justifying such projects, traditional planners focus on potential flood damages measured in dollars and cents, whereas the scientific community addresses vague issues that are long term and often require subjective evaluation. Additionally, scientific investigations are often expensive and time-consuming; meanwhile, the flood threat remains. In short, engineers and economists use historical data and empirical analysis to predict the socioeconomic consequences of the “without project condition.” They confidently talk of the facts of flooding, i.e., the potential damages to life and property, while scientists argue about values, some of which cannot easily be empirically verified. Engineers remain cautious technological optimists who identify attainable goals, whereas scientists often only imperfectly define objectives.

In the United States, the bureaucratic response to water issues depends very much on organizational culture. In the period from about 1965 to 1985, a kind of institutional dissonance existed. With a tradition firmly linked to economic development, engineering agencies at the state and federal levels lagged in responding to emerging public environmental values. Perhaps this lag was predictable. Agencies not only have missions; they have attitudes. The Corps of Engineers, which arguably changed faster than most development agencies within the federal government (Mazmanian and Nienaber 1979), nevertheless used numerous civilian engineers and Army officers who believed that the agency’s mission was to “improve” rivers for navigation, flood control, and hydropower, not to compromise engineering safety or economic efficiency for the sake of preserving ecological services. Eventually, their attitude changed, and today the Corps of Engineers counts the “environmental mission” among its primary missions.

Although progress has been made in reorienting organizational cultures, efforts to eliminate organizational dysfunction such as the bureaucratic barriers that impede rational, scientifically valid administration have not been equally successful. For example, the hydrological cycle describes the integrated, interdependent circulation of water under, on, and above the Earth. Groundwater, surface water, and precipitation combine to determine river flows, floods, and droughts. Nevertheless, no one agency oversees all aspects of the water cycle. Instead, in the United States numerous agencies are involved. At the federal level alone, these include the Weather Service, the Geological Survey, the Environmental Protection Agency, the Army Corps of Engineers, the Natural Resources Conservation Service, and the Bureau of Reclamation. Literally, dozens of agencies and congressional committees and tens of thousands of people are involved in determining the regulation of river flows, pollution standards, flood insurance standards, and water availability for numerous purposes. No efficient, integrated approach to water control and development can come from such a large, overlapping, bureaucratic structure, and none seems likely in the foreseeable future.

CONCLUSION: A LOOK FORWARD

Competition and cooperation are not only present in ecosystems, but they also define bureaucratic organizations. In the case of the natural resource agencies charged to protect and/or develop the environment, the success or failure of ecosystem management might directly affect the stability of both the environment and the agencies themselves. Ecological stability might lead to greater cooperation among state and federal resource agencies. Conversely, ecological instability could threaten bureaucratic agreements and entice agencies to resurrect earlier, competing plans that reflect particular missions and organizational cultures. Planners and politicians may raise new arguments about appropriate flow lines at different times of the year or the merit of various ecological values. Old questions about how much a tree, flower, fish, or deer is worth will once again attract attention, no doubt with little consensus as a result. Attempts to remedy damage to an ecosystem will raise objections among some ecologists who oppose any mitigation that falls short of restoring the “natural system.” In fact, the mitigation may actually introduce new problems.

In effect, science has changed the relationship between the agencies and their missions. Greater ecological awareness forces both an ethical and professional transformation. The ethical change is undoubtedly the more difficult challenge. It requires the reconciliation of two seemingly disparate objectives: defense of the environment and the satisfaction of a broad range of human needs. Neither blasé insistence that the objectives are compatible nor the philosophical argument that nature has rights will likely force change in mankind’s attitude toward the environment. Instead, an environmental ethic must evolve that reconciles public choice, economic efficiency, and some sort of moral intuition. Balance is necessary, and in a democracy balance is always a moving target. Projects need to be affordable and supported by a broad range of diverse interests. Properly understood, an environmental ethic will reduce demands for water, stress that water is a finite resource, and insist that competing interests acknowledge mutual obligations for the sake of regional harmony. Constraints must be placed on public choice.

