SCIENCE, ENGINEERING, AND THE PERCEPTION OF ENVIRONMENTAL RESTORATION

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I. INTRODUCTION

For the purposes of this Article, environmental restoration can be considered to be "the return[ing] of an ecosystem to a close approximation of its condition prior to disturbance."[1] The National Research Council recognizes three levels of possible restoration: (1) repairing the ecological damage; (2) recreating the structure and function of the ecosystem; and (3) emulating the natural resource.[2] These levels are incorporated into restoration goals as follows: "Merely recreating the form without the function, or the functions in an artificial configuration bearing little resemblance to a natural resource, does not constitute restoration. The goal is to emulate a natural, functioning, self-regulating system that is integrated with the ecological landscape in which it occurs."[3]

Several points stand out that are broadly applicable in environmental restoration. First, action must be taken to achieve desired form, function, and other attributes of a system. It is the role of engineering to implement the actions decided upon by society. Engineering applies the best of our thought about such matters, which is generally equated to environmental science. Second, there is a desire to achieve some past condition of natural functioning, prior to damage or disturbance. This means that there is a historical dimension to the problem of restoration, and the best of our thought, or science of such matters, needs to

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1. NATIONAL RESEARCH COUNCIL, RESTORATION OF AQUATIC ECOSYSTEM: SCIENCE, TECHNOLOGY AND PUBLIC POLICY 18 (1992).

2. *See id.* at 19.

3. *Id.* at 18.

incorporate environmental history. Finally, there is a value judgment involved in deciding what is natural, or when one emulates nature, rather than merely recreates nature's function.

Belief can be pragmatically defined as a kind of behavioral disposition that causes one to act.[4] One can come to beliefs through various methods, including tenacity, reason, and authority, but it is the method of science that tends to cause beliefs to converge to a common position accepted by all who seriously inquire into some matter.[5] Unfortunately, as in many matters of public policy, environmental restoration does not just involve science. Values compel beliefs based on criteria other than scientific criteria. Because inquiry into such matters does not methodologically tend to converge, conflicts of belief are inevitable. In such conflicts, how one perceives the world is as important as scientific information on the objective aspects of the world. This Article explores the relationships of science and perception in achieving action on the issue of environmental restoration. The goal is to explore ways of transcending conflict that produces inaction.

Part II of this Article deals with the interrelating of science, engineering, and values in achieving action on environmental matters. These interrelationships have become a source of conflict, in part because of the misuse of science as an authoritative basis for the justification of action.

Part III examines science more closely, especially its historical varieties, which may be as essential to environmental affairs as the law-like, ahistorical sciences commonly applied to solving purported environmental problems. Historical sciences identify the realities of the time-varying environment, thereby identifying the environmentally relevant problem to be solved.

Part IV returns to the issue of achieving wise environmental action, but in the context of human perception. The role of science in regard to human perception of the environment is emphasized to contrast to the authoritative role described in Part II.

Part V proposes that both values and science can be combined into a pragmatic approach to resolving environmental issues.

II. SCIENCE, VALUES, AND ENVIRONMENTAL ACTION

It is one of the great myths of our time that science constitutes a repository of authoritative knowledge. The corollary to this myth is that action can be confidently based on this authority. The myth is sustained by definitions of science such as the following: "[A] branch of knowledge or study dealing with a

4. This idea, originated by the Scottish philosopher and psychologist Alexander Bain, formed the basis for the philosophy of pragmatism developed by Charles S. Peirce. *See* CHRISTOPHER HOOKWAY, PEIRCE 254–55 (1985).

5. *See* Charles S. Peirce, *Illustrations of the Logic of Science: First Paper—The Fixation of Belief*, POPULAR SCI. MONTHLY, Nov. 1877, at 1–15.

body of facts or truths systematically arranged and showing the operation of general laws."[6]

The problem is that this definition applies not to science, a process of inquiry into the world, but rather to a body of knowledge for which claims are made, including claims of truth and law-like operation. There can be no process of scientific inquiry into a truth; one merely has it. Scientific inquiry seeks to determine truths and law-like operations of nature. If these goals seemingly have been achieved, the only role left to science is to question them, or seek better ones. Ultimately, science as inquiry eschews authority. Science as authority is a form of hypocrisy.

