2001

The Missouri River and Adaptive Management: Protecting Ecological Function and Legal Process

John Davidson, *University of South Dakota School of Law*
Thomas Geu, *University of South Dakota School of Law*

John H. Davidson and Thomas Earl Geu*

The Missouri River and Adaptive Management: Protecting Ecological Function and Legal Process

TABLE OF CONTENTS

* John Davidson and Tom Geu are Professors of Law at the University of South Dakota School of Law. Portions of this Article have appeared elsewhere as parts of other articles or books written by either Davidson or Geu. Geu thanks Ralph Stacey, Professor of Management and Director of the Complexity and Management Center at the University of Hertfordshire School of Management for the chance to discuss the general topic of integrating complexity with organizational design and for the opportunity to deliver a presentation as part of the Center's Distinguished Lecture Series the Fall of 1999.

I. INTRODUCTION

George A. Cowan, former head of research at Los Alamos, was disconcerted by his experience as a member of the White House Science Council, in part, because the policy issues with which he dealt concerned areas of expertise within the narrow bands of hard sciences but, also, substantive areas far outside those narrow sciences:

> "These were very provocative lessons in the interlinked aspects of science, policy, economics, the environment, even religion and morality," says Cowan. Yet he felt incapable of giving relevant advice. Nor did the other academic types on the Science Council seem to be doing much better. How could they? These issues demanded expertise over a broad range. Yet as scientists . . . most of them had spent their entire lives being specialists. The corporate culture of science demanded it.[1]

Yet closer to the issue at hand, Edward O. Wilson, professor emeritus of biology at Harvard, suggested in his controversial book *Consilience*[2] that public policy-making includes the following components: analytical framework, substantive knowledge, and information. Indeed, he used environmental issues to visually illustrate the relation-

---

1. M. MITCHELL WALDROP, COMPLEXITY: THE EMERGING SCIENCE AT THE EDGE OF ORDER AND CHAOS 60 (1992) (quoting George A. Cowan). *Cf.* MARTIN ANDERSON, IMPOSTERS IN THE TEMPLE 92-93 (1993) (arguing that much academic research ignores real world problems and is, thus, trivial). Peter Drucker, a well known management consultant, author, and academic suggests what kind of person will be in demand for employment given that so many issues will come from linked substantive areas:

> We neither need nor will get "polymaths" who are at home in many knowledges; in fact, we will probably become even more specialized. But what we do need—and what will define the educated person in the knowledge society—is the ability to *understand* the various knowledges . . . .
>
> Without such understanding, the knowledges themselves will become sterile, will indeed cease to be "knowledges." They will become intellectually arrogant and unproductive. For the major new insights in every one of the specialized knowledges arise out of another, separate speciality, out of another one of the knowledges.

PETER F. DRUCKER, POST-CAPITALIST SOCIETY 217 (1993).

2. *See generally* EDWARD O. WILSON, CONSILIENCE: THE UNITY OF KNOWLEDGE (1998) [hereinafter CONSILIENCE].

ship of substantive knowledge used to analyze environmental issues. The illustration consists of two intersecting perpendicular lines (an x and y-axis). He labels the upper left quadrant "environmental policy"; the upper right quadrant "ethics"; the lower right quadrant "biology" (science); and the lower left quadrant "social science."[3] He then asserts that most real world environmental problems lie near the center of the diagram where the lines cross. Therefore, policy decisions require an understanding of all four quadrants and a dependent analysis is necessary to solve the real world problems (as opposed to an independent analysis of each quadrant).[4]

More specifically, Professor J.B. Ruhl addresses ecosystem protection and environmental law in his article *Thinking of Environmental Law as a Complex Adaptive System*.[5] He states that ecosystem management "increasingly has become synonymous with adaptive management," finding that a greater number of the studies and other literature define ecosystem management as "continuous monitoring and assessment *and* the modification of management choices on the basis of new information."[6] Indeed there has been a growing volume of literature specifically addressing adaptive management and environmental law.[7] Some of the literature, like that of Professor Ruhl,[8] also specifically explores the law's "capacity to operate as a complex adaptive system,"[9] a concept that goes beyond mere *adaptive* regula-

3. *Id.* at 10.
4. *Id.*
5. J.B. Ruhl, *Thinking of Environmental Law as a Complex Adaptive System: How to Clean Up the Environment By Making a Mess of Environmental Law*, 34 HOUS. L. REV. 933 (1997).
6. *Id.* at 999 n.267 (quoting Rebecca W. Thomson, *Ecosystem Management: Great Idea, but What Is It, Will It Work, and Who Will Pay?*, NAT. RESOURCES & ENV'T, Winter 1995, at 42, 70-72).
7. *See, e.g.*, Kai N. Lee & Jody Lawrence, *Adaptive Management: Learning from the Columbia River Basin Fish and Wildlife Program*, 16 ENVTL. L. 431 (1986); Janet C. Neuman, *Adaptive Management: How Water Law Needs to Change*, 31 ENVTL. L. REP. 11432 (Dec. 2001); John M. Volkman & Willis E. McConnaha, *Through a Glass, Darkly: Columbia River Salmon, The Endangered Species Act, and Adaptive Management*, 23 ENVTL. L. 1249 (1993); Joy B. Zedler, *Adaptive Management of Coastal Ecosystems Designed to Support Endangered Species*, 24 ECOLOGY L.Q. 735 (1997). *See also* ADAPTIVE ENVIRONMENTAL ASSESSMENT AND MANAGEMENT, 3 WILEY INTERNATIONAL SERIES ON APPLIED SYSTEMS ANALYSIS (C.S. Holling ed., 1978). *Cf.* Sandra B. Zellmer, *The Virtues of "Command and Control" Regulation: Barring Exotic Species from Aquatic Ecosystems*, 2000 U. ILL. L. REV. 1233 (2000).
8. Ruhl, *supra* note 5, at 933. *See* Gerald Andrews Emison, *The Potential for Unconventional Progress: Complex Adaptive Systems and Environmental Quality Policy*, 7 DUKE ENVTL. L. & POL'Y F. 167 (1996); *see also* A. Dan Tarlock, *The Nonequilibrium Paradigm in Ecology and the Partial Unraveling of Environmental Law*, 27 LOY. L.A. L. REV. 1121 (1994).
9. Ruhl, *supra* note 5, at 938.

tion, and takes law to the cutting edge of the science of decision making.

The theoretical policy and decision-making alternatives known as "adaptive management" are no longer hypothetical in the Missouri River Basin. Obviously, the Missouri River is not the first instance of implementing the concept of adaptive management;[10] nonetheless, the conversion of adaptive management from theory to reality in the context of the Missouri River Basin occurred with the publication of the *Revised Draft Environmental Impact Statement, Master Water Control Manual, Missouri River* (RDEIS) by the Army Corp of Engineers in August 2001, and the later publication of the National Academy of Sciences' project entitled *Missouri River Basin: Exploring the Basis for Recovery*. Each of these documents, at the urging of the Missouri River Basin Association, embrace adaptive management.[11] Supplemented by a comprehensive biological opinion on river operations from the U.S. Fish and Wildlife Service (USF&W Service) decisions concerning the future management of the Missouri River can be seen as something like a "perfect storm"[12] of complex natural resources decision-making in the context of national public policy.

The purpose of this Article is to describe and comment on the management alternatives in the RDEIS as refined by the newly published National Academy of Sciences project and to assess those alternatives in the context of the eco-regulatory political history of the Missouri River and the new science of complex adaptive systems theory. The text of this Article, therefore, necessarily includes a general history of the regulation and management of the Missouri River[13]; a procedural history and content summary of the RDEIS as well as the project report on adaptive management of the River by the National Academy of Sciences[14]; and a descriptive overview of complex adaptive system theory both generally and as applied to environmental regulation.[15] It concludes with a critical assessment of, and suggestions concerning, the revision of the *Master Water Control Manual of the Missouri River*.[16]

More particularly, following this Introduction, Part II of this Article provides a descriptive overview of the Basin and its current political and regulatory state, which serves as the baseline, or initial condition, on which the Revised Draft relies. It also contains a relatively detailed description of the history of this baseline in order to

10. For applied project descriptions and studies, see, e.g., Volkman & McConnaha, *supra* note 7, and Zedler, *supra* note 7.
11. *See infra* Parts III B. and C.
12. *See* SEBASTIAN JUNGER, THE PERFECT STORM (1999).
13. *See generally infra* Part II.
14. *See generally infra* Part III.
15. *See generally infra* Parts IV and V.
16. *See generally infra* Part V.

demonstrate the dynamic interactive forces that yielded the current state, and which may continue to shape River policy. Those readers with a solid understanding of these historical matters and pressed for time might skip, or lightly read, Part II without damaging the integrity of the Article. Finally, Part II also includes a subpart titled *Evolving into the Future: Political Reality*, that describes more recent developments in the historical regulatory framework that animate the RDEIS.

Part III, importantly, describes the regulatory and practical authority of the *Master Control Manual 33* and the process which has resulted in the RDEIS. It also discusses the reports embedded within it. It reviews the description of the adaptive management alternatives delineated in the RDEIS and its constituent reports and documents. In addition it discusses adaptive management as described by the various Missouri River reports, and selectively reviews literature commenting on the use of adaptive management elsewhere in the environmental regulatory scheme.

Next, Part IV describes the science of complex adaptive systems (CAS) theory and the related concepts of chaos and complexity which are related component parts of the CAS separately and apart from the adaptive management alternatives contained in the RDEIS.

Finally, Part V then summarizes suggestions from CAS and adaptive management literature in the context of RDEIS adaptive management. In particular, Part V analyzes the proposed processes and makes implementation suggestions informed by CAS for implementing adaptive management in the Missouri River Basin. The Article concludes that the adaptive management *process* alternatives in the RDEIS are inadequately detailed and lack evidence of the kind of intensive planning and study necessary to fulfill the promise that is embedded within the concept, and largely ignores the new decisional science of complex adaptive systems theory.

II. BASIN CONDITIONS: AN OVERVIEW OF ITS NATURAL, GEOPOLITICAL, AND REGULATORY BASELINE

A. Variety as Measured Several Ways

The Missouri River Basin is diverse. It contains areas such as the Big Horn in Wyoming, where only six inches of annual rainfall can be expected, and areas in Missouri, where 44 inches of annual rainfall are not unusual. The Basin produces rainfall at both ends, but in the vast middle is a sub-humid region which contributes very little water to the flow of the river. The forested lands of the Rockies and Black Hills constitute only seven percent of the basin's area but produce half

of the water that flows past Sioux City, Iowa.[17] Henry C. Hart describes it as follows:

> The Missouri is the longest river in the United States. At 2,473 miles, it is three miles longer than the Mississippi, twice as long as the Columbia, the Colorado, and the Ohio, and almost four times as long as the Tennessee. Like the Colorado, and the Rio Grande, it crosses hundreds of miles of level land deficient in rainfall, where the water supply sets the limit to agriculture and population. Any continuous increase in the flow of the river through this great area depends entirely upon the treatment of relatively small mountain watersheds, most of them remote from the area where the water can be used. In the case of the Missouri, comprehensive development is further complicated by the fact that at Yankton [South Dakota], sixteen hundred miles below its source, it re-enters a relatively moist climate, which becomes definitely humid for its last four hundred miles, Kansas City to St. Louis. Here water is in nature a surplus, subject to uses which in semiarid American would be insanely prodigal. Yet until the Missouri receives its tributaries from humid lands of Iowa and Missouri, water for surplus uses can only come across a thousand miles of semiarid country from the Rockies.[18]

Climatic factors other than water also define the Basin. Temperatures vary greatly, especially in the upper basin where Siberian winters are followed by summers of searing heat. Wind, not viewed as an element to be taken seriously in most parts of the nation, provides a distinguishing hallmark of the Plains, Northwestern Ranching and Eastern Border regions. Pounding from the north in the winter and the south in the summer, the wind is ever-present. From the perspective of water suppliers, the relentless, dry, southerly wind evaporates unimaginable quantities of river water during each growing season.

Unregulated Missouri River flows vary greatly. The Corps of Engineers estimates that the natural runoff above Sioux City, Iowa, has fluctuated from a low of 10.7 million acre-feet in 1931 to a high of 40.6 million acre-feet in 1978.[19] Natural runoff for a one-month period has varied from 180,000 acre feet in August of 1988 to 13.2 million acre-feet in April of 1952.[20] The long term mean natural flow exceeded 24 million acre-feet a year at Sioux City.[21] The effect of this is a moderate supply in the upper basin, and a threat of flood in the lower. But the key is the great natural variation. The upper basin was regularly threatened with short supplies. The lower basin was regularly threatened with flood.

The Missouri Basin thus presents us with a world of striking contrasts. This world is, first of all, diverse, encompassing ten states, twenty-five Indian tribes, and nearly the full range of known human

17. HENRY C. HART, THE DARK MISSOURI 6 (1957).
18. *Id.* at 8-9. The distances given for the Missouri do vary. The Corps now sets it at 2341 miles. The River drains one-sixth of the nation, over 500,000 square miles.
19. JOHN R. FERRELL, BIG DAM ERA: A LEGISLATIVE AND INSTITUTIONAL HISTORY OF THE PICK-SLOAN MISSOURI BASIN PROGRAM, at ix (1993).
20. *Id.* at x.
21. *Id.*

land uses. It includes major metropolitan areas as well as vast unpopulated expanses. It includes sub-humid dry land and lands of water abundance.

The upper basin, which is usually thought of as that area north of Sioux City, Iowa, has no major city.[22] It is in the upper basin, however, that we find the great Sioux nation, the northern great plains, and large sections of the Rocky Mountains. The lower basin includes such cities as Omaha, St. Louis and Kansas City. If the upper basin finds its history in the old west, range life, and the agricultural settlements generated by the homestead movement, the lower basin finds its history in the Mark Twain world of river commerce from New Orleans, the deadly border struggles leading up to and through the American civil war, the civil war itself, and the opening of the transcontinental Union Pacific Railroad. Whereas the economy of the upper basin remains agricultural, that of the lower basin has risen with the tide of post-World War II investment and industrial growth.

Water concerns of the upper basin are those associated traditionally with shortage—storage, irrigation, and careful allocation. The water concerns of the lower basin reflect concern for water abundance—flood control, navigation and land drainage. This difference is reflected in the prevailing state water laws. Upper basin states rely upon some form of the historic law of prior appropriation—a system that assumes periodic shortage and requires careful management—whereas the water law of the lower basin states is rooted in riparian systems, which are better suited to areas of water abundance. When the upper basin states speak of water development, they refer to irrigation, municipal and industrial supply, water storage, and conservation; the lower basin states refer to levees, flood control dams, and navigation channels.

Although the wildlife resource is rich throughout the Basin, the upper basin includes a large portion of the great Prairie Pothole region, one of the nation's major remaining production areas for migratory waterfowl, and a fresh water resource comparable to the Great Lakes and the Everglades. The historic Missouri River corridor was chronicled by Lewis and Clark as so rich in wildlife numbers and diversity as to defy contemporary powers of imagination.

In the upper basin, the federal government is a significant landowner. This ownership takes the form of Bureau of Land Management grazing land, National Forests, National Grasslands, National Parks, and National Wildlife Refuges. Together, this ownership gives the federal government a claim to a share of the upper basin water

22. Denver is, technically speaking, a lower basin city in the Missouri River watershed. Of course, it takes the larger share of its water supply from outside of the Missouri Basin—the western slopes of the Rocky Mountains—and therefore actually adds water by way of the Platte River.

rights. Add to this the fact that the United States, with the various Indian tribes of the upper basin, assert a substantial *Winters* doctrine reserved water right in the River.[23] Few such proprietary-style federal claims exist in the lower basin.

The continuing story of the Missouri Basin is the story of Missouri River development. To understand the history of this river's development, it is essential to recognize that it has come as a result of the constant playing-out of the tensions and conflicts inherent in the Basin. The River today is radically different from that which Lewis and Clark explored. It is, in fact, an intensively developed river. Upstream there are six massive mainstream reservoirs which convert the River north from Yankton, South Dakota, into one large flat-water lake. South from there the River is severely channeled within levees, revetments and dikes which assure navigation and guide it to its mouth near St. Louis.

Development of the River has been at federal expense and occurred only after a tough political struggle which was defined by the contrast and conflicts among Basin interests. The legal status of the River today is, in turn, defined by *change* combined with the numerous ambiguities, compromises, miscalculations, and misperceptions buried in the federal development legislation. The physical, social, and economic facts in the Basin are changing. The players—tribes, states, and public interest organizations—are changing. Federal water policy is changing. The needs of people in surrounding water basins are changing.[24] Technology allows us now to contemplate tasks that were not considered during the earlier development period. Nonetheless, the old legal and political compromise remains in place. Add to this a fact of potentially overriding significance for the future of the River: although the developed Missouri River, with its huge dams and reservoirs, appears to hold a vast supply of unappropriated water, it borders the American West, where water supplies are over appropriated and in short supply.

The political institutions in the Basin are as diverse as the Basin itself. At least twenty-five Indian tribes are organized politically and located geographically across the Missouri River Basin. These tribes are players in the water policy game because their establishment on reservations entitles them to assert potentially substantial water rights, and to participate in water management decision-making on the River and its tributaries.[25]

---

23. Winters v. United States, 207 U.S. 564 (1908).

24. *See, e.g.*, REPORT TO THE WESTERN WATER POLICY REVIEW COMM'N, WESTERN LAND USE TRENDS AND POLICY: IMPLICATIONS FOR WATER RESOURCES (1997).