This approach to water resources planning can cause substantial turmoil within a water development agency. It requires new kinds of expertise and places more emphasis on process and less on product. Successful projects are not simply economically efficient but respond to a broad range of objectives with the least disturbance to the environment. Such projects may be nonstructural in nature and may even be as simple as new water-use agreements among regional parties. Planning is always holistic and comprehensive. Given this approach, ecologists must help transform agencies without sacrificing agency morale and technical expertise. They can help their planning colleagues choose from among rational choices that balance ecological and human demands, provide advice when planning guidance is drafted, assist engineers in designing projects that lead to ecologically responsible solutions, and help monitor results. For a truly sustainable world, ecologists must be firmly integrated into the planning process.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol10/iss1/art34/responses/

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LITERATURE CITED

Anfinson, J. 2003. *The river we have wrought: a history of the Upper Mississippi.* University of Minnesota Press, Minneapolis, Minnesota, USA.

Arnold, J. L. 1988. *The evolution of the 1936 Flood Control Act.* Office of History, U.S. Army Corps of Engineers, Fort Belvoir, Virginia, USA.

Byrne, J. 1987. Policy science and the administrative state: the political economy of cost-benefit analysis. Pages 70-93 *in* F. Fischer and J. Forester, editors. *Confronting values in policy analysis: the politics of criteria.* Sage yearbooks in politics and public policy, Volume 14. Sage Publications, Newbury Park, California, USA.

Carson, R. 1962. *Silent spring*. Houghton-Mifflin, Boston, Massachusetts, USA.

Chorley, R. J., A. J. Dunn, and R. P. Beckinsale. 1964. *Geomorphology before Davis: the history of the study of landforms or the development of geomorphology. Volume 1.* Methuen, London, UK.

Elton, C. 1927. *Animal ecology.* Macmillan, New York, New York, USA.

Gilbert, G. K. 1877. *Report on the geology of the Henry Mountains.* U.S. Department of the Interior, U.S. Geographical and Geological Survey of the Rocky Mountain Region, Washington, D.C., USA.

Horton, R. E. 1945. Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology. *Bulletin of the Geological Society of America* **56**:275-370.

Kingsland, S. 2004. Conveying the intellectual challenge of ecology: an historical perspective. *Frontiers in Ecology and the Environment* **2**:367-374.

Leopold, A. 1933. The conservation ethic. *Journal of Forestry* **31**:634-643.

Leopold, L. B., and T. T. Maddock, Jr. 1953. *The hydraulic geometry of stream channels and some physiographic implications.* Professional paper 252. United States Geological Survey, Washington, D.C., USA.

Leopold, L. B., M. G. Wolman, and J. P. Miller. 1964. *Fluvial processes in geomorphology*. W. H. Freeman, San Francisco, California, USA.

Lindeman, R. 1942. The trophic-dynamic aspect of ecology. *Ecology* **23**:399-417.

Mazmanian, D. A., and J. Nienaber. 1979. *Can organizations change: environmental protection, citizen participation, and the Corps of Engineers*. Brookings Institution, Washington, D.C., USA.

Odum, E. 1975. *Ecology: the link between the natural and social sciences.* Second edition. Holt, Rinehart and Winston, New York, New York, USA.

Pisani, D. J. 2002. *Water and American government: the Reclamation Bureau, national water policy, and the West, 1902-1935.* University of California Press, Berkeley, California, USA.

Reuss, M. 1991. *Reshaping national water politics: the emergence of the Water Resources Development Act of 1986.* Institute for Water Resources, U.S. Army Corps of Engineers, Alexandria, Virginia, USA.

Reuss, M. 1992. Coping with uncertainty: social scientists, engineers, and federal water resources planning. *Natural Resources Journal* **32**:101-135.

Sack, D. 1992. New wine in old bottles: the historiography of a paradigm change. *Geomorphology* **5**:251-263.

Strahler, A. N. 1950. Davis' concepts of slope development viewed in the light of recent quantitative investigations. *Annals of the Association of American Geographers* **40**:209-213.

Strahler, A. N. 1952. Dynamic basis of geomorphology. *Bulletin of the Geological Society of America* **63**:923-938.

Tansley, A. G. 1935. The use and abuse of vegetational concepts and terms. *Ecology* **16**:284-307.

Worster, D. 1977. *Nature's economy: a history of ecological ideas*. Cambridge University Press, Cambridge, UK.