The issue of science and authority is made more complex by the broad range of phenomena and scientific methodologies. At one end of this range is the experimental/theoretical methodology applied to phenomena that can be manipulated through controlled experimentation. Such phenomena have classically been studied by physics, which is "the science devoted to discovering, developing and refining those aspects of reality that are amenable to mathematical analysis."[7] Reductionist philosophers may argue, on nonscientific grounds, that all science eventually will reduce to physics. Nevertheless, it is clear that not all phenomena of the world yield to this type of analysis, whether one believes this to be an intrinsic property of those phenomena or merely the incomplete state of our knowledge about those phenomena. Because most environmental matters are of this type, it is necessary to explore the range of scientific styles needed for their understanding.

The approach of physics "is conceptual, seeking universal classes of phenomena that can be generalized by means of the underlying physical laws presumed to govern nature."[8] This style of science is focused on abstract entities, like theories, laws, models, and mathematical relationships, rather than on the particular things seen in the world about us. The latter are important to this type of science, but mainly as objects for testing or verifying the all-important abstract relationships embodied in models, theories, and laws. The term "system" is commonly employed in such science because this term designates abstracted objects and relationships that functionally can be tied together. In modeling such systems, the scientist must select from the natural world those elements believed to represent essential workings of the world.[9] Because theories based on such selection are intrinsically fallible, they must be tested objectively.

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6. THE AMERICAN COLLEGE DICTIONARY 1086 (C.L. Barnhart ed., 1970).

7. JOHN ZIMAN, RELIABLE KNOWLEDGE: AN EXPLORATION OF THE GROUNDS FOR BELIEF IN SCIENCE 28 (1978).

8. Victor R. Baker, *Hydrological Understanding and Societal Action*, 34 J. AM. WATER RESOURCES ASS'N 819, 821 (1998).

9. *See* Victor R. Baker, *Palaeohydrology and the Hydrological Sciences*, *in* PALAEOHYDROLOGY AND ENVIRONMENTAL CHANGE 1, 2 (G. Benito et al. eds., 1998).

The professional culture of the mathematical/predictive/experimental/theoretical scientist involves a world of objective facts, proofs, rational methods, measurements, and incremental progress. In contrast, the world of policymakers revolves around subjective values, beliefs, emotions, perceptions, and deadlines or crises.[10] The way in which these worlds intersect to achieve policy can be partly understood by reflecting on the following principles:

1. The less the societal consensus on an issue, the greater the scientific certainty required for action; and
2. The higher the societal costs of a policy, the greater the scientific certainty required for action.[11]

Consensus and cost are political issues, so it is natural to claim some level of scientific certainty when consensus is needed or high costs must be justified. The mathematical/predictive sciences produce the highest certainty, so they are preferentially invoked for claims to authority in achieving political requirements in policy matters.

III. HISTORICAL SCIENCE AND ENVIRONMENT

The historical sciences lie at the other end of the physical science spectrum from the mathematical/predictive and experimental/theoretical. These sciences do not focus on idealized theories that can be definitively tested in experimental laboratories. Instead, they treat realized phenomena observed in the natural world, and uncontrolled by artificial constraints.[12] Rather than defining elements of nature (systems) capable of controlled study, the historical scientist must take the world (nature) as it is. Historical scientific study is focused on concrete particular happenings, the richest source of which lies in the past.[13] The study of the past comes from various indicators, including sediments, fossils, and other signs of natural operation. Such sciences are interpretive,[14] and they rely on a complex logic for the interpretation of signs.[15]

The interpretive/historical sciences include field ecology and many areas of geology. These are crucial environmental sciences that need to be involved

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10. *See* J. Christopher Bernabo, *Communication Among Scientists, Decision Makers and Society: Developing Policy-Relevant Global Climate Change Research*, *in* CLIMATE CHANGE RESEARCH: EVALUATION AND POLICY IMPLICATIONS 103, 105 (S. Zwerver et al. eds., 1995).