25. For a discussion these issues, see John H. Davidson, *Indian Water Rights, The Missouri River, and the Administrative Process: What Are the Questions?*, 24 AM. INDIAN L. REV. 1 (1999). It may not be entirely correct to describe an Indian tribe

according to whether or not it is situated on a reservation in the Basin. Many tribes are more properly identifiable apart from their association with a particular reservation. Nonetheless, for our purposes, the reservations are the source of a distinct legal status. The following are the Basin reservations.

(a) Blackfeet Reservation. Located in northwestern Montana on the east side of Glacier National Park. Established in 1855, it has nearly 960,000 acres held in trust and about 7,000 tribal members living on the reservation. Surface waters include some tributaries of the Missouri.

(b) Cheyenne River Sioux Reservation. Located in northwestern South Dakota on the west bank of the Oahe Reservoir on the Missouri River mainstem. Established in 1868 by treaty, it has nearly 1,300,000 acres held in trust, and about 5,000 tribal members live on the reservation. Not only does this reservation sit on a Missouri River reservoir, it is also served by the tributary Moreau and Cheyenne Rivers.

(c) Crow Reservation. Located in southcentral Montana, and established in 1851. 2,300,000 acres are in trust and about 5,00 members live on the reservations. The Big Horn and Little Big Horn rivers are on the reservation. The Yellowtail Reservoir on the Big Horn River contains substantial stored water. Around 6,000 acres of Crow Reservation land was condemned for the reservoir.

(d) Crow Creek Sioux Reservation. Located on the east side of the Missouri River, adjacent to the reservoirs of the Big Bend and Fort Randall dams in central South Dakota and established in 1868. The Crow Creek Reservation lost 9,514 acres of prime bottom land to the Fort Randall Dam, and another 6,417 acres to the Big Bend Dam. Over 130,000 acres of reservation land are in trust and about 12,800 people reside on the reservation.

(e) Flandreau Santee Sioux Reservation. A small reservation on the tributary Big Sioux River in northeastern South Dakota. This reservation has open boundaries and 2,360 acres of trust land.

(f) Fort Belknap Reservation. Located in northcentral Montana, on the Milk River and Peoples Creek. Established by statute in 1888.

(g) Fort Berthold Reservation. Located in western North Dakota and established by treaty in 1851. About 8,000 people reside there on a land base of which 419,000 is held in trust. Lake Sakakawea, the reservoir behind Garrison Dam, inundated 152,360 acres of Missouri River bottom land on this reservation. The reservation is also served by the Little Missouri River.

(h) Fort Peck Reservation. Located in northeastern Montana on the north share of the Fort Peck Reservoir on the Missouri River. Established in 1862. The principal streams are Porcupine Creek, Poplar River and Big Muddy Creek. Water rights were quantified as part of an agreement with the Montana Reserved Water Rights Compact Commission.

(i) Iowa Tribe of Kansas and Nebraska Reservation. Located in northeastern Kansas and parts of adjoining Nebraska on 985 acres. Created in 1861, this small reservation lies in the Nemaha River tributary.

(j) Kickapoo of Kansas Reservation. Located in northwestern Kansas and established on 7,000 acres in 1854, it lies in the Delaware Basin tributary.

(k) Lower Brule Sioux Reservation. Located in central South Dakota on the west bank of the mainstem of the Missouri River. Established in 1863, there are nearly 133,000 acres in trust, and about 1,800 persons live on the reservation. The reservation lost 7,997 acres of bottom land to Fort Randall Dam and 14,609 acres to Big Bend Dam.

(l) Northern Cheyenne Reservation. Located in southeastern Montana on the Tongue River. Established in 1884, there are 439,000 acres held in trust, and about 3,800 members reside on the reservation.

The Missouri Basin includes nine states. In the process of developing and managing the River, each operates as an independent governmental authority, implementing its own water policy. Each has its own water rights laws and each has sovereign authority to deal with Indian tribes, other states and federal agencies. However, states in the Basin are in fact drawn together or organized by the commercial interests which they inevitably represent. Lower basin states, for example, come together to assert the needs of navigation and flood con-

---

(m) Omaha Reservation. Located in northeastern Nebraska on about 30,000 acres of trust land. Established by treaty in 1854. This reservation lies on the mainstem of the Missouri River.

(n) Pine Ridge Reservation. Located in southwestern South Dakota. This very large reservation has a total of 1,800,000 acres, of which 862,000 are in trust. The tributary White River flows across the Pine Ridge. Established in 1887.

(o) Prairie Band Potawatomi Reservation. Located in northeastern Kansas along the tributary Kansas River. Established in 1837 on about 77,000 acres of trust land.

(p) Rocky Boy Reservation. Located in north central Montana. Established in 1921 on about 108,000 acres of trust land. The land is served by a tributary to the Milk River.

(q) Rosebud Sioux Reservation. Located in south central South Dakota and established in 1887. Drained by two small tributary rivers and also by the northern tip of the Oglala aquifer.

(r) Sac and Fox Tribe of Missouri. Located in northeastern Kansas and adjacent Nebraska lands. Established in 1861, but most of the original reservation land has been sold.

(s) Santee Sioux Reservation. Established in 1866 on the tributary Niobrara River in Nebraska. The current reservation in comprised of 3,600 acres of trust land and 2,200 acres of allotted land. This reservation sits on the south shore of Lewis and Clark Lake on the mainstem of the Missouri River.

(t) Sisseton-Wahpeton Sioux Reservation. Located in northeastern South Dakota and adjacent lands in North Dakota and established in 1867 on a land base of some 108,000 acres. About 3,500 persons reside on the reservation. The southern portion of the reservation is in the headwaters of the Big Sioux River, a tributary of the Missouri.

(u) Standing Rock Sioux Reservation. In central North and South Dakota, on the west side of the mainstem Oahe Reservation. This large reservation was created in 1868 and about 8,300 people now reside there. The Oahe Dam flooded 56,000 acres of the reservation's bottom lands.

(v) Wind River Reservation. Located in west central Wyoming and established in 1863. The Wind River flows across the reservation, after which it becomes known as the Big Horn. The reservation is now comprised of about 1,800,000 acres of trust land. The Wind River Arapaho and Shoshone Tribes and continue to litigate their water rights in Wyoming state court.

(w) Winnebago Reservation. Located in northeastern Nebraska on lands acquired from the Omaha Reservation. About 27,000 acres are currently held in trust and about 3000 people reside there. This reservation lies on the west bank of the Missouri River.

(x) Yankton Sioux Reservation. Located in southern South Dakota on the north bank of the Missouri River at Fort Randall Dam, which inundated about 3,400 acres of the reservation's bottom land. The reservation is now comprised of about 40,000 acres of trust land.

trol. Upper basin states unite to assert the perceived need for control over water allocation, for irrigation and, in recent years, for commercial recreation on and around the great reservoirs.

States from time to time come together in organizations in order to advance a common cause. In 1942, the Basin states formed the Missouri River States Committee to advance federal development of the River.[26] In 1961, a Missouri River Basin Commission was created by Executive Order to develop a comprehensive basin development plan, but was abolished in 1981.[27] The states have more recently formed a Missouri River Basin Association to promote coordination among Basin states.[28] However, the degree of cooperation between and among Basin states depends upon the extent to which their interests on any particular issue coalesce. When it suits an individual state's interests to advance an independent policy, they certainly do so.

Management of the River is most heavily influenced, however, by several federal agencies. Predominant among these is the U.S. Army Corps of Engineers (Corps) which has primary authority over the entire mainstem, including the reservoir. In 1988, the United States Supreme Court ruled that the Flood Control Act of 1944 gave the Corps the authority to contract for domestic and industrial uses of surplus waters in Corps reservoirs.[29] This power over the reservoirs, combined with the long-standing authority over downstream navigation, places the Corps in practical control of the River.

The Bureau of Reclamation in the United States Department of the Interior has a declining role in River policy. It is principally involved in managing the several federal irrigation projects, and in transporting electric power. The Western Area Power Administration (WAPA) has responsibilities for marketing and distributing the hydroelectric power produced by federal dams on the River.[30]

B. The River's Regulatory History

1. *Early Developments in the Basin: Before 1944*

The focus of the modern Missouri River is development authorized by the Flood Control Act of 1944. Before the 1944 legislation authorized comprehensive multi-purpose river development, however, development was already under way to a limited extent, nearly all of which focused on navigation. In 1832, a snag removal program on the River was instituted by Congress. In 1910, Congress authorized development of a 6 foot navigation channel from Kansas City to the mouth,

26. FERRELL, *supra* note 19, at 179.
27. *Id.* at 185.
28. *Id.* at 186.
29. ETSI Pipeline v. Missouri, 484 U.S. 495 (1988).
30. 42 U.S.C. §§ 7101 *et seq.* (1982).

which was extended to Sioux City, Iowa in 1929.[31] In 1935, Congress authorized construction of the Fort Peck Dam in Montana. This was primarily for navigation control on the lower River. Thus, the clear intent of the pre-1944 legislation was to improve the River for the purpose of navigation.[32]

Nonetheless, there were precursors to development for purposes other than navigation. The irrigation movement of the late nineteenth and early twentieth centuries was influential in the enactment of the Reclamation Act of 1902.[33] In fact, one of the first federal irrigation projects was constructed in the basin at Belle Fourche, South Dakota.[34] In 1922, Congress authorized the Corps to do so-called "308 planning," which for the first time introduced the concept of multiple purpose river development, encompassing navigation, flood control, hydroelectric power and irrigation.[35]

2. *1944: The Pick-Sloan Plan and Basin Wide Development*

Marian E. Ridgeway opens her book on Missouri River development with the following:

> Legislation always originates out of conditions and events which somehow impress certain persons that a situation exists which requires governmental action. If no authority for that action can be found in law, then authority must be established.
>
> While a given law's origins may extend far back into past events and conditions, a specific happening will sometimes occur which provides the impetus necessary to set the legislative process in motion in all of its manifold aspects. Such happenings occurred in the early spring of 1943, while the United States was waging the most costly war of its history.
>
> At that time, rains and melting snows disturbingly entered the wartime picture to add to the burdens of hard-pressed farmers, factory owners, and persons engaged in Missouri River basin commerce and transportation. Federal, state, and municipal officials of the Missouri Valley found their cares mounting. In March and April, again in May, and once again in June, torrents of water descended on the land. The results in loss of human lives and capital damages were impressive. Such flood conditions furnished the impetus necessary to start in motion a train of legislative activities which resulted in passage of certain important laws for the Missouri River basin.[36]

It took a great catastrophe at home—the floods on the Missouri River—to divert Congress from the war in Europe.

---

31. FERRELL, *supra* note 19, at 175.
32. John R. Guhin, *The Law of the Missouri*, 30 S.D. L. Rev. 350, 352 (1985).
33. A.D. TARLOCK ET AL., WATER RESOURCES MANAGEMENT 681-686 (4th ed. 1993).
34. HERBERT S. SCHELL, HISTORY OF SOUTH DAKOTA 359 (3d ed. rev. 1975).
35. NAT'L RESEARCH COUNCIL, COMM. TO ASSESS THE U.S. ARMY CORPS OF ENGINEERS, NEW DIRECTIONS IN WATER RESOURCES PLANNING FOR THE U.S. ARMY CORPS OF ENGINEERS 11 (1999).
36. MARIAN E. RIDGEWAY, THE MISSOURI BASIN'S PICK-SLOAN PLAN: A CASE STUDY IN CONGRESSIONAL POLICY DETERMINATION 3 (1955).

Within ninety days after the floods, Lewis A. Pick, a colonel with the Corps' Missouri River Division, prepared and submitted to the Chief of Engineers in Washington a document that would thenceforth be known as the Pick Plan.[37] The Pick Plan, although brief and somewhat vague, proposed to construct 15,000 miles of levees on both sides from Sioux City to the River mouth, seven reservoirs on tributaries, and five major dams on the main channel of the River. The Plan called for a total storage capacity of 60 million acre feet, much more than was thought necessary for flood control and irrigation, and offered little in the way of specifics concerning hydroelectric power and navigation.[38]

A few months after the Pick Plan surfaced, the Bureau of Reclamation published its report and recommendation, named after the agency engineer responsible for its development, William G. Sloan. The Sloan Plan aimed first at drought, then flood. It would build 90 reservoirs to achieve the same storage as the Pick Plan and would add 4.7 million acres of irrigation.[39] Its proposed reservoirs were located as far into the headwaters as possible, where they could more economically benefit irrigable lands.[40] Noticeably, the Sloan Plan reduced the water available for navigation below Sioux City.[41]

The two plans—so different in their every aspect—clearly set the upper basin states into a political struggle with the lower basin states for what each group defined as a battle for the future of the River. The themes developed during that initial struggle continue to impact current management, policy, and decision making.

To gain some feeling for the nature of this conflict, consider the Pick Plan from the perspective of the upper basin states. In the upper basin, the goal was irrigation agriculture. Irrigation, of course, removes water from the stream and consumes a portion of it, and thus reduces the supply available for instream use below the point of diversion. Moreover, irrigation water law in the upper basin states was based on state-granted prior appropriation proprietary rights. To upper basin states, the Pick Plan, with its emphasis on main-stem storage for flood control and a deep channel for downstream navigation, appeared to threaten usurpation of the upstream regime of water rights. At the time of the Pick Plan, the Corps was supported by strong constitutional authority holding that Congress could regulate navigation pursuant to the Commerce Clause. Navigation powers

37. HART, *supra* note 17, at 120.
38. *Id.* at 122.
39. *Id.* at 125.
40. *Id.*
41. *Id.*

were broadly construed and by 1944 had been extended into headwater areas.[42] As Farrell recently described:

> Upper Missouri basin interests feared that the federal government might use this broad activist interpretation of the commerce clause to impair rights acquired under state laws. With discussions of an expanded federal program of water developments in the postwar period, westerners were concerned that the federal government might claim unappropriated water under the navigation powers. It might also use its property rights as owner of public lands.... These views, supported by federal legal opinions, caused serious concern about the security of upper basin water rights and the potential for irrigation expansion.[43]

From this perspective the Pick Plan was more than merely suspect. The vast channel improvements below Sioux City clearly foretold a heavy emphasis on downstream navigation, which would require a large and steady water supply. Of the seven smaller headwater dams, five were on the Republican River, downstream from irrigation country, and two were on the Yellowstone and Big Horn rivers, upstream from irrigation country.[44] The five major main channel (mainstem) dams called for by the Pick Plan could store much more water than necessary for flood control and irrigation. Upper basin states could only conclude that the extra storage was to supply a navigation channel considerably deeper (and thirstier) than that previously described in planning documents.

Add to this the fact that the upper basin states had become accustomed not only to the appropriation and regulation of water under state law, but also to the Reclamation Law of 1902, which governed the development of federal irrigation projects initiated by the Bureau of Reclamation. That law directed the Bureau of Reclamation to follow the policy of prior appropriation, and to use water for irrigation in compliance with state water law.[45] The thought that this system would be unsettled in favor of navigation interests determined the attitudes and political strategy of the upper basin.

As the two basins and their associated interests groups fought out their differences, a bill was introduced in Congress that would authorize a regional river basin authority along the lines of the Tennessee Valley Authority.[46] This new threat effectively compelled a gradual compromise between the Bureau of Reclamation and the Corps, each of which saw compromise between themselves to be slightly more palatable than an independent valley authority. As a result, the Flood Control Act of 1944 was enacted in December. Reasons for enactment

42. FERRELL, *supra* note 19, at 21. *See, e.g.*, United States v. Twin City Power Co., 350 U.S. 222 (1956); United States v. Chandler-Dunbar Water Power Co., 229 U.S. 53 (1913).
43. FERRELL, *supra* note 19, at 22.
44. HART, *supra* note 17, at 121-122.
45. 43 U.S.C. § 383 (1984).
46. FERRELL, *supra* note 19, at 73.

were flood control, jobs for returning soldiers, navigation and other uses. The Act is a general plan for the comprehensive development of the Missouri River, and the complex legislation is still being interpreted by courts and administrative agencies.

The reconciled plans allocated jurisdiction between the Corps and the Bureau of Reclamation. The former would determine mainstem and tributary reservoir capacities for flood control and navigation, and the latter would determine capacities for irrigation purposes. Five mainstem dams were to be constructed, and are now known as Gavins Point (Yankton, S.D.), Garrison (Bismarck, N.D.), Fort Randall (Chamberlain, S.D.), Big Bend (below Pierre, S.D.) and Oahe (Pierre, S.D.). A reallocation of the small tributary dams was made. The preexisting Fort Peck Reservoir in Montana was integrated into the Missouri River plan.

Guhin offers the following observations concerning the Flood Control Act of 1944:

> There are two keys to understanding the intricacies of the Act. The first key lies in the realization that Congress, at the very time it was considering the Flood Control Act, also was considering what was to become the Rivers and Harbors Act of 1945. This latter Act ultimately authorized a nine foot channel for navigation in the Missouri River below Sioux City, Iowa. The perception that water necessary to fill this nine foot navigation channel would not be available for upstream irrigation led to the demand for the protection of upper basin consumptive uses such as irrigation; hence the O'Mahoney-Milliken Amendments were drawn and adopted.
>
> A second key to understanding of the Act lies in the fact that the heart of the Act for the upstream states . . . may not lie in the text of the Act itself. Arguably, it lies within certain documents submitted to Congress, including the Pick Plan, the Sloan Plan and Senate Document 247. These documents were incorporated by reference in Section 9 of the Flood Control Act. It is within these documents that the programs for construction of the dams and for the construction of large-scale irrigation projects were contained. These documents can be interpreted to supply answers to legal controversies even when the words of the Act imply otherwise.[47]

Several commentators recently wrote:

---

47. Guhin, *supra* note 32, at 352-353. Because the legislation incorporates by reference some lengthy documents, the essential legislation is found in the following:

The Flood Control Act of 1944. Act of Dec. 22, 1944, Pub. L. No. 78-534, ch. 665, 58 Stat. 887, codified at 16 U.S.C. 460d, 825s; 33 U.S.C. § 701-1, 701a-1, 701b-1, 708, 709; 43 U.S.C. § 390. And, notes at 33 U.S.C.A. §§ 701c, f and j.