11. *See id.* at 106.

12. *See* Victor R. Baker, *Discovering Earth's Future in its Past: Palaeohydrology and Global Environmental Change*, *in* GLOBAL CONTINENTAL CHANGES: THE CONTEXT OF PALAEOHYDROLOGY 73, 75 (J. Bangon et al. eds., 1996).

13. *See id.* at 75.

14. *See* Robert L. Frodeman, *Geological Reasoning: Geology as an Interpretive and Historical Science*, 107 GEOLOGICAL SOC'Y AM. BULL. 960–68 (1995).

15. *See* Victor R. Baker, *Geosemiosis*, 111 GEOLOGICAL SOC'Y AM. BULL. 633–45 (1999).

more in the science and engineering issues of environmental restoration. If an ecosystem is to be returned to some past condition, prior to damage or disturbance, then one must determine the nature of that past condition. Moreover, there is an even more important role for interpretative sciences. To emulate a natural resource, environmental restoration projects require a knowledge of that resource. The resource is not just some static state; the resource is also a dynamic operation through time. One cannot confidently, yet arbitrarily, specify the appropriate time scale for an operating environmental resource. This time scale and its operations must be discovered, and the only source of real world information from which to make such discovery is the operation of that resource in the past. One learns of the latter interpretively, through study of the signs of past operation.

Just as a resource is not restricted to some static state in time, it also is not restricted to some arbitrary location in space. One does not specify the time and space of a resource for restoration in advance via fundamental laws or general principles. Rather, these must be interpreted from the natural indicators of the resource itself, operating through time and space. This is the most important role of the historical sciences.

Let us consider the example of ephemeral alluvial rivers in the sedimentary basins of the southwestern United States. Such rivers have long histories of channel change, incision, and aggradation, operating on time scales of several decades to centuries.[16] These rivers have also been disturbed by many types of human activity, including grazing, water withdrawal, and bank stabilization.[17] These activities often have severely impacted the plant communities that are developed along rivers.[18]

The "answer" to an environmental restoration problem on such rivers is generally a form of engineering. The engineer applies the best available theory, usually derived from mathematical/predictive sciences, to achieve an accurate representation of the system of interest. From this system, the engineer formulates a design that resolves the problem. The system is the key element here. It presumes the spatial character and operation of some river sector needing restoration, where the 'operation' implies some time period of natural river operation. Notice that this crucial step defines in advance: (1) what the relevant portion of the river is, and (2) what the relevant time period is. Of course, this must be done because cost considerations prevent one from engineering for all possible portions of the river and all time periods. This step is really the problem definition. It is, in essence, the "question" for which an engineering design will

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16. *See, e.g.*, Robert H. Webb & Victor R. Baker, *Changes in Hydrologic Conditions Related to Large Floods on the Escalante River, South-Central Utah, in* REGIONAL FLOOD FREQUENCY ANALYSIS 309–23 (Vijay P. Singh ed., 1987) (examining the patterns of flooding for the Escalante River).

17. *See generally* RONALD U. COOKE & RICHARD W. REEVES, ARROYOS AND ENVIRONMENTAL CHANGE IN THE AMERICAN SOUTH-WEST (1976).

18. *See* Julie C. Stromberg et al., *Effects of Groundwater Decline on Riparian Vegetation of Semiarid Regions*, 6 ECOLOGICAL APPLICATIONS 113, 113 (1996).

become an eventual "answer." But here we have a dilemma—how does one formulate the "question" when mathematical/predictive sciences are oriented to providing answers. They deal with abstract generalities. Does one pose the question in terms of these generalities?

In the case of southwestern rivers, engineering solutions have commonly been posed that solve problems as defined by the scientific analysts.[19] It is then discovered that what were thought to be answers later turn out to be new environmental problems. This is because the original problem definition ("the question") did not correspond to how the river actually behaved.[20] The new problems are often more intractable and expensive to resolve than the original.

The resolution of the above dilemma is in the use of historical/interpretive sciences to discover the actual operations of natural resource phenomena, such as rivers. Rather than arbitrarily posing the question for environmental restoration, one discovers in nature, via signs,[21] the natural operation of the resource, including its relevant temporal and spatial scales. This approach to environmental problem definition seeks naturally relevant questions, rather than efficient answers. It derives from a long geological tradition of studying indices of real processes operating in the past.[22]

IV. SCIENCE AND ENVIRONMENTAL PERCEPTION

It has long been argued by behavioral scientists that the direct perception of phenomena is more important to instilling belief than are abstract concepts.[23] In a democratic process of policy development, these beliefs must be incorporated as societal factors, equal in importance to technical information.[24] Thus, the abstract concepts used to provide answers to environmental problems cannot provide the authoritative basis for acting on those problems. Instead, the basis for action lies in the complex of factors that instill belief. The basis for action is more in the realm of percepts than in that of concepts.

Percepts are elements of a person's subjective experience of the world. They contrast the objective, detached abstractions that characterize concepts. Percepts refer to particular individual objects, and they exist in sensation,

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19. *See* Victor R. Baker, *Geological Understanding and the Changing Environment*, 44 TRANSACTIONS GULF COAST ASS'N GEOLOGICAL SOC'Y 13, 16 (1994).

20. *See id.* at 17.

21. *See generally* Victor R. Baker, *Geomorphological Understanding of Floods*, 10 GEOMORPHOLOGY 139 (1994).

22. *See* Frodeman, *supra* note 14, at 962–66.

23. Research on human perception of flood risk is an excellent example. *See, e.g.*, GILBERT F. WHITE & J. EUGENE HAAS, ASSESSMENT OF RESEARCH ON NATURAL HAZARDS *passim* (1975); C.H. Green et al., *The Risks from Flooding: Which Risks and Whose Perception?* 15 DISASTERS 227 (1991); S.A. Schumm, *Erroneous Perceptions of Fluvial Hazards*, 10 GEOMORPHOLOGY 129 (1994).

24. *See* Bernabo, *supra* note 10, at 104.

intuitions, and insights. Concepts, on the other hand, refer to universals, classes, and generalizations, and they exist in complex thought. Concepts are central to the realm of mathematical/predictive sciences, which have little relationship to percepts. However, because the interpretive/historical sciences deal with signs of real, particular phenomena, they have a role in the world of human percepts. These sciences thus have an affinity to the common sense perceptional basis that underpins human action.[25]

The accelerating power and versatility of digital computer technology is facilitating mathematical, predictive, and theoretical aspects of modern science. This advance, which receives great attention for solving problems like environmental restoration, is an advance in the application of concepts. However, what matters to the implementation of restoration policy are often the popular belief systems, grounded in local realities, that can be perceived by all participants in the policy process. Given present and foreseeable future levels of public scientific literacy, the public is unlikely to abandon its commonsense approach to the fixation of belief.[26] Powerful as conceptualizations may be for providing guidance to the potential engineering solutions to environmental restoration, they remain idealizations of lesser pragmatic significance in perception-driven restoration policy.

The interpretive/historical sciences explore the great repository of natural experience that is closely attuned to the human percepts that compel societal action. The results of these sciences can be used to trigger perception-based action by responsible decisionmakers. The role of this science is to call attention to potential problems and promote them into the policy agenda.[27] Thus, science should not be viewed solely as a basis for policy solutions; it should be involved in the process of policy development and appraisal.

V. A PRAGMATIC APPROACH TO ENVIRONMENTAL RESTORATION

Science relies on the branch of philosophy known as logic, or more generally semiotic (the doctrine of signs), which concerns what ought to be in regard to thought.[28] However, for policy in regard to environmental restoration, one must also consider ethics, what ought to be in regard to action.[29] Environmental ethics analyzes the relationship of humanity to the non-human natural world. The classical distinctions are between: (1) teleological ethics in which consequences of the act determine its worth or correctness, and (2) deontological ethics in which formal rules determine correctness of the act.