Sloan Plan. Senate Doc't No. 191, 78th Cong., 2d Sess., Apr. 12, 1944. "Missouri River Basin: Conservation, Control and Use of Water Resources."

Pick Plan. House Doc't No. 475, 78th Cong., 2d Sess. March 2, 1944. "Missouri River Basin: Letter from the Secretary of War."

Pick-Sloan Plan. House Doc't No. 247, 78th Cong., 2d Sess., Nov. 21, 1944. "Missouri River Basin: [Report to Congress on the Conciliation of H. Doc't 191 and H. Doc't 475]."

> The two plans were fundamentally inconsistent, but refusing an "either-or" choice, Congress chose "and." The Pick-Sloan Plan, as incorporated into the Flood Control Act of 1944, was sold as a compromise but in fact was an impossible attempt to satisfy the competing agencies. The legislation contained nearly every project proposed in both Pick's and Sloan's plans. Writing shortly after the Act was passed, historian Albert Williams termed it a "majestic pork-barrel and log-rolling spree." Perhaps because it aimed at pleasing everyone, there was little opposition to the legislation.[48]

With passage of the Act, construction on the mainstem dams got under way. A comprehensive legislative and administrative history is too extensive and detailed to be laid out here, though such a history is arguably an important part of this Article. Suffice it to suggest, however, that other published resources exist which are comprehensive, diverse, perceptive, and worthy of careful attention.[49]

3. *A Key Provision of the 1944 Legislation: The O'Mahoney-Milliken Amendment*

The principal controversy during the legislative debate was whether the upstream consumptive water uses would have priority over the downstream use of water for navigation. As Guhin has put it: "Quite simply, the upstream states wished to assure themselves that they could consume the water rather than let it flow down below Sioux City for navigation."[50] The issue was clearly before Congress because of the parallel introduction and consideration of a second bill, which became the Rivers and Harbors Act of 1945, and authorized the construction of a nine-foot channel below Sioux City, Iowa, for purposes of enhancing navigation. A nine-foot channel consumes a great deal of water. Unlike navigation on other rivers where ships and barges are moved through a stable system of locks, Missouri River shipping moves on open water, relying upon continual releases from upstream dams. To protect the upstream interests, the Act contains the following provision:

> The use for navigation, in connection with the operation and maintenance of such works herein authorized for construction, of waters arising in States lying wholly or partly west of the ninety-eighth meridian shall be only such use as does not conflict with any beneficial consumptive use, present or future, in States lying wholly or partly west of the ninety-eighth meridian, of such

48. SARAH F. BATES ET AL., SEARCHING OUT THE HEADWATERS: CHANGE AND REDISCOVERY IN WESTERN WATER POLICY 125 (1993).

49. FERRELL, *supra* note 19; HART, *supra* note 17; MICHAEL L. LAWSON, DAMMED INDIANS: THE PICK-SLOAN PLAN AND THE MISSOURI RIVER SIOUX, 1944-1980 (1982); THE NORTHERN LIGHTS INSTITUTE, BOUNDARIES CARVED IN WATER (1989-1990); RIDGEWAY, *supra* note 36; ROBERT KELLEY SCHNEIDERS, UNRULY RIVER: TWO CENTURIES OF CHANGE ALONG THE MISSOURI (1999); JOHN E. THORSON, RIVER OF PROMISE, RIVER OF PERIL: THE POLITICS OF MANAGING THE MISSOURI RIVER (1994); Guhin, *supra* note 32.

50. Guhin, *supra* note 32, at 384.

> waters for domestic, municipal, stock-water, irrigation, mining, or industrial purposes.[51]

Senator O'Mahoney summarized the meaning of this provision in the following language.

> I may say for the benefit of all those who have cooperated in the preparation of the amendment . . . that the purpose has at all time been to protect the historic and traditional rights of the people of the West to use the waters rising in the West in the manner which has been recognized by law and by court decision for almost 100 years.[52]

This amendment, bolstered as it is by considerable legislative history, states that when there is a conflict between irrigation or other upstream consumptive uses and downstream navigation, the upstream interests shall be given deference. Did Congress really intend this? The answer must be "yes," followed by a quick qualifier. The more accurate answer is that Congress hoped, by authorizing and constructing a system with immense storage capacity, that both uses could be satisfied, thereby deferring a decision on priorities.[53] In today's world, this requires that the River be *managed* in order to avoid the direct conflict to which the O'Mahoney-Milliken Amendment seems to provide but one answer.

4. *Evolving into the Future: Political Reality and Managing: The Emergence of Recreation "and Other Purposes"*

The debate about whether upper basin states will control the River's supplies will surface and resurface. A recent skirmish found the upper basin states in a position they had always sought to avoid: dealing directly with the Corps in a debate over how the River should be managed. In the late 1980s drought placed more stress on the mainstem reservoirs than since any time after they had been filled.[54] This drought "compounded the enmity between upstream and downstream interests, [and] amplified the imbalance between realized and unrealized lower and upper basin Pick-Sloan program benefits."[55] Again, focus was upon issues that had not been dealt with seriously in the Flood Control Act of 1944. This time the interest was the use of the upper basin reservoirs for recreation, an industry that had grown lucrative, particularly at Oahe Dam in South Dakota and Garrison Dam in North Dakota. When drought came, the upper basin states concluded that the Corps was drawing-down the reservoirs in order to carry downstream navigation through the barge traffic seasons, and went to court.

---

51. Flood Control Act of 1944, ch. 665, 58 Stat. 889, 33 U.S.C. § 701-1(b).
52. 90 CONG. REC. 8420 (1944).
53. HART, *supra* note 17, at 134.
54. FERRELL, *supra* note 19, at 156.
55. *Id.*

South Dakota v. Hazen[56] was brought by the upper basin states, who sought to enjoin the Corps from dropping the water level in Lake Oahe below that necessary to assure a successful walleye fish spawn. The Corps claimed it could not reduce releases under the rules in the Master Manual, the internal agency document governing its operation of mainstem reservoirs. The district court issued a preliminary injunction prohibiting the Corps from lowering the level of Lake Oahe until June 1, 1990, by which time the walleye spawn would have been complete. The district court rejected the Corps' contention that its actions were unreviewable.

On expedited appeal, the Eighth Circuit Court of Appeals issued an order in which it stated that it had serious doubts whether the Corps' decisions regarding river management were reviewable.[57] The court also said that even if the Corps' decision were reviewable, a preliminary injunction should not have been granted because the record did not support the district court's conclusion that the decisions of the Corps were arbitrary and capricious. In a subsequently rendered formal opinion, the Eighth Circuit declined to decide the reviewability issue, holding that the case was moot because the walleye spawn was complete.[58]

A second suit was brought by the upper basin states after the drought persisted, and reservoir levels continued to decline. This time, the plaintiff states contended that the Flood Control Act of 1944 established only two priorities: flood control and upstream beneficial consumptive uses. They argued that all other priorities have been established administratively by the Corps, that the Flood Control Act provides flexibility and requires the Corps to regularly balance the use of water storage and develop a plan of operation that reflects *contemporary* uses and needs of the basin. The plaintiffs further argued that if the Corps treated fish, wildlife, and recreational uses appropriately, more water would be left in the upstream reservoirs since the priorities for the water would be based on a realistic assessment of the benefits of lower basin navigation in relation to the benefits of upper basin recreational uses. The plaintiffs based their argument on assertions that the navigation industry that was envisioned in 1944 has never materialized and navigation on the lower Missouri has declined in recent years. Upstream benefits from fish, wildlife, and recreation, on the other hand, were at that time estimated at $67 million annually, while the annual benefit of downstream navigation was estimated at less than $14 million.[59] The second suit did not go to trial, as a settle-

56. 914 F.2d 147 (8th Cir. 1990).
57. Missouri v. Craig, 163 F.3d 482 (8th Cir. 1998).
58. *Id.*; *see* Brian Morris, *Unanswered Prayers: The Upper Missouri River Basin States Take On the U.S. Army Corps of Engineers*, 68 N.D. L. REV. 897 (1992).
59. 24 Water Law Newsletter, No. 1 (1991).

ment based upon the willingness of the Corps to draft a new Master Manual was reached.

This recent controversy raises the issue of identifying the priorities the Corps is obligated to consider when managing the River. Does the Flood Control Act direct the Corps to manage for "other purposes"? If so, what are they? Does the Corps have the authority to alter the purposes for which it manages the reservoirs?

The Pick-Sloan documents refer almost exclusively to the purposes of flood control, navigation, irrigation and hydroelectric power. The phrases "and other uses" or "and other purposes" do appear in some places. On this basis the Corps has determined that it has authority to operate Corps projects to benefit recreation consistent with and subordinate to other purposes.[60] Enactment of the Endangered Species Act and the Fish and Wildlife Coordination Act has caused the Corps to consider fish and wildlife as an independent purpose as well as a purpose subsumed under "recreation."[61]

III. FOCUS ON THE MASTER MANUAL AND ITS MANDATE FOR ADAPTIVE MANAGEMENT

A. An Overview and a Starting Point

As it has with most complex river systems, the Corps follows a system of written operation instructions. Known as the "Master Manual," it was prepared in 1960 and is reviewed and updated periodically. Although not promulgated as administrative rules, the Master Manual sets the rules and priorities for management of the River. It is, in effect, a set of rules imposed by the Corps upon itself. Subsumed in the Master Manual, however, are many of the key policy choices.

In 1989, when the Corps agreed to revise and reconsider the Master Manual it undoubtedly understood that the process would be complicated. For the first time management of the River would be subject to open review under the National Environmental Policy Act, and guided by the Administrative Procedure Act. Also for the first time since 1944 the Corps would be forced to discuss the relative priority of River uses. After all, much had changed. Navigation on the lower river had failed to develop a significant economic enterprise whereas recreation in the upper basin had become a large and lucrative industry with a diverse and numerous constituency. Irrigation in the upper basin had failed to materialize, largely because the soils in the proposed irrigation districts had proven to be unirrigable. This, in

60. FERRELL, *supra* note 19, at 157.
61. The Corp's internal legal memorandum analyzing its authority to manage the Missouri River for recreation is reprinted at 4 GREAT PLAINS NAT. RES. J. 25 (1999).

turn, meant that large-scale diversions from the main stem reservoirs for in-basin use were unlikely. Even given these changes, the Master Manual review must have seemed manageable in 1989.

The process of developing a revised Master Manual is far from simple, and its consequences are both direct and immediately apparent on the ground. Once in place, the revised Master Manual governs every aspect of the river's flow, and influences every use. Those whose day-to-day economies rely on the river—such as hydropower users, recreation concessionaires, barge users, domestic and agricultural water suppliers, downstream cities, and industries—are affected directly. Flow patterns have an equally direct impact on the natural river ecosystems, especially those based in the riparian zone. More importantly, because of both the administrative and practical complexities, once implemented, the Master Manual is not easily changed. While not a "permanent" solution, the Master Manual, as a practical matter, is a final rule that is likely to govern for an extended period of time.

To gain some perspective, it is possible to analogize the Master Manual administrative process to a judicial process leading to a final appellate court decision and order. The final Master Manual will, after all, be subject to judicial review. If particularly controversial, some sort of Congressional oversight is theoretically available. Conceding that, however, it is indeed our suggestion that the final Master Manual has the potential to fix the status of specific river uses with a firmness that is every bit as solid as many Supreme Court equitable apportionments. Any given process is as important as the finality and enforceability of the final decision, be it judicial legislative or administrative. For Missouri River water users, the Master Manual process may be as important as the litigation in *Arizona v. California* was to Colorado River water users. In other words, for the Missouri, it can be the "law of the river."[62]

The Master Manual review proposed by the Corps in 1989 would have been remarkably complicated even had the Corps limited its analysis to the framework which had become rather traditional under the Pick-Sloan plan. The review process encountered further complexities, however, which have gradually come to dominate. Some are found in laws enacted after 1944, others in changes in fact, and include:

(i) National Environmental Policy Act. Although the Master Manual was published in December of 1960, it had not been promulgated as a rule pursuant to the Administrative Procedure Act. Revised in 1973, 1975, and 1979,[63] the Master Manual had also eluded review

62. Charles J. Meyers, *The Colorado River*, 19 STAN. L. REV. 1 (1966).

63. U.S. FISH AND WILDLIFE SERV., BIOLOGICAL OPINION ON THE OPERATION OF THE MISSOURI RIVER MAIN STEM RESERVOIR SYSTEM, OPERATION AND MAINTENANCE OF THE MISSOURI RIVER BANK STABILIZATION AND NAVIGATION PROJECT, AND OPERA-

under the National Environmental Policy Act (NEPA).[64] Clearly, however, the proposed review is a "major federal action" requiring a complete environmental analysis.[65] Therefore, public participation, among other things, is mandatory, and the agency is required to describe the environmental impact of any proposed actions, consider alternatives, and consult actively with states, tribes and other federal agencies.[66] For the Corps, NEPA assured review of the environmental impacts of operation of the Missouri River system of dams and navigation channels.

(ii) Changing Economics. There can be little doubt that the Congressional authors of the Pick-Sloan Plan contemplated that the principal economic enterprises supported by the development would be hydropower, Bureau of Reclamation irrigation and main channel navigation. Of these three, only hydropower has prospered. From the outset irrigation was a dream without foundation in fact, science, or economic demand.[67] Navigation, despite the Corps' provision of an expensive nine-foot channel from Sioux City, Iowa to the mouth, requiring lavish amounts of water, had not developed into an enterprise of noticeable size or need; it is an experiment that has failed, delivering less than 1 percent of the overall economic benefits produced by the River.[68] Meanwhile, as irrigation and navigation had failed to materialize, a tasty sport fish—the Walleye—became the base of a fast growing recreation industry in the upper basin, particularly around the large Oahe and Garrison reservoirs.

(iii) Endangered and Threatened Species. Directly relevant to the Master Manual review is the listing of one bird and a fish as "endangered," and two birds as "threatened" under the provisions of the Endangered Species Act. Two of the birds—the Piping Plover[69] and the Least Tern[70]—are shorebirds which require open sandbar habitat for roosting.[71] Under natural conditions a river such as the Missouri would flood during the spring, creating new sandbars, or would scour existing sandbars free of vegetation, thus assuring the necessary nest-

---

TION OF THE KANSAS RIVER RESERVOIR SYSTEM 36 (Nov. 30, 2000) [Hereinafter BIOLOGICAL OPINION].

64. 42 U.S.C. §§ 4321-4370(d) (1994).
65. 42 U.S.C. § 4332 (1994).
66. *Id.* While records are not kept on these matters, this process is certainly one of the longest among those which were not delayed by litigation.
67. The saga of irrigation is described in PETER CARRELS, UPHILL AGAINST WATER: THE GREAT DAKOTA WATER WAR (1999).
68. For the full story read PHILLIP BAUMEL, THE COMPETITIVE BENEFITS OF MISSOURI RIVER NAVIGATION (1998) and MICHAEL W. BABCOCK & DALE G. ANDERSON, DOES BARGING ON THE MISSOURI RIVER PROVIDE SIGNIFICANT BENEFITS? (1999).
69. 50 Fed. Reg. 50726 (1985), listed at 50 C.F.R. § 17.11 (2001).
70. 50 Fed. Reg. 21784 (1985), listed at 50 C.F.R. § 17.11 (2001).
71. Critical habitat for the Piping Plover remains under consideration. *See* 66 Fed. Reg. 67165 (Dec. 28, 2001).

ing environment. Channelization of the Missouri River below Sioux City eliminated all such habitat, as did the vast reservoirs in the upper basin. The third bird—really a raptor—is the Bald Eagle, which feeds, rests, and nests in the tall cottonwood trees that naturally prosper in the Missouri's riparian zone. However, river development has decimated these trees.

The fish is the Pallid Sturgeon, known to occur in the Missouri River, the Mississippi River downstream of the mouth of the Missouri, and the lower Yellowstone.[72] The listing document associates the decline of the Pallid Sturgeon with the "extensive developments of the 1950s and 1960s of the Missouri and Mississippi rivers," and all observers attribute the decline to "habitat modifications":[73]

> Factors include physical blocking of normal movement patterns of the fish by construction of the big dams; alteration of water quality and temperature; alteration of flows which may affect reproduction, timing of reproduction, or food sources; alteration of previous spawning habitats; reduction of habitat diversity; and reduced productivity of the river systems.[74]

For purposes of the Master Manual review, the three species have in common the fact they are all dependent on the Missouri River's natural flow patterns. In other words, the natural flow of the River *is* the distinctive habitat necessary for the species to recover, and because the current water management regime alters the nature flow in a radical way, a conflict is inevitable.