25. *See* Baker, *supra* note 15, at 636.

26. *See* Baker, *supra* note 8, at 823.

27. *See* Roger A. Pielke, Jr. & Radford Byerley, Jr., *Beyond Basic and Applied*, PHYSICS TODAY, Feb. 1998, at 42, 45–46.

28. *See* JAMES J. LISZKA, A GENERAL INTRODUCTION TO THE SEMEIOTIC OF CHARLES SANDERS PEIRCE 5 (1996).

29. *See id.*

Despite the development of various environmental ethical theories, there has been relatively little influence of these theories on environmental policy.[30] For this reason, there is now a move by environmental philosophers toward environmental pragmatism, defined as, "the open-ended inquiry into the specific real-life problems of humanity's relationship with the environment."[31]

Pragmatism both embodies science, as a creative human activity, and also criticizes the scientistic philosophy that objectifies nature and posits a separation between humanity and the natural world.[32] For pragmatists, such as John Dewey, humans are always active experimenters in the world.[33] Value is not defined in advance, but it emerges as one connects past experience with future possibilities. For a pragmatist, what ought to be in regard to action is shaped by the continual fixation of belief,[34] that is by continual appraisal by actors in the light of their accumulated experience.

The great ecologist Aldo Leopold was influenced by pragmatic philosophy,[35] and this is evident in his view of environmental ethics: "All ethics so far evolved rest upon a single premise: that the individual is a member of a community of interdependent parts."[36] "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise."[37]

Note that Leopold's ethic relates individuals to a community. Humanity is not separate from nature, but part of it. There is also a tying of rightness to a process that preserves qualities of the biotic community. Leopold's ethic calls for action to preserve integrity, stability, and beauty. Such action requires people to perceive the qualities that require preservation. This would seem to involve the interpretive/historical sciences influencing the development of environmental policy, rather than being authoritatively cited as the basis for policy.

Environmental pragmatism requires that one not perceive the natural community as an objective system, isolated from humanity, and specified in advance in terms of its temporal and spatial scales. The attributes of nature are to be discovered for each specific circumstance. People are to be involved in the natural community, and the interpretative science of that community should influence the thought of its human members. The wise acts that follow will require employing a scientific process that addresses the questions appropriate to the problem as well as idealized answers or solutions. This is actually a much broader notion of "experiment" than that applied in mathematical/predictive physical

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30. *See* ANDREW LIGHT & ERIC KATZ, ENVIRONMENTAL PRAGMATISM 1 (1996).
31. *Id.* at 2.
32. *See id.* at 7.
33. *See* PAUL SCHILPP, THE PHILOSOPHY OF JOHN DEWEY 600–01 (1939).
34. *See supra* note 4 and accompanying text.
35. *See* LISZKA, *supra* note 28, at 9.
36. ALDO LEOPOLD, A SAND COUNTY ALMANAC 219 (1966).
37. *Id.* at 240.

sciences. For the latter, controlled experiments serve to test theories and other conceptual schemes. Pragmatic experiments, however, are broadly conceived as questions put to nature. Interpretive/historical sciences are essential to achieving such pragmatic experiments and to their relation to the actions that must follow. Environmental restoration is particularly susceptible to these issues because of its requirement for action, its relationship to past conditions of a disturbed environment, and its need to invoke value considerations.

VI. SUMMARY

Environmental restoration requires action informed by (1) engineering science that solves problems, and (2) historical science that identifies appropriate problems to be solved. The values that underpin action never should be conflicted with science. Science is best used, not as an authoritative basis for action, but rather to trigger human perceptions. This pragmatic approach to environmental issues is particularly relevant to restoration problems because of their relationship to past conditions of a disturbed environment, the need for action to remedy the disturbed condition, and the value considerations that attend to any proposed action.