(iv) Ecosystem Management. Related closely to the endangered species listing was a policy change announced by the United States Fish and Wildlife Service (the Service) in 1994.[75] The Service, which enforces the Endangered Species Act (ESA), announced that henceforth its regulatory and other functions would be guided by the concept of ecosystem management, which requires that the total habitat be managed, not just the small specie-by-specie segments. As stated in the agency's announcement:

> Species will be conserved best not by a species-by-species approach but by an ecosystem conservation strategy that transcends individual species. The future for endangered and threatened species will be determined by how well the agencies integrate ecosystem conservation with the growing need for resource use.

---

72. 55 Fed. Reg. 36641 (1990), listed at 50 C.F.R. § 17.11 (2001).
73. *Id.* at 36642.
74. Other actions may be relevant to the Missouri but have yet to affect the Master Manual process directly. The Topeka Shiner, a small fish, was listed as endangered, 63 Fed. Reg. 69008 (1998), listed at 50 C.F.R. § 17.11 (2001). Its habitat is many of the rivers tributary to the Missouri River.

    The U.S. Fish and Wildlife Service formally declined to list either the Sicklefin Chub or the Sturgeon Chub, both native to the Missouri. 66 Fed. Reg. 19910 (2001).
75. U.S. FISH AND WILDLIFE SERV., AN ECOSYSTEM APPROACH TO FISH AND WILDLIFE CONSERVATION: AN APPROACH TO MORE EFFECTIVELY CONSERVE THE NATIONS' BIODIVERSITY (1994).

. . .

> [The agencies shall] [d]evelop and implement recovery plans for threatened and endangered species in a manner that restores, reconstructs, or rehabilitates the structure, distribution, connectivity and function upon which those listed species depend. In particular, these recovery plans shall be developed and implemented in a manner that conserves the biotic diversity (including the conservation of candidate species, other rare species that may not be listed, unique biotic communities, etc.) of the ecosystems upon which the listed species depend.[76]

Although this change may appear slight at first glance, in fact it can represent a major shift in how the ESA is applied. If the regulatory focus changes from the specific specie-by-specie approach to one which examines the overall well-being of the surrounding ecosystem, the potential scope of authority is broadened. It demands that resource management decision-making be centered around the concept of ecosystem functions, rather than the avoidance of jeopardy to a specific specie. As a leading legal commentator summarizes: "Each specie is part of a dynamic, co-adapted assemblage of species dependent on and interacting with the surrounding habitat. It is that total package that must be managed, not just some of the bits and pieces."[77] Ecosystem management is discussed in more detail later in this Article.

(v) The Midwest Flood of 1993. If the Master Manual review process began during drought, it has been significantly influenced by flood. In 1993, unprecedented rains caused floods in the upper Mississippi River basin and the lower Missouri. In the aftermath of the great flood, the President established an Interagency Floodplain Management Review Committee to describe and examine the consequences of the flood, to evaluate the performance of existing floodplain management and related watershed management programs, and to make recommendations for changes in current federal policies and programs that most effectively would achieve risk reduction, economic efficiency, and environmental enhancement in the floodplain and related watersheds. The Committee report, *Sharing The Challenge: Floodplain Management into the 21st Century* ("*Galloway Report*")[78] has become essential reading, something of a contemporary text on floodplain management. It summarizes the flood:

---

76. 59 Fed. Reg. 34274 (1994); *see also*, U.S. FISH AND WILDLIFE SERVICE, MAKING THE ESA WORK BETTER: IMPLEMENTING THE 10 POINT PLAN . . . AND BEYOND (1997); Jamie Rappaport Clark, *The Ecosystem Approach from a Practical Point of View*, 13 CONSERVATION BIOLOGY 679 (1999). Also instructive is R. Edward Grumbine, *What Is Ecosystem Management?* 8 CONSERVATION BIOLOGY 27 (1994).

77. J.B. Ruhl, *Ecosystem Management, The ESA, and The Seven Degrees of Relevance*, 14 NAT. RESOURCES & ENV'T 156, 158-59 (2000).

78. INTERAGENCY FLOODPLAIN MGMT. REVIEW COMM., SHARING THE CHALLENGE: FLOODPLAIN MANAGEMENT INTO THE 21ST CENTURY (1994). The report became known immediately as The Galloway Report after the head of the Committee, Corps Brigadier General Gerald E. Galloway. [hereinafter GALLOWAY REPORT].

> The Midwest Flood of 1993 was a hydrometeorological event unprecedented in recent times. It was caused by excessive rainfall that occurred throughout a significant section of the upper Mississippi River Basin. The damaging impacts of this rainfall and related runoff were felt both in upland areas and in the floodplains. Pre-flood rainfall saturated the ground and swelled tributary rivers. Subsequent rains quickly filled surface areas, forcing runoff into the lower lands and creating flood conditions. The recurrence interval of the flood ranged from less than 100 years at many locations to near 500 years on segments of the Mississippi River from Keithsburg, Illinois, to above St. Louis, Missouri, and on segments of the Missouri River from Rulo, Nebraska, to above Hermann, Missouri. At 45 U.S. Geological Survey (USGS) gauging stations, the flow levels exceeded the 100-year mark. The duration of the flood added to its significance. Many areas were under water for months.[79]

The *Galloway Report* called for greater emphasis on non-structural solutions, including the acquisition and restoration of wetlands.[80] It also called for a shift in the focus of floodplain management away from structural solutions towards non-structural alternatives, and minimization of the impact of floods.[81]

> The Review Committee supports a floodplain management strategy of, sequentially, avoiding inappropriate use of the floodplain, minimizing vulnerability to damage through both structural and non-structural means, and mitigating flood damages when they do occur.
>
> By controlling runoff, managing ecosystems for all their benefits, planning the use of the land and identifying those areas at risk, many hazards can be avoided. Where the risk cannot be avoided, damage minimization approaches, such as elevation and relocation of buildings or construction of reservoirs or flood protection structures, are used only when they can be integrated into a systems approach to flood damage reduction in the basin.[82]

With respect to the Master Manual review and protection of wildlife, the *Galloway Report*'s significance is its recognition that the navigation channel south from Sioux City, Iowa, is too constricting, and harnessing the energy of flood waters so tightly that they are bound to break-out somewhere downstream. According to the *Galloway Report*, flood damage could be reduced significantly by allowing the River to wander in selected parts of the original flood plain, thereby releasing its force and spreading itself at flood stage. Of course, such practices, if adopted, might be termed "restoration" of the flood plain, and recreation of the habitat for wildlife that had been eliminated almost completely when the channelization project was constructed.[83]

---

79. *Id.* at viii to ix.
80. *Id.* at v.
81. *Id.*
82. *Id.*
83. The GALLOWAY REPORT is discussed in Bruce Babbitt, *Restoring Our Natural Heritage*, 14 NAT. RESOURCES & ENV'T. 147, 149 (2000) and Robert Jerome Glennon & John E. Thorson, *Federal Environmental Restoration Initiatives: An Analysis of Agency Performance and the Capacity for Change*, 42 ARIZ. L. REV. 483, 504-505 (2000).

(vi) An Evolving List of Additional Complicating Elements. Over the years of operation, additional complicating factors became apparent, each of which, by itself, is a natural resources management challenge. For the Corps—the River manager—each of these must be incorporated into its administrative management process. To examine each of these in detail would convert this Article into an environmental impact statement, which is not the purpose. As evidence of the complexity of River management, however, a few are mentioned.

The critical background to new and emerging river issues is the fact that there is very little flexibility in the developed system. This is because the Pick-Sloan Plan developed the river so fully that after each principal purpose is served, there is little, if any, capacity with which to address new issues. Adding to this is the reliance interest which has grown-up around each component of river development. Hydroelectric power generating facilities, for example, operate to "optimize power production and maximize revenues,"[84] and any serious alteration in the scheduled discharges from mainstem dams is sure to lose money for the federal treasury and interfere with the plans of those who customarily purchase power. Similarly, barge operators expect a flow of at least 25 thousand cubic feet per second for their navigation channel throughout a scheduled navigation season, and coal-burning electric generating plants along the navigation channel have come to rely on the prodigious navigation flow to absorb their heated water discharges. In sum, the starting point for reconsideration of river management leaves little space for new issues.

Nevertheless, new issues continue to emerge, which are almost endless in number and variety. For example, because the dams settle out the naturally occurring sediments, the river bed below Gavins Point dam has degraded (deepened) to a point which deprives surrounding land of wetlands and habitat. In the upper basin, housing development spreads across the riparian ground, and owners demand that river flows not erode their newly-acquired front yards. When these lot owners improvise shoreline stabilization projects, the Corps must determine whether to grant "Section 404" permits under the Clean Water Act.[85] In the lower basin, stabilization of the channel allowed for new farmland to emerge by the process of accretion, and the farmers who succeeded to title in this land now insist that river flows not interfere with their cultivation schedules. Tributary rivers, of which there are many, contribute an additional group of issues. For example, at least two tributaries empty into reservoirs, and their sediment loads have interfered seriously with reservoir use. Downstream, tributaries add considerably to the flow of the main stream.[86]

84. BIOLOGICAL OPINION, *supra* note 63, at 44.
85. 33 U.S.C. § 1344 (1994).
86. The EIS includes the Kansas River and other lower basin tributaries.

Politically, Congress designated the two small remnant river stretches in South Dakota and Nebraska as "recreational rivers" under the Wild and Scenic Rivers Act,[87] bringing the National Park Service into the management mix. Also, in 2001, private conservation groups filed a "60-day" letter with the Corps and USF&W Service threatening a citizens suit to enforce the ESA. Thus, the Master Manual review process has gained in complexity at every stage.

B. The Emerging Preferred Alternative for Management of the Missouri River

Before it is concluded, the Master Manual Review process will certainly qualify for nomination to the elite category of "most studied" federal decisions. An early draft of an EIS appeared in 1994 and, although many of the supporting reports retain relevance, further review followed. Another Preliminary Revised Draft EIS (PRDEIS) appeared in August, 1998, and a Revised Draft (RDEIS) in March of 2000. A Preferred Alternative was announced by the Corps on January 13, 2000. A final EIS appeared in the autumn of 2001. The current goal is implementation in the Spring of 2003.[88]

Folded into the Master Manual Review and environmental analyses are the consultation requirements of the ESA. On April 3, 2000 the Corps asked the U.S. Fish and Wildlife Service to formally consult on existing river operations, and a complete Biological Opinion was released in November of 2000, concluding that:

> Operations under past and present operating criteria and annual operating plans have severely altered the natural hydrology and the riverine, wetland, and terrestrial flood plain habitats and fish and wildlife resources of the Missouri River and lower Kansas River ecosystem. Those alterations contributed to the subsequent listing of the tern, plover, and pallid sturgeon as federally endangered or threatened species. If the MR, BSNP, and KR Operations continue without significant alterations, the continued existence of these species on the Missouri and Kansas Rivers will be threatened. The Federal listed status of these species under the ESA is a symptom of the degradation of the ecosystem and a direct attempt (Section 2(b) of the ESA) to focus attention on the conservation of the ecosystem upon which they depend.
>
> After reviewing the current condition of the bald eagle, least tern, piping plover, and pallid sturgeon, the environmental baseline for the action area, the effects of the Corps' proposed operation of the Missouri River Main Stem Reservoir System, the BSNP, and the Kansas River Reservoir System, and the cumulative effects, it is the Service's biological opinion that these actions, as proposed, are likely to jeopardize the continued existence of the least tern, piping plover, and pallid sturgeon, but are not likely to jeopardize the continued existence of the bald eagle. No critical habitat currently has been designated for these species, therefore, none will be affected.

87. 16 U.S.C. §§ 1271-1287 (2000).

88. The Reasonable and Prudent Alternative states: "The Corps shall implement flow modification no later than 2000 . . . ." BIOLOGICAL OPINION, *supra* note 63, at 243.

> Current MR, BSNP, and KR Operations, if continued without significant alterations, likely will cause further declines in other native species (e.g., blue sucker, shovelnose sturgeon, and two candidate species—the sturgeon chub and sicklefin chub) and likely result in additional species listed as threatened or endangered. If more Missouri River species are listed in the future, operational conflicts and constraints will increase, while flexibility to manage the system will decrease. Therefore, the Corps should make conservation of Federally listed endangered and threatened species, and the ecosystem upon which they depend, a priority objective in future operations.[89]

The Biological Opinion runs well over 300 pages and, considering the size of the river basin to which it applies, is surely one of the more significant actions by the U.S. Fish and Wildlife Service. It addresses only the current management regime. The Reasonable and Prudent Alternative suggested by the Opinion is helpful in delineating the issues:

> 1. *Flow enhancement*: The Service has determined that a spring rise and summer drawdown must be implemented from Gavins Point Dam to restore, in part, spawning cues for fish, maintain and develop sandbar habitat for birds and fish, enhance aquatic habitat through connection of the main channel to backwaters and side channels, and improve habitat conditions for summer nesting terns and plovers, forage availability, and fish productivity. A spring release from Fort Peck Dam will provide spawning cues and increase the amount of warm water habitat available to pallid sturgeon and native river fish.
>
> 2. *Habitat restoration/creation/acquisition*: The Service has determined that a portion of the historic habitat base must be restored, enhanced, and conserved in riverine sections that will benefit the listed birds and fish. Habitat restoration goals are 20-30 acres of shallow water (<5 feet deep, <2.5 ft/sec. velocity) per mile. Similar, variable goals by river segment for emergent interchannel sandbar habitat are also identified.
>
> 3. *Unbalanced system regulation*: Unbalancing of the upper three reservoirs when runoff conditions permit, by holding one reservoir low, one at average levels, and one rising on a 3-year rotation will benefit spawning fish and increase forage, increase the availability of tern and plover habitat in reservoirs in drawdown years, create tern and plover sandbar habitat in riverine segments below Fort Peck or Garrison Dams in years of higher releases due to reservoir drawdown, and increase availability of tern and plover sandbar habitat in riverine segments below Fort Peck and Garrison in years of steady or rising reservoir levels.
>
> 4. *Adaptive Management/Monitoring*: The Corps should embrace an adaptive management process that allows efficient modification/implementation of management actions in response to new information and to changing environmental conditions to benefit the species. The two components of this process will be the establishment of an interagency coordination team that will coordinate and guide development and implementation of a robust monitoring program to better understand baseline conditions, analyze actions, and identify modification to improve results.
>
> 5. *Propagation/Augmentation*: The Corps and the Service will work together to increase pallid sturgeon propagation and augmentation efforts, while habitat and hydrology improvements are being implemented. This

89. *Id.* at 229-230.

> short-term action will ensure genetic integrity and prevent extinction of existing pallid sturgeon populations.[90]

The Corps published a Draft Implementation Plan for Final Biological Opinion in December of 2000, in which it accedes to most of the recommendations in the Biological Opinion, including the initiation of flow modification no later than 2003.

According to the *Revised Draft Environmental Impact Statement, Master Water Control Manual, Missouri River*, the Corps assumes that it is legally bound by three constraints in selecting a new water control plan: (1) congressionally authorized project purposes; (2) the contemporary needs of the basin as defined by the basin states and tribes; and (3) avoiding jeopardy to the continued existence of threatened and endangered species.[91] The RDEIS acknowledges that: [t]he RPA [reasonable and prudent alternative] in the BiOP [Biological Opinion] added considerably to the complexity of developing plans that could meet these two goals plus the third.[92]

The EIS alternatives all purport to address the needs of endangered and threatened species in one way or another. Important, however, is that all five are to be buttressed by a process known as adaptive management. The EIS defines adaptive management this way:

> Adaptive management is an overall strategy for dealing with change and scientific uncertainty. This strategy promotes an environment for testing hypotheses and exploring promising changes based on sound scientific data and analysis. Monitoring and evaluation of actual results of changes in the operation of the Mainstem Reservoir System and the flexibility to adapt as new information becomes available are the key elements of the strategy. All of the alternatives presented in [the RDEIS] accommodate an adaptive management strategy.[93]

Implementation of the adaptive management strategy is to be through Corps' cooperation with an Agency Coordination Team "made up primarily of Federal biologists"[94] who will:

> review and evaluate monitoring data on system operations as it determines if operational changes are needed for the benefit of threatened and endangered species. If is finds that operational changes are necessary, it will make a recommendation to the Corps for those changes.[95]

The proposal of the RDEIS is, on its face, consistent with the *U.S. Fish and Wildlife Service's Biological Opinion*, which states:

> The Corps should embrace an *adaptive management process* that allows efficient modification/implementation of management actions in response to new information and to changing environmental conditions to benefit the species.

90. *Id.* at 2-3.
91. RDEIS at 6-1.
92. *Id.*
93. *Id.* at 6-4.
94. *Id.*
95. *Id.*

> The two components of this process will be the establishment of an interagency coordination team that will coordinate and guide development and implementation of measures to benefit the species; and development and implementation of a robust monitoring program to better understand conditions, analyze actions, and identity modification to improve results.[96]

The adaptive management approach to managing the River for species survival is bolstered by the recommendation of the most influential stakeholder group—the states and tribes of the basin. Speaking through the Missouri River Basin Association, they urge that "[t]he key to MRBA's environmental recommendations is the *development of an adaptive management process* to help recover the basin's threatened and endangered fish and wildlife populations."[97]

In the RDEIS proposal for adaptive management, the Corps anticipated that its process would be refined after it received a report from a National Research Council (NRC) project. That report is now available, thus adding to the mix of recommendations as to how the River should be managed.

The NRC project bears the title *Missouri River Ecosystem: Exploring the Prospects for Recovery*.[98] The Committee's original task was defined in the following language:

> This committee will provide a general characterization of the historical and current status, and important ecological trends, of the Missouri River and floodplain ecosystem. The committee will provide a review of the available scientific information on the Missouri River and floodplain ecosystem, and will identify and prioritize scientific information needs for improved Missouri River management. The committee will also recommend policies and institutional arrangements that could improve scientific knowledge of the Missouri River and floodplain ecosystem, and those that could promote *adaptive management* of the Missouri River and floodplain ecosystem.

The committee's task specifies three objectives:

> 1) Characterize the historical and current ecological status of the Missouri River and Floodplain ecosystem. This overview will identify key ecological conditions, changes, and processes, endangered and threatened species, trends and relevant times scales, and gaps in and the limits of that knowledge.
>
> 2) Identify and describe the general state of existing scientific information on the Missouri River and floodplain ecosystem. Identify and prioritize the key scientific questions to be addressed and the key scientific information needed for improved Missouri River management.
>
> 3) Recommend policies and institutional arrangements for improving Missouri River and floodplain ecosystem monitoring and research, and those that could promote an *adaptive management* approach to Missouri River and floodplain ecosystem management.[99]

---

96. *Id.*
97. MO. RIVER BASIN ASS'N, THE MISSOURI RIVER REPORT 4-5 (2000).
98. NAT'L RESEARCH COUNCIL, COMM. ON MO. RIVER ECOSYSTEM SERV., THE MISSOURI RIVER ECOSYSTEM: EXPLORING THE PROSPECTS FOR RECOVERY (2002) (Prepublication copy) [Hereinafter NRC REPORT].
99. http://www.nationalacademies.org.

C. Reallocating Priorities Under a Fixed-Priority River Law: Striking a New Balance

If a new Master Control Plan is implemented in 2003, as the Corps projects, it will mark the conclusion of a complex and contentious process, spanning 14 years. During the review the Missouri Basin has experienced both drought and flood. Although to some observers this drawn-out process may evidence a major fault in our administrative and environmental decision-making process, a case can be made that under the circumstances the difficulties are built into the case. As we have described, the Pick-Sloan Plan was developed and written in the 1940s, and the theory behind it was maximum development of the River, without regard for the ecosystem and its biodiversity. Maximum development was the paradigm which dominated thinking when the law was written, and which continues to dominate the Corps, whose principal constituencies are the industries benefited by the initial legislation, as well as the basin states.

These original mandates have not been revised by Congress, but they have been supplemented by preservation and biodiversity protection mandates, foremost of which (but not alone) is the ESA.[100] On one hand, the long review process on the Missouri is the result of the Corps' struggle to accommodate the conflicts between the old and the new. On the other, it is the result of the sheer weight of complexity. The principal tools for seeking a new balance appear to be ecosystem management and adaptive management.

The phrases "ecosystem management" and "adaptive management" are closely related and sometimes seem to be synonymous. As already introduced, "ecosystem management" is used to refer to the emerging science of natural resources planning and science, and "adaptive management" refers to current attempts to bring science to the planning and decision making table.

The theories that led to ecosystem management may have begun at river's edge, with studies of turbulence. John M. Barry, in his book *Rising Tide: The Great Mississippi Flood of 1927 and How It Changed America*, relates that the turbulent effects of a river combined with river hydraulics "quickly go beyond the merely complex. Indeed, studies of flowing water in the 1970s helped launch the new science of chaos."[101] Chaos theory was for physicists, but it shows up in nearly every discipline. In biology it led to the field called Conservation Biology, the home of ecosystem management.

The underlying theme of ecosystem management is that disequilibrium is the norm. So, what shall we do about it? The message

100. A. Dan Tarlock, *Biodiversity Federalism*, 54 MD. L. REV. 1315, 1332 (1995).
101. JOHN M. BARRY, RISING TIDE: THE GREAT MISSISSIPPI FLOOD OF 1927 AND HOW IT CHANGED AMERICA 37 (1997).

for administrators, policy-makers and lawyers is that the biological sciences, including ecology, have changed dramatically since they were incorporated into environmental law during the 1970s and 1980s.

In the 1960s, the science of ecology rested upon the idea of ecosystem equilibrium, and was a deterministic science. In law it led to the suggestion that "qualitative environmental standards could provide the administrative coherence historically lacking in natural resources policy."[102] It is this idea that may prove to be in error. Since the 1960s, the science of ecology has rejected the concept of ecosystem equilibrium.[103] It is now clearly understood that such theories as that of succession leading to climax vegetation are wrong, and have been replaced by disequilibrium. We can thus observe how lagging the law and policy have been to pick-up on what has been going on in science. As Bosselman and Tarlock say,[104] equilibrium has been replaced with the ideas that "system disturbances are both predictable and random," and that "[c]hange and instability are the new constants"; "[a]t best, ecosystems can be managed rather than restored or preserved, and management will consist of a series of risky experiments."[105]

---

102. Fred P. Bosselman & A. Dan Tarlock, *The Influence of Ecological Science on American Law: An Introduction*, 69 CHI.-KENT L. REV. 847, 867 (1994).
103. *Id.* at 869.
104. *Id.* at 869.
105. *Id.* at 869-870. In a 1994 essay, Daniel Farber made two suggestions to improve environmental regulation. The first was to decentralize decision making to "improve the responsiveness of environmental protection to changing circumstances and new information," subject, of course, to "appropriate controls." Daniel A. Farber, *Environmental Protection as a Learning Experience*, 27 LOY. L.A. L. REV. 791, 799 (1994). Farber's suggestion was to give more authority to states under the "Brandeisian ideal of states as laboratories." *Id.* at 801. Forthrightly stated:

> No matter how much we try to improve the regulatory process, many of our best ideas will fail while less promising ideas sometimes will be unexpectedly successful. Or, more bluntly, we are always going to make a lot of mistakes. Given this reality, we ought to run a lot of experiments to test regulatory proposals.

Id.

Farber's second suggestion was to make "regulatory agencies more dynamic." *Id.* This second suggestion seems to be the other side of the same coinage used for his first suggestion. According to Farber:

> Our current regulatory paradigm focuses on maximizing the quality of each individual agency decision. Except in a static situation, however, this may not optimize regulatory outcomes over time. We need to move agencies toward a more dynamic mode, in which regulation is viewed as an ongoing cycle of experimentation and evaluation.

Id. at 802.

Farber's statement implicitly carries with it the idea of adaptive management. Moreover, Dan Tarlock has argued that both environmental law and ecology are nonequilibrium systems. A. Dan Tarlock, *The Nonequilibrium Paradigm in Ecology and the Partial Unraveling of Environmental Law*, 27 LOY. L.A. L. REV. 1121, 1122 (1994).

The word "management" can be overemphasized. Many observers seem to conclude that an emphasis on non-equilibrium functioning necessitates asking how we should "manage" ecosystems. But, it is as possible to reject human tampering with *processes* as with specific conditions. Ecosystem scientists are quick to suggest that function and process should be protected first. For example, it may be better to protect the *function* of fire than protect a stretch of forest; we might consider protecting a *function* or *process* in a manner similar to the way we protect a particular piece of ground such as Yosemite Park or Black Hills National Forest. Thus, ecosystem scientists will argue that "environmental and land management decision-making must be centered around the concept of ecosystem functions."[106] Ecosystem management presents the problem of *scientific uncertainty* and *risk*. How are natural resources to be managed when the only certainty is uncertainty, and when all choices involve risk? A leading conservation biologist suggests some rules that ought to apply when managing resources at the ecosystem level:

> Maintaining viable ecosystems is usually more efficient, economical, and effective than a species-by-species approach.
>
> . . . .
>
> Biodiversity is not distributed randomly or uniformly across the landscape. In establishing protection priorities, focus on "hot spots."
>
> . . . .
>
> Ecosystem boundaries should be determined by reference to ecology, not politics.
>
> . . . .
>
> Because conservation value varies across a regional landscape, zoning is a useful approach to land-use planning and reserve network design.
>
> . . . .
>
> Ecosystem health and integrity depend on the maintenance of ecological processes.
>
> . . . .
>
> Human disturbances that mimic or simulate natural disturbances are less likely to threaten species than are disturbances radically different from the natural regime.
>
> . . .
>
> Ecosystem management requires cooperation among agencies and landowners and coordination of inventory, research, monitoring, and management activities.
>
> . . . .
>
> Management must be adaptive. . . . Recognizing that every land management practice is an experiment with an uncertain outcome, research and monitoring should be coordinated to test hypotheses about the effects of management treatments on biodiversity and ecological integrity. The information gained from these experiments should be used to adjust management in a desirable direction.
>
> . . . .

106. J.B. Ruhl, *Ecosystem Management, the ESA, and the Seven Degrees of Relevance*, 14 NAT. RESOURCES & ENV'T 156, 157 (2000).

> Natural areas have a critical role to play as benchmarks or control areas for management experiments.[107]

There is no doubt that ecosystem management is the intended process for species recovery on the Missouri. In the *Biological Opinion on the Missouri River*, the USF&W Service states:

> An ESA section 7 consultation addresses the effects of a Federal action on listed species and the ecosystems upon which they depend. An ecosystem approach to endangered species and action analysis is consistent with section 2(b) of the Act which states that "The purposes of this ESA are to provide a means whereby the Ecosystems upon which endangered species and threatened species depend may be conserved . . . ." The ESA consultation Handbook (USF&W Service and NMFS 1998) suggests that consideration be given to conducting ecosystem-based consultations when ongoing or future agency activities may affect one or more species within a regional planning area. When the Federal action at issue is complex or has wide-ranging effects, an ecosystem approach to ESA Section 7 consultation may be appropriate. An "ecosystem approach" means that the Service looks at the action and its effects throughout an ecosystem, such as a river.[108]

D. Adaptive Management

1. *On the Missouri and Generally*

Definitions of Adaptive Management. On the Missouri River, as well as other developed river systems, there appears to be an emerging consensus that adaptive management should replace traditional water resources management. Two questions arise. First, what is "adaptive management" and, second, is what is proposed for the Missouri River in fact adaptive management?

In general, adaptive management (AM) is the process of bringing science to the resources management table. AM concedes that resources management encounters both scientific uncertainty and risk, and that systems are complex ecologically because many different components interact directly and indirectly. AM goes further, however, and recognizes that systems are also complex socially because of a large number of user groups, most with conflicting goals involving multiple components of the same system.[109] As explained by one commentator, AM is intended:

> not to maintain an optimal state of the resource, but to develop an optimal management capacity. This is accomplished by maintaining ecological resilience . . . that allows the system to react to inevitable stresses and by generating flexibility in institutions and stakeholders that allow managers to react when conditions change.[110]

---

107. Reed F. Noss, *Some Principles of Conservation Biology, As They Apply to Environmental Law*, 69 CHI.-KENT L. REV. 893, 904-907 (1994); *see also* Judy L. Meyer, *The Dance of Nature: New Concepts in Ecology*, 69 CHI.-KENT L. REV 875 (1999).
108. BIOLOGICAL OPINION, *supra* note 63, at 31.
109. B.L. Johnson, *The Role of Adaptive Management As an Operational Approach for Resource Management Agencies*, 3 CONSERVATION BIOLOGY 8 (1999).
110. *Id.*

Further attempts at general definition offer the following:

> Adaptive management recognizes scientific uncertainty as an essential assumption in resource policy development. Adaptive management suggests that ecosystem management, including ecosystem management policy, should take place in incremental but reversible steps, or probes, designed to test hypotheses concerning appropriate management techniques. For proponents of adaptive management, outcomes become less important than the knowledge gained from them.[111]

But, *what is AM*? There is no set definition, but there is a general idea.

From conservation biologists, we can glean a sort of ideal outline of process. AM filters issues through an *independent science review*, conducted by disinterested parties, which presents its findings to decision-makers in some sort of open forum. Next, the AM process assembles all interested parties—known everywhere as "stakeholders"—to discuss the management problems and the available data. Alternative management possibilities are developed and compared, using computer models. Gaps in data are filled, and uncertainties identified and articulated. It is hoped that the management plan that is developed will help to meet management goals and generate new information to reduce critical data gaps and uncertainties. The management plan is implemented along with a monitoring plan. As monitoring proceeds, plans are revised, opportunities explored, and experiments undertaken and monitored.[112] Of course, it cannot be that simple.

Definitions from Missouri River Proposals. The Biological Opinion issued by the USF&W Service is limited to the current condition of the river rather than to any proposals for new management schemes; but its version of AM is described in general terms as "a process that allows regular modifications of management actions in response to new information and to changing environmental conditions,"[113] and as a way "to insert variability and flexibility in river operations."[114] It contemplates oversight by an Action Coordination Team made up of the Corps, USF&W Service, and "other parties *with biologic or engineer-*

---

111. Thomas T. Ankersen & Richard Hamann, *Ecosystem Management and the Everglades: A Legal and Institutional Analysis*, 11 J. LAND USE & ENVTL. L. 473, 495 (1996). Other useful articles include Lance Gunderson, *Resilience, Flexibility and Adaptive Management—Antidotes for Spurious Certitude?*, 3 CONSERVATION ECOLOGY 7 (1999); Kai N. Lee, *Appraising Adaptive Management*, 3 CONSERVATION ECOLOGY 3 (1999); Richard E. Sparks, *The Need for Ecosystem Management of Large Rivers and Their Floodplains*, 45 BIOSCIENCE 168 (1995).

    Attempts at definition also appear in NATIONAL RESEARCH COUNCIL, NEW DIRECTIONS IN WATER RESOURCES: PLANNING FOR THE U.S. ARMY CORPS OF ENGINEERS 31 (1999).

112. *See* Barry L. Johnson, *The Role of Adaptive Management as the Operational Approach for Resource Management Agencies*, 3 CONSERVATION BIOLOGY (1999).

113. BIOLOGICAL OPINION, *supra* note 63, at 237.

114. *Id.*

ing expertise."[115] Actions are to be taken through an evolving action plan.[116] Central to the plan is constant scientific monitoring. Clearly, the Biological Opinion expects that AM will occur within the context of principles of ecosystem management, and that recovery plans pursuant to ESA will focus on restoration of the "structure, distribution, connectivity and function upon which those listed species depend."[117]

The AM contemplated in the Biological Opinion varies from our ideal outline in several ways. First, action decisions will be filtered through an independent science review board, rather than through a qualified panel of agency employees. It also excludes a requirement that there be participation by a stakeholders group. Monitoring is central to the process envisioned by the Biological Opinion.

In the Master Manual, the Corps commits itself to AM in each of the five preferred alternatives, but speaks of it only in general terms of "an overall strategy for dealing with change and scientific uncertainty."[118] It proposes an Agency Coordination Team made up primarily of federal biologists to review and evaluate monitoring data and to make recommendations to the Corps.[119] Because the Corps limits the scope of the EIS to river flow and reservoirs, is constrained by the project purposes stated in authorizing legislation, will likely be hounded by a large and diverse group of stakeholders, and faces limited decisional flexibility, it is not surprising that it has chosen to play very few specific AM cards. Nonetheless, if and when the Corps proceeds to decision in the Master Manual, it appears ready to commit to an AM process of some kind.

The NRC Committee on the Missouri River was more willing to go into detail in its AM recommendations. It claimed to be defining a process solely in terms of science rather than law, and focused on recovery of the system. Unlike the Corps' focus on flows, the NRC Committee asserts that its goal is recovery of the entire river corridor. Moreover, the NRC report claims no institutional constraints, and appears to be convinced that the institutional system is unacceptable, such that a new institutional arrangement needs to be established that is structured to accomplish recovery.

The NRC Committee devotes an entire chapter to AM, and also places AM squarely in the center of its recommendations. The basic definition of AM which it employs is more helpful:

> An adaptive management strategy explores ways to couple natural and social systems in mutually beneficial ways. It seeks to maintain or restore ecosystem resilience which is defined as the capacity of key ecosystem structures

115. *Id.*
116. *Id.* at 240.
117. *Id.*
118. RDEIS at 6-4.
119. *Id.*

> and processes to persist and adapt over time in the face of natural and anthropogenic challenges.
>
> . . . .
>
> . . . In addition to flux in natural systems, [AM] assumes that human systems change and intervene, and thus induce subsequent ecological adjustments. These interactions then contribute to or detract from ecological stability and resilience. [AM] seeks to narrow differences among stakeholders by encouraging them to implement new approaches that will allow people to live with and profit from natural ecosystem variability at socially-acceptable levels of risk.[120]

The NRC Committee has, with this language, stepped well out ahead of the Biological Opinion and the EIS in that it first describes the goal as overall system resilience, and, second, places "social systems," and the impact of man on nature, in the middle of the process. Resilience is the true goal of ecosystem management and integral to true AM processes. But, ecosystems include human activities, and AM must include human activities in the mix. In this way AM can seek-out that level of risk that is acceptable *both* for the ecosystem as well as the human enterprises underway in that ecosystem.

2. *Lessons and Literature*

At some level, the American legal system through its Constitutional separation of powers, its evolved two-party political system, and the development of common law already has formal adaptive features absent from other more highly ordered and brittle systems.[121] Moreover, there is a kind of informal administrative flexibility even where the legal authority for such flexibility is difficult to find.

Professor Holly Doremus found an example of this informal flexibility even in the Endangered Species Act under which "[a]gency discretion . . . is limited by the Act's irreducible commands to avoid jeopardy and unpermitted take, and to list species that are in danger of extinction."[122] By using the ESA the tightly drawn exception amendment process to listing as an example, she explained one source of flexibility came from the political and governmental funding process itself:

---

120. NRC REPORT, *supra* note 98, at 88-89.

121. *See* Thomas Geu, *Chaos, Complexity, and Coevolution: The Web of Law, Management Theory, and Law Related Services at the Millenium (Part II)*, 66 TENN. L. REV. 137, 190-215 (1998) (and sources cited therein). For an example of empirical legal research that attempts to prove law is a complex system, see David G. Post & Michael B. Eisen, *How Long Is the Coastline of the Law? Thoughts on the Fractal Nature of Legal Systems*, 29 J. L. STUD. 545 (2000). Post and Eisen use the same kind of citation counting system as does Posner in his book PUBLIC INTELLECTUALS: A STUDY OF DECLINE (2001) (identifying the top 100 public intellectuals based on number of citations, but for different purposes).

122. Holly Doremus, *Adaptive Management, the Endangered Species Act, and the Institutional Challenges of "New Age" Environmental Protection*, 41 WASHBURN L.J. 50, 59 (2001).

> Although the amendments to the ESA added very little flexibility, several legislators used the occasion of oversight hearings in 1979 to forcefully remind the Fish and Wildlife Service of the political cost of listing non-charismatic species [like the snail darter] or species that could interfere with significant economic development. The Service could hardly fail to get the message that aggressive implementation of the ESA might lead to its repeal. Not surprisingly, the story of ESA implementation since 1978 consists generally of the Services exploiting their discretion to the fullest to avoid political controversy. That tendency has been checked only by the ability of citizen suits to force the agencies to perform politically unpalatable duties.[123]

As discussed elsewhere in this Article,[124] planning and the organization of institutions will remain necessarily important, but those features must remain flexible to be viable. However, even when adaptability is designed into the system there are inherent risks and uncertainties as illustrated by the disintegration of the Soviet Union and the resultant attempts to reform its economic, social, and political systems:

> By 1989, Ligachev and the orthodox wing of the Communist Party came to blame Yakovlev, Gorbachev, and Shevardnadze for radicalizing perestroika to the point of creating a "bourgeois" state, for abandoning the "class approach" to politics, *for failing to provide a blueprint for the future*. "Some of our conservatives now say that *a group of adventurists began to restructure things without a concept*," Yakovlev replied. "But imagine what would have happened if we'd just gone into an office and created an entire scheme. Marx did that and look what it led to! *One should take things from life, and adjust them every day*. Our whole trouble is that we are inert, we think in dogmas. Even if reality tells us to change things, we always check first in a book."[125]

Philip K. Howard, in his 1994 book entitled *The Death of Common Sense: How Law Is Suffocating America*, compared the United States' bureaucratic command and control regulatory system to that of the Soviet Union, and stated: "The Soviets tried to run their country like a puppeteer pulling millions of strings. In our country, the words of law are like millions of trip wires, preventing us from doing the sensible thing."[126] He called for the return of judgment and personal account-

123. *Id.* at 58 (footnotes omitted).

124. *See infra* notes 198-209 and accompanying text (discussing complex adaptive systems and the general idea of the "edge of chaos").

125. DAVID REMNICK, LENIN'S TOMB: THE LAST DAYS OF THE SOVIET EMPIRE 298 (1993) (emphasis added). Perhaps George Guilder's observations on maturing business organizations apply equally to political and legal institutions (like planning in the Soviet system) as well. Guilder, for example, has stated that business organizations that are established and prosper based on "curve of mind" (innovation, agility, and adaptability) "often abandon it when they establish themselves in the world of matter" as they begin to fight to preserve the value of their material investments and "begin to exalt expertise and old knowledge, rights and reputation, over the constant learning and experience of innovative capitalism." GEORGE GUILDER, MICROCOSM: THE QUANTUM REVOLUTION IN ECONOMICS AND TECHNOLOGY 113 (1989).

126. PHILIP K. HOWARD, THE DEATH OF COMMON SENSE: HOW LAW IS SUFFOCATING AMERICA 21 (1994).

ability to government by emphasizing the goals of the various laws rather than by minutely governing the manner and process of detailed rule based compliance that dictate sometimes unintended results.[127] Thus, he argued that most regulatory rules should be in the style of common law principles which, quoting Ronald Dworkin, "incline a decision one way, though not conclusively, and permit a judgment that fits the situation."[128] Howard further stated that "[p]rinciples allow us to think."[129] Stated another way, the "common law has plenty of rules and guidelines, but they are subservient to broader principles. If applying a guideline in a particular case seems inconsistent with the principle, an exception is made."[130] Under the common law, "circumstances are critical"[131] even if it sacrifices certainty. Cardozo "said he was 'disheartened' when he realized there was no 'solid land of fixed and settled rules.'"[132] He explained, however, using the word *complex* without reference to *complexity* or CAS (which, of course, was unknown at the time):

> No doubt the ideal system, if it were attainable, would be a code at once so flexible and so minute, as to supply in advance for every conceivable situation the just and fitting rule. But life is too complex to bring the attainment of this idea within the compass of human power.

Cardozo further worried that the quest of unattainable certainty in law would result in "intolerable rigidity."[133] It is the appropriate mix of fluidity and rigidness that moves a system toward the CAS critical state at the edge of chaos. Howard simply opined that the command and control regulatory system had gone too far toward rigid order. He cited Nobel laureate Friedrich Hayek as supporting something that sounds close to adaptive decision making and hints at the importance of both diversity and aggregation which are CAS features:

> How can anything good happen, Hayek asked, if individuals cannot think and do for themselves? Rules preclude initiative. Regimentation precludes evolution. Letting accidents happen, mistakes be made, results in new ideas. Trial and error is the key to all progress. The Soviet system of rules and central planning is doomed to failure, Hayek stated with confidence fifty years ago, because it kills the human faculty that makes things work.[134]

Luminary academic environmental lawyers like Daniel Farber share some of Howard's more general concerns as they relate specifically to the rule-making model in environmental law. While the many successes of the current environmental regulatory scheme are expressly acknowledged, Farber illustrated his two-fold concern by de-

127. *See id.* at 176.
128. HOWARD, *supra* note 126, at 176.
129. *Id.*
130. *Id.* at 175.
131. *Id.* at 28.
132. *Id.* at 52.
133. *Id.*
134. *Id.* at 50-51.

lineating two exemplary issues within the current regulatory scheme for pollution control. "First, imposing high levels of pollution control is sometimes quite wasteful in terms of any corresponding environmental benefit."[135] Second:

> [T]his method of pollution control is inherently cumbersome. The EPA must learn the pollution control technologies and economic conditions in each industry to determine the best available technology. A major EPA rule may require tens of thousands of pages of documentation, including careful responses to dozens of arguments raised by the industry. Even with all this effort, the EPA cannot fully master the economics and technologies of dozens of industries .... It is bound to make mistakes in both directions: asking more than some industries can reasonably achieve and letting others off too lightly. Because the regulatory process is so cumbersome, these mistakes are difficult to correct when they are later discovered.[136]

In a slightly different context he stated that, "scientific evidence has rapidly evolved, leaving environmental policy struggling to keep up"[137] and, further, that major environmental issues often are imbedded in unresolvable scientific uncertainty.[138]

Farber's criticism is directed at a specific "first generation" environmental regulation. Professor Stewart provided a more general criticism of such environmental regulations:

> The criticisms of the "first generation" system of centralized federal command-and-control regulation are by now familiar. It has been criticized on the grounds that it is unduly rigid, cumbersome, and costly; fails to accommodate and stimulate innovation in resource-efficient means of pollution prevention; fails to prioritize risk management wisely; is patchwork in character, focusing in an uncoordinated fashion on different environmental problems in different environmental media and often ignoring functional and ecosystem interdependencies; and relies on remote centralized bureaucratic apparatus that lacks adequate democratic accountability. While acknowledging its past accomplishments, critics of the command and control central planning system maintain that it is reaching its inherent limits and is no longer capable of ensuring sustainable environmental progress at tolerable social cost.[139]

In some ways AM is similar to, and may share some of the pitfalls of, negotiated rulemaking ("Neg-Reg") which is a rulemaking "process by which representatives of the interests that would be substantially

135. Daniel A. Farber, *Environmental Protection as a Learning Experience*, 27 LOY. L.A. L. REV. 791, 794 (1994).

136. *Id.* at 794-95.

137. *Id.* at 795.

138. *Id.* at 797.

139. Richard B. Stewart, *A New Generation of Environmental Regulation?* 29 CAP. U. L. REV. 21, 21 (2001). (Stewart's article is part of a symposium, *The National Symposium on Second Generation Environmental Policy and the Law*, 69 CAP. U. L. REV. 1 (2001)). Stewart's article addresses a number of alternatives to the command-and-control model including, *inter alia*, "OMB Supervision of Regulatory Agency Cost-Benefit Analysis," "Adaptive Implementation," "Environmental Agreements," and "Economic Incentive Systems." *Id.* at 40, 54, 60, 94 (respectively).

affected by a proposed rule negotiate to reach a *consensus*."[140] Thus a general caveat on the limited circumstances which Neg-Reg seems to work well may, too, help inform the use of adaptive management:

> Many disputes that come before agencies are not good candidates for negotiated settlement, however. Settlement is unlikely if the applicable legal rules are unclear or unstable; if the relevant facts are unclear, uncertain, indeterminate, or inaccessible to a party; if there are numerous parties with widely varying interests . . . or if one or more parties perceives a major advantage in delaying resolution of the dispute. Unfortunately, most major rulemakings involve all of these conditions. Thus, most major rulemakings are poor candidates for resolution through Neg-Reg, which has succeeded in only about 20 percent of the rulemaking in which it has been tried.[141]

Indeed, there has been a spirited recent debate concerning Neg-Reg in some of the literature.[142]

The warning about negotiated rulemaking emphasizes the practical necessity of trying to push AM of the Missouri River to a CAS critical state and seems to imply that relying on consensus works only in a limited number of political circumstances.

Aside from the politico-structural design of a particular AM scheme, AM seems to make sense only for a certain kind of ecological states.

Holly Doremus recently described the best ecological candidates for AM as follows:

> Adaptive management is most sorely needed when the resource is suffering under the status quo, we do not fully understand why or what changes will most effectively remedy the situation, and we are under heavy economic or political pressure to minimize changes in the status quo. The management of resources that are already severely impacted and upon which many people

---

140. Philip J. Harter, *Assessing the Assessors: The Actual Performance of Negotiated Rulemaking*, 9 N.Y.U. ENVTL. L.J. 32, 32 (2000) (emphasis added). Stated more simply: "As the name implies, Neg-Reg is a process through which policy disputes raised by a rulemaking proposal are resolved through a negotiation process." DAVIS & PIERCE, *infra* note 155, § 7.14, at 373. For an extended discussion of negotiated rulemaking, see Stewart, *supra* note 139, at 87-94.

141. DAVIS & PIERCE, *infra* note 155, § 7.14 at 374-5 (citation omitted). Illustratively:

> Another analogy also helps to illustrate the low probability that most major rulemakings can be resolved through negotiated settlement. Promulgation of a major rule resembles closely passage of a major statute. The stakes are high, and a large number of parties will be affected in disparate and complicated ways. Neg-Reg requires agreement among representatives of all affected interests. This is analogous to requiring Congress to enact all major pieces of legislation under a unanimous consent rule. Just as most major legislation could not be enacted under such conditions, most major rulemakings cannot be concluded through use of Neg-Reg.

Id. at 375.

142. *Compare* Harter, *supra* note 140, *with* Cary Coglianese, *Assessing the Advocacy of Negotiated Rulemaking: A Response to Philip Harter*, 9 N.Y.U. ENVTL. L.J. 386 (2001).

> have developed substantial economic reliance, such as the Columbia River or the Florida Everglades, is an example.[143]

The Missouri River, like the Columbia River, seems to be just the kind of ecosystems for which Doremus suggests AM. She cautions, however, that unless there is meaningful design and implementation:

> Adaptive management provides a plausible-sounding avoidance mechanism [and that] . . . the Services are prone to invoke adaptive management almost as a talisman, without disclosing to the public the precise parameters of the particular adaptive management proposal and, for all a reader of their public statements can tell, perhaps even without considering those parameters.[144]

For whatever reason, adaptive management has not led to gains on the Columbia River.[145]

This paralysis, however, seems to be most attributable to the AM process that was originally established for the river and in which Congress vested ostensible authority in the Pacific Northwest Electric Power and Conservation Planning Council (Council). The Council, consisting of two representatives appointed by each of the States of Idaho, Montana, Oregon, and Washington, creates a "pluralistic intergovernmental and public review process."[146] Moreover, the Northwest Power Act, which established the Council,[147] expressly required the Council to, *inter alia*, "favor biological outcomes over economic ones,"[148] and "lowered the burden of proof for undertaking action by requiring that the remedial program . . . be based only on 'best available scientific knowledge,' not scientific certainty."[149] Nonetheless, the Bonneville Power Administration has final authority to determine Columbia River management; however, it was expected to "act consistently with the Council's program."[150] According to a 1994 Ninth Circuit opinion, this process did not live up to its promise. Instead the

143. Doremus, *supra* note 122, at 71.

144. *Id.* at 76.

145. *Id.* at 80. Doremus suggests, however, that the "precariousness" of salmon in the Columbia River coupled with strong economic pressures and no clear scientific evidence for a best alternative has led to a paralysis for experimentation. *Id.*

146. Northwest Res. Info. Ctr., Inc. v. Northwest Power Planning Council, 35 F.3d 1371, 1378 (9th Cir. 1994). The court quoted extensively throughout its opinion from Michael C. Blumm, *Fulfilling the Parity Promise: A Perspective on Scientific Proof, Economic Cost, and Indian Treaty Rights in the Approval of the Columbia River Basin Fish and Wildlife Program*, 13 ENVTL. L. 103 (1982); Michael C. Blumm & Andy Simrin, *The Unraveling of the Parity Promise: Hydropower, Salmon, and Endangered Species in the Columbia Basin*, 21 ENVTL. L. 657 (1991); Robert C. Lothrop, *The Misplaced Role of Cost-Benefit Analysis in Columbia Basin Fishery Mitigation*, 16 ENVTL. L. 517 (1986); Volkman & McConnaha, *supra* note 7.

147. *Northwest Res. Info. Ctr.*, 35 F.3d 1371, *at* 1377 (1994).

148. *Id.* at 1378.

149. *Id.*

150. *Id.* at 1379.

Council became moribund in consensus building. As stated by the court:

> Unfortunately, the record reveals few profound successes resulting from these innovations in thinking. The Council's approach seems largely to have been from the premise that only small steps are possible, in light of entrenched river user claims of economic hardship. Rather than asserting its role as regional leader, the Council has assumed the role of consensus builder, sometimes sacrificing the Act's fish and wildlife goals for what is, in essence, the lowest common denominator acceptable to power interests and DSIs.[151]

Although the Northwest Power Act established priorities and organization it was, in this case, the Council itself that adopted AM.[152] In any event, the case points out the danger inherent in organizing and implementing AM.

As previously discussed, AM is one of several responses to both specific and general criticism of traditional "top-down" regulation. These criticisms include the lack of flexibility and accountability in regulation generally, and the necessity to provide regulatory room for judgment. Designing AM programs requires the study of past successes and failures. Even a brief review of literature and selective cases suggests that Congress should be involved in designing both constraints (or parameters) for the process and decisions thereunder, as well as relaxing constraints in some areas of laws which provide unnecessary restraints on flexibility. Moreover, as a general matter, it might be helpful to look at features of the common law judicial process which, as lamented by Cardozo, was supplanted by a more rigid regulatory process in the search for certainty. Perhaps some of those features could be included as appropriate for system design. Further, as the single case discussed in this section suggests, and as one commentator implies, "consensus" may not be a viable decision-making process even where there are agreed upon goals.

Finally, this section serves as evidence of a growing amount of literature worthy of review in designing and implementing AM. For example, one of the articles quoted and cited extensively in this section contained its own series of suggestions for AM. Included among these suggestions is the notion of balancing the "political asymmetry" which places agencies under intense scrutiny and lobbying by, for example, land owners through the use of independent scientists. Other suggestions include the wide dissemination of data and information, the use of decision making capacity building grants for private citizen groups, access to the decision making table, and pre-negotiated response to certain specified data sets.[153]

---

151. *Id.* at 1395.

152. *Id.* at 1380 n.18.

153. Doremus, *supra* note 122, at 80-87.

3. *Adaptive Management and Science*

The role of science within AM is cannot be overemphasized. As the National Research Council stated within the context of AM in the Glen Canyon Dam and the Colorado River Ecosystem: "The Strategic Plan should include a strategy for using—and evaluating the usefulness of—new scientific information in testing management alternatives, including their impacts on the welfare of different stakeholder groups." Thus, AM and its judicial review has direct implications for the standard of scientific certainty where opportunities for intervention and experiment present themselves. In turn, the standard of scientific certainty affects the admissibility of scientific evidence as well as the applicable standard of proof; that is, it impacts the kind of scientific evidence that can be used to support an intervention as well as the quantum of evidentiary support needed to take action for purposes of judicial review. Thus, an introductory discussion of selected issues concerning the standard of scientific certainty is warranted since these issues may well play a key role in the success or failure of any adaptive management scheme.[154]

---

154. The purpose of this Article is to comment on the adaptive management provisions proposed for Missouri River management. This purpose, however, is intertwined with the more general issue of the use of science in law and in legal institution design. Both the use of science in law and in legal institution design merit more study than the scope of this Article allows.

In 1994 Professor A. Dan Tarlock opined that, "Environmental law derives its political power and legitimacy from science." A. Dan Tarlock, *The Nonequilibrium Paradigm in Ecology and the Partial Unraveling of Environmental Law*, 27 LOY. L.A. L. REV. 1121, 1121 (1994). He noted his statement was "deliberately provocative." *Id.* at 1144 n.1. He further noted:

> It rejects the argument that environmental law is—or should be—grounded in nonanthropocentric "rights of nature" . . . . It also rejects the idea that the extremely difficult scientific problems that permeate environmental law can be avoided *simply* by recasting them as ethical. Of course, there is no constitutional requirement that environmental regulation be based on scientific understanding, and there are nonscientific justifications for environmental regulation. However, science has driven the environmental movement by identifying problems and solutions and by establishing the legitimacy of intensive regulation of human activity. It will continue to do so for the future.

Id. (citations omitted). Later in the same article he argued forcefully:

> Through science, simple and sophisticated, we have increasingly come to see natural processes as phenomena to be respected rather than manipulated. This new-found respect can support laws that recognize the value of new resource functions enacted in advance of conclusive scientific evidence. This is the thrust of the newly emerging precautionary principle in international law. However, as long as we value rationality—an open question with respect to some strains of modern environmentalism—science will continue to serve an important regulating function. The need for some scientific justification, however probabilistic, for environmental regulation is necessary to constrain the potential arbitrariness and unfairness that can result from the substitution of intuition for verification.

At base, AM recognizes the limits of scientific knowledge and becomes part of the scientific method itself where field experiments, such as those relating to flow, are conducted in an effort to strengthen ecosystems and gain additional knowledge for use in future ecosystem management. The test *should* be whether the experiment is based on a reasonable hypothesis and not on whether the desired positive result is certain or even more likely than not. Neither agency adjudication nor agency rule-making were designed for this purpose.[155] Even in adjudicative proceedings, however, an agency is not required to apply the Federal Rules of Evidence and, indeed, "[n]o rules of evidence apply to informal adjudication because that procedure does not involve an oral evidentiary hearing."[156] Therefore, the agency has broad dis-

---

Id. at 1137-38 (footnotes omitted). Professor Tarlock suggests that adaptive management "is premised on the assumption that management strategies should change in response to new scientific information." *Id.* at 1139. This use of science as data for decision making and policy is analogous to the use of science as evidence in trials; even though, perhaps, the standards of admissibility are somewhat different. There is another use of science and that is the use of scientific knowledge and data in the *design* of legal or social institutions. Adaptive management as discussed in this Article includes both of the foregoing uses of science. *See* Thomas Geu, *Policy and Science: A Review Essay of Wilson's Consilience: The Unity of Knowledge*, 44 S.D. L. REV. 612, 620-27 (1999). *Compare* KENNETH R. FOSTER & PETER W. HUBER, JUDGING SCIENCE: SCIENTIFIC KNOWLEDGE AND THE FEDERAL COURTS (1997), *with* John Veilleux, Note, *The Scientific Model in Law*, 75 GEO. L.J. 1967 (1987).

A strong caveat to the use of science as evidence for dispute resolution or for the design of legal institutions seems appropriate because science can easily be misused for a variety of reasons. For example, "science" played a central role in "Hitler's 'Aryan Physics,' Stalin's 'Marxist Genetics,' . . . [and] Mao's 'Communist Psychology.'" PETER F. DRUCKER, POST-CAPITALIST SOCIETY 211 (1993). *Compare Science and Profit*, ECONOMIST, Feb. 17, 2001, at 21 (noting the necessity of profit to encourage drug innovation), *with Publication Ethics: Truth or Consequences*, ECONOMIST, Sept. 15, 2001, at 70 ("The issue topping the editorial agenda is the honesty of research that is sponsored by drug companies to test the safety of their wares."). For a wonderful narrative of an example of the admixture of politics and science in the United States, see EDWARD J. LARSON, SUMMER FOR THE GODS: THE SCOPES TRIAL AND AMERICA'S CONTINUING DEBATE OVER SCIENCE AND RELIGION (1997). At some level the state of science forms part of, and influences, the larger worldview affecting public debate of a variety of issues. As a result, it is arguably impossible to isolate science from politics. *See, e.g.*, Wendy E. Wagner, *The Science Charade in Toxic Risk Regulation*, 95 COLUM. L. REV. 1613 (1995). *Cf.* I. BERNARD COHEN, SCIENCE AND THE FOUNDING FATHERS, (1995); CARL SAGAN, THE DEMON-HAUNTED WORLD: SCIENCE AS A CANDLE IN THE DARK 423-34 (1995) ("Scientific findings and attitudes were common in those who invented the United States.").

155. *See generally* KENNETH CULP DAVIS & RICHARD J. PIERCE, JR., ADMINISTRATIVE LAW TREATISE, ch. 10 ("Evidence"), ch. 7 ("Rulemaking Procedure"), ch. 8 ("Statutory Requirements for Adjudication").

156. *Id.* § 10.1, at 117. Generally the Federal Rules of Evidence limit the admissibility of expert scientific testimony, for example, based on *Daubert v. Merrill Dow Pharmaceuticals, Inc.*, 509 U.S. 579 (1993), as follows:

cretion as to the type of scientific evidence it considers. Thus, assuming that the general rules apply to AM, both the scientific advisory council and the actual decision-makers will be left largely as their own evidentiary gatekeepers. Moreover, should court review be allowed, it seems likely that the ultimate decision should be subjected to the "arbitrary and capricious test [applied] when an agency acts through informal adjudication or informal rulemaking"[157] for purposes of AM. It is not clear, however, that this is currently the case.[158]

Indeed, without specific Congressional action for implementing AM on the Missouri, both the standard of review and the quantum of scientific evidence necessary to take action are at best uncertain and probably at odds with the meaningful expeditious implementation of AM or management actions thereunder. For example, Judge Patricia Wald has written a widely cited article on judicial deference in the related area of negotiated rule making. According to one commenter:

> The well-known dissent from this view was expressed by Judge Patricia Wald. Judge Wald argues that an appellate court has an "independent obligation to insure that the agency is not thwarting Congressional intent, regardless of how many parties agree with the agency's rule." Accordingly, the "interest test" should not intrude into the appellate review process. She rejects the idea that everyone must either demand to participate or trust a participating interest group to represent his or her interests. Echoing some of Professor Funk's concerns, Judge Wald argues that, as only a limited number of groups can take part in the negotiations, they should not be allowed to bind everyone. Thus, the court should apply the same scope of review and criteria of legality to every rule, regardless of whether it is the product of negotiation consensus or traditional notice-and-comment rule-making. This appears to be the current law.[159]

> In *Daubert*, the Supreme Court offered the following, non-exclusive list of factors to guide the assessment of the reliability of scientific evidence: (1) whether the theory or technique has been or can be reliably tested; (2) whether it has been or can be subjected to peer review; (3) the known or potential rate of error of the technique; and (4) the "general acceptance" of the technique. An additional "tainted research" factor has added on remand, namely: "whether the experts are proposing to testify about matters growing naturally and directly out of research they have conducted independent of the litigation, or whether they have developed their opinions expressly for the purpose of testifying."

JACK B. WEINSTEIN & MARGARET A. BERGER, WEINSTEIN'S EVIDENCE MANUAL, STUDENT EDITION § 13.02(4)(b), at 13-14 (5th ed. 2001) (footnotes omitted).

157. DAVIS & PIERCE, *supra* note 155, § 11.4, at 200. Whatever else comprises the arbitrary and capricious test, it is arguably less demanding than the substantial evidence test which is applied to formal adjudication and formal rulemaking. *Id.* § 11.2, at 174; § 11.4, at 202.

158. For example, there was specific legislation dispensing with the required formal rule-making process under the Administrative Procedures Act for actions by the Northwest Power Planning Council on the Columbia River. *See* Northwest Res. Info. Ctr., Inc. v. Northwest Power Planning Council, 35 F.3d 1371, 1378 (9th Cir. 1994).

159. Richard B. Stewart, *A New Generation of Environmental Regulation?* 29 CAP. U.L. REV. 21, 93-94 (2001) (footnotes omitted) (quoting Patricia M. Wald, *Negoti-*

The standard of review is important to AM, in part, because it operates either to encourage or discourage private suits. As such, it also sets internal parameters for action based decision making.

The standard for scientific evidence is important for the same reasons as the general standard of review. It is particularly relevant to AM because AM recognizes that the results of action are uncertain and unpredictable. Here, the ESA itself causes concern because it requires that the decision to list a species as endangered or threatened must be made "solely on the basis of the best scientific and commercial data available."[160]

Both the admissibility criteria and the standard of judicial review need to provide the flexibility necessary for AM. There may be a question, however, of whether they together provide enough structure within which to regularly take decisive action. At the very least it would seem that the AM structure should be self-conscious of evidentiary and decision standards and evolve its own pre-negotiated loose framework of informal working rules within which to make decisions.[161] Obviously, too high a standard almost assures that no interaction or experimentation will occur.[162] Thus the decisions must be made within a particular context and for a particular purpose. There

---

ation of Environmental Disputes: A New Role for Courts?, 10 COLUM. J. ENVTL. L. 1, 19-20 (1985)).

160. 16 U.S.C. § 1533 (b)(1)(A) (2000). For a discussion of the "ESA as a Barrier to Adaptive Management," see Doremus, *supra* note 122, at 78-80.

161. In this regard adaptive management seems similar to "protective regulation" like that of assessing the potential risk of toxic substances even though there is an expectancy of a higher frequency of "failures" within the adaptive management framework. *See generally* CARL F. CRANOR, REGULATING TOXIC SUBSTANCES: A PHILOSOPHY OF SCIENCE AND THE LAW (1993).

162. One suggestion growing out of the area of toxic substances has been made by Carl Crantor and described by Professor Alyson C. Flournoy as follows:

> The question he poses is whether these assumptions and standards are appropriate to the context of toxic substances regulation.
>
> . . . .
>
> This work grew out of his recognition that not every regulatory decision need be made with the same degree of certainty chosen by research science. Indeed, not every decision made by scientists is based on this degree of proof. Cranor explores the possibilities of a relatively quick and inexpensive scientifically recognized technique known as expedited risk assessment. He concludes that for purposes of some regulatory decisions—such as decisions to issue warnings and priority setting—we may do better relying on expedited risk assessments rather than acting with no basis for judging the risks of the many untested substances, paralyzed by the cost and time required to know the impacts of the many untested substances with ninety-five percent certainty. Cranor has since worked with regulators in California to explore the use of expedited risk assessment as a tool for obtaining enough certainty about the potential risks of chemical substances to support a more rational ordering of regulatory priorities.

Alyson C. Flourney, *Coping with Complexity*, 27 LOY. L.A. L. REV. 809, 822 (1994).

is a very real issue as to whether the law allows enough flexibility within which such a standard might develop. If it does not allow for such flexibility the law must be changed to allow for it or amended to provide workable parameters. Moreover, Congress itself should provide the flexibility for AM by relaxing decision standards, tasks and statutory goals under specific legislation like the ESA.

E. The Conflict Inherent in the Missouri River Review Process

In the 1970s biologists were discarding equilibrium theories. At the same time, the last of the great Missouri River dams was being closed—the very antithesis of ecological thinking. At best the dams were conservation projects. In fact, they were built to provide jobs for returning soldiers, prevent floods and to irrigate land in North and South Dakota, two states which lusted for a share of federal expenditures.

As of 2002, the Corps has been asked to revise the project to reflect contemporary scientific knowledge and to implement something which resembles ecosystem management. What may be most remarkable is how real the possibilities are of a management plan which reflects ecosystem thinking, given the current state of the River. Of course, whether those possibilities are ever to be explored is another question. But, ecosystem management and AM are on the table, and it appears that they will be applied to this most complex of issues.

IV. COMPLEX ADAPTIVE SYSTEMS

A. Complex Adaptive Systems

Beyond AM, the science of complex adaptive systems, and its foundational component parts, chaos and complexity, is at least instructive as to the potential of true AM. Professor John H. Holland, a computer scientist, helped launch the study of complex adaptive systems (CAS) in February 1987 when he delivered a paper at the Santa Fe Institute entitled *The Global Economy as an Adaptive Process*:[163]

---

163. WALDROP, *supra* note 1, at 144.

The Santa Fe Institute in New Mexico is a lively center for exchange and debate on complex systems. In the words of the economist Brian Arthur of Stanford University, now the Citibank Professor at the institute, "It is the only place where a biologist can come and hear an economist explain how a jet engine works."

> The institute is the brain-child of George A. Cowan, former head of research at Los Alamos National Laboratory near Santa Fe. It soon received the backing of top scientists in a number of fields, including Philip W. Anderson, Nobel Prize winner for his work on condensed matter physics, Murray Gell-Man, Nobel Prize winner for the discovery of quarks, which are among the most fundamental of all particles, and

Holland started by pointing out that the economy is an example par excellence of what the Santa Fe Institute had come to call "complex adaptive systems." In the natural world such systems included brains, immune systems, ecologies, cells, developing embryos, and ant colonies. In the human world they included cultural and social systems such as political parties or scientific communities. Once you learned how to recognize them, in fact, these systems were everywhere.[164]

> Kenneth Arrow, economist and Nobel Prize winner for the general equilibrium theory of economics.

BAK, *infra* note 180, at 114.

For a very recent account of how complexity is being used to study interdisciplinary problems, see Jonathan Rauch, *Seeing Around Corners,* ATL. MONTHLY, Apr. 2002, at 35. For a general tour of how chaos and complexity are being studied by computer scientists under one of several terms, including "artificial intelligence," see Thomas Geu, *The Tao of Jurisprudence: Chaos, Brain Science, Synchronicity, and the Law*, 61 TENN. L. REV. 933, 942-55 (1994) (including a basic discussion of "genetic algorithms"). In addition to the works cited therein, serious or technically inclined readers might consult DOUGLAS HOFSTADTER & THE FLUID ANALOGIES RESEARCH GROUP, FLUID CONCEPTS & CREATIVE ANALOGIES: COMPUTER MODELS OF THE FUNDAMENTAL MECHANISMS OF THOUGHT (1995), and BARBARA VON ECKARDT, WHAT IS COGNITIVE SCIENCE? (1993). For an enjoyable and informative read in this area, see DAVID FREEDMAN, BRAINMAKERS: HOW SCIENTISTS ARE MOVING BEYOND COMPUTERS TO CREATE A RIVAL TO THE HUMAN BRAIN (1994). See the following part of this Article.

A practical application of CAS theory can be seen at a Deere & Company plant where custom scheduling is now done by a computer program using genetic algorithms based on a precursor of CAS theory. The program engineered a solution to the plant's scheduling problems caused by re-engineering:

> Deere had re-engineered itself into a corner. "It became obvious we had an ongoing problem," says engineer Dick McKinnon. "I made some phone calls." One of the calls went to Bill Fulkerson.
>
> . . . .
>
> Purely by chance a short time earlier, a Deere executive had stopped by Mr. Fulkerson's cubicle. Looking at the mathematician's notoriously messy desk, the boss made a comment about a book on the emerging science of chaos theory, then wished him a Merry Christmas and walked away. That was in December 1992.

Thomas Petzinger Jr., *At Deere They Know a Mad Scientist May Be a Firm's Biggest Asset*, WALL ST. J., July 14, 1995, at B1. Of course, this is a success story: "Planters now flow smoothly through the assembly line, with monthly output up sharply. Overtime has nearly vanished." *Id.* A more recent practical application of complexity is the agent-based modeling used by NASDAQ in its consideration of lowering the minimum price changes on its national securities market from 1/8 of a dollar (approximately twelve cents) to 1/100 of a dollar (one cent). Eric Bonabeau, *Predicting the Unpredictable*, HARV. BUS. REV., Mar. 2002, at 109. The same article states that "[e]mergent phenomena are not just academic curiosities; they lie beneath the surface of many mysteries in the business world." *Id.* at 110.

164. WALDROP, *supra* note 1 at 145. Professor Ruhl offers the following "examples of complex adaptive systems in the subject matter of environmental law": (a) ecosystems, (b) technology, (c) economies, (d) land use. Ruhl, *supra* note 5, at 934, 953-967 (Ruhl's article is necessary reading for anyone interested in applying complex adaptive systems theory to environmental law).

In that paper, Holland posited that complex adaptive systems share the following "crucial properties": (1) "each of these systems is a network of many 'agents' acting in parallel";[165] (2) "a complex adaptive system has many levels of organization, with agents at any one level serving as the building blocks for agents at a higher level";[166] (3) "all complex adaptive systems anticipate the future"[167] by "constantly making predictions based on its various internal models of the world—its implicit or explicit assumptions about the way things are out there [either by conscious choice or through instinct]";[168] and (4) "complex adaptive systems typically have many *niches*, each one of which can be exploited by an agent adapted to fill that niche."[169]

Other physical scientists studying this special kind of complexity previously observed that at least some kinds of these of yet unnamed systems also exhibited other properties like "emergence, collective behavior, and spontaneous organization."[170]

In a subsequent book, Holland revised and expanded his four crucial properties of complex adaptive systems into seven basic elements consisting of four properties and three mechanisms.[171] His four properties are diversity;[172] aggregation;[173] nonlinearity;[174] and flow.[175] He then moved internal models into his mechanism category.[176] These labels, with one or two exceptions, are descriptive

165. Waldrop, *supra* note 1, at 145.
166. *Id.*
167. *Id.* at 146.
168. *Id.*
169. *Id.* at 145.
170. *Id.* at 149.
171. JOHN H. HOLLAND, HIDDEN ORDER: HOW ADAPTATION BUILDS COMPLEXITY 11- 40 (1995).
172. *Id.* at 27.
173. *Id.* at 10.
174. *Id.* at 15.
175. *See id.* at 23.
176. The other mechanisms are "building blocks" (a prior crucial property) and "tagging." Tagging "facilitates the forming of aggregates." *Id.* at 12. Thus, tags are important in boundary formation between aggregates. *Id.* at 13-15. Examples of tags include a banner or flag under which armies congregate and rally and "headers" in Internet addresses. *Id.* "Building blocks" help generate internal models. At bottom, they are component subcategories of a larger category. For example, Holland uses "faces" as the larger (meta) category and eyes as one of the component subcategories. *Id.* at 36. Now, imagine your mother with the eyes of a tiger. Can you do it? The set including different kinds of eyes is a building block. Of course, our categories are nothing more than abstraction, and somehow this seems to be related to creativity, as suggested by the following:

> Arthur Koestler: "Einstein's space is no closer to reality than Van Gogh's sky. The glory of science is not in a truth more absolute than the truth of Bach or Tolstoy, but in the act of creation itself. The scientist's discoveries impose his own order on chaos, as the composer or painter impose his-an order that always refers to limited aspects of reality, and is biased

enough for the purposes of this Article not to warrant further discussion. A couple of the labels, however, probably benefit from additional comment.

First, *aggregation* is used in two senses: (1) in the sorting sense—that is, the "standard way of simplifying complex systems . . . [b]y aggregat[ing] similar things into categories—trees, cars, banks—and then treat[ing] them as equivalent. Humans analyze familiar scenes in this way with the greatest of ease";[177] and (2) in the sense that "concerns the emergence of complex large-scale behaviors from the aggregate interactions of less complex agents":[178]

> An ant nest serves as a familiar example. The individual ant has a highly stereotyped behavior, and it almost always dies when circumstances do not fit the stereotype. On the other hand, the ant aggregate—the ant nest—is highly adaptive, surviving over long periods in the face of a wide range of hazards. It is much like an intelligent organism constructed of relatively unintelligent parts.[179]

Relatedly, therefore, Holland undergirds the importance of aggregation by suggesting that emergence hints of "intelligence of large numbers of interconnected neurons [in the brain] . . . or even the coherence and persistence of a large city."[180]

> by the observer's frame of reference, which differs from period to period, as a Rembrandt nude differs from a nude by Monet."

RICHARD M. RESTAK, M.D., THE MODULAR BRAIN 135 (1994). According to the book's back cover, Restak is a neurologist and serves on the advisory councils of the National Brain Tumor Foundation, the National Foundation for Brain Research, and the United States Congress-sponsored New Developments in Neuroscience Project. He is author of THE BRAIN and THE MIND, which accompanied the PBS series of the same names, as well as other books. *Id.*

In fact, it seems that the root of modeling is in mathematics, science, and art:

> Imagination—the making of images—lies at the root of all human creativity, and directs our conscious experience of the world. From early childhood, we are constantly making pictures of things, of people, and of places. As we grow older, we learn new ways of doing it. Photography, painting, descriptive writing, sculpture, poetry: all are means of capturing images in permanent form, so we can savour and re-experience the fruits of our imagination. Science is another quest to make images of the world. It has different goals and often requires different skills, but its beginnings had much in common with those of art: the accurate observation and representation of the world. Yet, there is more to the world than meets the eye. The accuracy of our perceptions of the world is not something that we can take for granted. Illusion is the dark side of imagination, and illusion tempts with self-delusion, under whose command we cannot long survive. The use of imagination to enlarge our picture of reality without, at the same time, subverting it is a delicate enterprise.

JOHN D. BARROW, THE ARTFUL UNIVERSE (1995).

177. HOLLAND, *supra* note 171, at 10.

178. *Id.* at 11.

179. *Id.*

180. *Id.* For a more detailed introduction to the brain as an emergent system, see Geu, *supra* note 121, at 963-71. In addition to the sources cited therein, see PER BAK, HOW NATURE WORKS: THE SCIENCE OF SELF-ORGANIZED CRITICALITY 175-182

Second, Holland's *diversity* property deserves discussion because it illustrates a fundamental tension in a CAS between the necessity of group formation (aggregation) and diversity (to provide system novelty at the individual level).[181]

Third, Holland's *internal model* mechanism for CAS is a necessary mechanism for the system to "learn." The most "critical characteristic of a model," according to Holland, is that it "allows us to infer something about the thing modeled."[182] Thus, it seems that the model is something like an analogy.

Holland then illustrates and identifies a tacit model as one that "simply prescribes a current action, under an implicit prediction of some desired future state," like a bacterium moving "in the direction of a chemical gradient, implicitly predicting that food lies in that di-

---

(1996). For an interesting book on the brain, which is largely consistent with the emergence theory of consciousness, see RESTAK, *supra* note 176. Restak writes:

> Put another way, consciousness must be understood as a very special *emergent* property of the human brain. It is not an indispensable quality, since we have seen the vast majority of the brain's activities do not involve consciousness. It is not always a desirable property, at least in its more self-reflected forms (conscious of myself as consciously thinking about conscious, and so on in an infinite regress, as with some of the characters depicted by Kafka and Dostoyevsky [sic]). But consciousness is a unique property of the brain made possible by a sufficient number of parallel interacting modules.

Id. at 135.

181. In the realm of society, perhaps,

> [s]ince "the more uncertain an environment potentially could be, the more would biological systems have diversified to dissipate that information," it follows that where there is no uncertainty there is no need for diversification. Diversity, versatility, variability, and variety all "represent (or, as reflected in object system behavior, measure) environmental uncertainties" and correlate positively with resilience. Thus, social diversity is not something to be lamented; on the contrary, spatial and temporal heterogeneity should be encouraged so as to ensure metastability—the system's ability to process increasingly complex environmental information. In other words, the meta-utopian ideal is a stew rather than a melting pot.

Alicia Juarrero-Roque, *Fail-Safe Versus Safe-Fail: Suggestions Toward an Evolutionary Model of Justice*, 69 TEX. L. REV. 1745, 1763 (1991) (footnotes omitted).

In one way or another, "evolution" usually includes the major conceptual elements of CAS theory. Other authors who have used evolutionary models for legal rules, for example, include E. Donald Elliott, *The Evolutionary Tradition in Jurisprudence*, 85 COLUM. L. REV. 38 (1985); Herbert Hovenkamp, *Evolutionary Models in Jurisprudence*, 64 TEX. L. REV. 645 (1985); M.B.W. Sinclair, *The Use of Evolution Theory in Law*, 64 U. DET. L. REV. 451 (1987).

Indeed, the failure of futurist Jacques Ellul to account for diversity, in this author's opinion, may be the reason his ultimate predictions miss their marks (even though many of his interim predictions ring true). Ellul, a French law professor, is a well-known futurist and his THE TECHNOLOGICAL SOCIETY is considered a classic in the area. *See* Robert M. Merton, *Forward* to JACQUES ELLUL, THE TECHNOLOGICAL SOCIETY, at vi (John Wilkinson trans., 1964).

182. HOLLAND, *supra* note 171, at 33.

rection."[183] Holland also identifies an overt model: "An overt internal model is used as a basis for *explicit*, but internal, explorations of alternatives, a process often called *lookahead*. The quintessential example of lookahead is the mental exploration of possible move sequences in chess prior to moving a piece."[184]

Importantly, if predictions based on either tacit or overt models are wrong, there are negative consequences to the agent. In the bacteria example, it gets no food and will die, and natural selection will favor a mutant bacteria or a different bacteria that has a better internal model. In the chess example, the player may lose the game and, if she was paying attention, change the model that resulted in the negative outcome. Therefore, the agents (or the system as an aggregate of the agents) learn (at least in some sense) from experience. As a result Holland's CAS explicitly accounts for feedback.[185] It also creates diversity as a product of progressive adaptations, with "each new adaptation opening the possibility for further interactions and new niches":[186]

> Roughly, each kind of agent fills a niche that is defined by the interactions centering on that agent. If we remove one kind of agent from a system, creating a "hole," the system typically responds with a cascade of adaptations re-

---

183. *Id.* at 32.
184. *Id.* at 33.
185. Moreover, since the bacteria's current fitness or the current state of our chess player's move reflects learning through experience, we also can say that the "system" has a memory or that history is embedded in the system's current state of affairs. It follows, in some sense, that the position of a baseball between pitcher and catcher (captured in a photograph) has a "memory" even though the baseball itself is not an adaptive agent. How can the baseball's position have a memory? Its position in the photograph was "determined" by a number of factors including the position of the pitcher's fingers on the ball when it was delivered. Therefore, the pitcher's finger placement is part of history "embedded" in the ball's current position.

    Fritjof Capra, furthermore, emphasizes the idea that mental models are not reality and also suggests why learning can be difficult:

    > Buddhist philosophy contains some of the most lucid expositions of the human condition and its roots in language and consciousness. Existential human suffering arises, in the Buddhist view, when we cling to fixed forms and categories created by the mind instead of accepting the impermanent and transitory nature of all things. The Buddha taught that all fixed forms—things, events, people, or ideas—are nothing but maya. Like the Vedic seers and sages, he used this ancient Indian concept but brought it down from the cosmic level it occupies in Hinduism, connecting it with the process of human cognition and thus giving it a fresh, almost psychotherapeutic interpretation. Out of ignorance (*avidya*), we divide the perceived world into separate objects that we see as firm and permanent, but which are really transient and ever-changing. Trying to cling to our rigid categories instead of realizing the fluidity of life, we are bound to experience frustration after frustration.

    FRITJOF CAPRA, THE WEB OF LIFE: A NEW SCIENTIFIC UNDERSTANDING OF LIVING SYSTEMS 294-95 (1996) (citations omitted).
186. HOLLAND, *supra* note 171, at 29.

> sulting in a new agent that "fills the hole." The new agent, [assuming the entire environment has not changed and that the niche still exists on the fitness landscape], typically occupies the same niche as the deleted agent and provides most of the missing interactions. This process is akin to the phenomenon called *convergence* in biology.[187]

Thus, complex adaptive systems theory may unlock the full potential of the synergism contemplated and suggested by AM. The next part of this Article looks in further detail at complex adaptive systems by discussing two of its components and complimentary ideas: chaos and complexity.

B. The Baseline: Chaos and Complexity

Complex adaptive systems use the concepts of both "chaos" and "complexity" by way of negative and positive definition, respectively. In effect chaos and complexity may be seen as either component parts of, or adjuncts to, CAS theory. In short, chaos is not the same as complexity,[188] but chaotic systems may exhibit complex behavior.[189] At its core, chaos is "a simple dynamical system" which if continually dialed, tweaked, or tuned correctly, may exhibit "complex dynamical system" behavior.[190] Both the chaotic and complex system share several common attributes.[191] First, their underlying mathematical equations, which in some sense determine their behavior, are nonlinear. "A system is nonlinear when actions can have more than one outcome and when actions generate nonproportional outcomes, in other words, when the system is more than the sum of its parts."[192] While these systems are determinative in the sense that they may be explained by mathematical equations, they are largely unpredictable. This has led one researcher to say that nonlinear equations "usually [have] multiple—and perhaps infinite—solutions. As in real life, there are many possibilities."[193]

---

187. *Id.* at 27.
188. Relatively detailed and more technical descriptions of chaos theory and complexity theory are provided in Geu, *supra* note 121, at 268-286.
189. *See generally id.* at 276-278.
190. BAK, *supra* note 180, at 29.
191. N. KATHERINE HAYLES, CHAOS BOUND: ORDERLY DISORDER IN CONTEMPORARY LITERATURE AND SCIENCE 11-14 (1990); *cf.* H. RICHARD PRIESMEYER, ORGANIZATIONS AND CHAOS: DEFINING THE METHODS OF NONLINEAR MANAGEMENT 7-19 (1992).
192. RALPH D. STACEY, COMPLEXITY AND CREATIVITY IN ORGANIZATIONS 288 (1996).
193. EDGAR E. PETERS, CHAOS AND ORDER IN THE CAPITAL MARKETS: A NEW VIEW OF CYCLES, PRICES, AND MARKET VOLATILITY 136 (1991). For an analysis of "determinism" and complexity theory in the context of sociology, which foreshadows further discussion later in this essay, see Robert Huckfeldt, *Structure, Indeterminacy and Chaos: A Case for Sociological Law*, 2 J. THEORETICAL POLITICS 413 (1990). As explained therein, the "debate" about whether there exists sociological law is largely one of the role of determinism in human behavior. In turn:

The second common attribute shared by chaotic and complex systems is that both systems are extremely sensitive to initial conditions. This is described by the nonproportionality of nonlinear mathematics. In fact, it was this feature that led Edward Lorenz, a Massachusetts Institute of Technology scientist studying computer-modeled weather predictions on his new computer in 1961, to rediscover and notice "chaos":

> [This new run] should have exactly duplicated the old. Lorenz had copied the numbers into the machine himself. The program had not changed. Yet as he stared at the new printout, Lorenz saw his weather diverging so rapidly from the pattern of the last run that, within just a few months [of the simulated weather, not in real time], all resemblance had disappeared. . . . His first thought was that another vacuum tube [in the analogue computer] had gone bad.
>
> Suddenly he realized the truth. . . . The problem lay in the numbers he had typed. In the computer's memory, six decimal places were stored: .506127. On the printout, to save space, just three appeared: .506. Lorenz had entered the shorter, rounded-off numbers, assuming that the difference—one part in a thousand—was inconsequential.
>
> A small numerical error was like a small puff of wind—surely the small puffs faded or canceled each other out . . . . Yet in Lorenz's particular system of equations [simulating the weather], *small errors proved catastrophic.*[194]

Simply summarized, systems exhibiting chaotic or complex behavior are extremely sensitive to initial conditions.

The third common attribute is the existence of feedback mechanisms that "create loops in which output feeds back into the system as input."[195] In computer network modeling, it means using the result of the last run as the starting point for the next run (the mathematical manipulation process). Each run also could be termed an experience. In other words, the last run caused the system to experience a change.

The fourth and final common attribute is methodological in that both systems are "mapped" and often studied using those resultant

---

> The often torturous debate over determinism within the social sciences frequently transcends the practice of empirical social science and addresses instead a theological dichotomy between Calvin's determinism (predestination) and Luther's free will. Some free will advocates have perceived a social scientific threat, particularly in early sociological efforts to specify [scientific] laws governing social relations and social behavior.

Id. at 414.

The article then argues "on the basis of a simple mathematical model, [chaos theory,] that the logic of a wholly determinate structure is capable of generating a seemingly stochastic process with an apparently indeterminate outcome." *Id.* at 413. Thus, Huckfeldt argues, not only may the "displacement of determinism by probabilism . . . be the wrong lesson," *id.*, but concludes that by "reacting too violently against the supposed naivety of the "determinists" we may be losing sight of a primary purpose for the social sciences—an identification of the structure and logic underlying human behavior," *id.* at 431.

194. JAMES GLEICK, CHAOS: MAKING A NEW SCIENCE (1987) (emphasis added).

195. HAYLES, *supra* note 191, at 14.

graphs. This methodological feature is actually more important than it might seem because it implicates the following statement by physicist Richard P. Feynman:

> The next great awakening of human intellect may well produce a method of understanding the qualitative content of equations. Today we cannot. Today we cannot see that the water-flow equations contain such things as the barber pole structure of turbulence that one sees between rotating cylinders. Today we cannot see whether Shrodinger's equation contains frogs, musical composers or morality—or whether it does not.[196]

The importance of the visual representation of results for both chaos and complexity is a paradox, however, because the "geometric" attribute is a unifying or common characteristic but because the actual patterns that are mapped provide one of the differences between chaotic systems and complex systems.[197]

To summarize, chaotic systems and complex systems share four common attributes: (1) they are nonlinear; (2) they are sensitive to initial conditions; (3) they contain feedback mechanisms as a central feature such that output feeds back into the system as input; and (4) they are studied by analyzing visual systemic maps.

There are, however, important differences between chaotic and complex systems. One way to explain the most important distinction, for purposes of this Article, is to think of chaos and complexity as adjacent areas on a continuum from true randomness to rigid order. Chaos borders randomness on the continuum, while complexity borders chaos on one side and continues through certain kinds of rigid order on the other.

Indeed, the most widely touted definition of complexity is that it is a narrow area on "the edge of chaos."[198] The basic idea is that nothing novel can emerge from systems with high degrees of order and stabil-

---

196. Richard P. Feynman, *quoted in* JACK COHEN & IAN STEWART, THE COLLAPSE OF CHAOS: DISCOVERING SIMPLICITY IN A COMPLEX WORLD, at iv (1994). There has been a heightened interest in the life and work of Richard Feynman since his death. For a very good biography, see JAMES GLEICK, GENIUS: THE LIFE AND SCIENCE OF RICHARD FEYNMAN (1992).

197. *See* BAK, *supra* note 180, at 31.

> [S]imple chaotic systems cannot produce a spatial fractal structure like the coast of Norway. In the popular literature, one finds the subjects of chaos and fractal geometry linked together again and again, despite the fact that they have little to do with each other. The confusion arises from the fact that [some] chaotic motion can be described in terms of mathematical objects known as strange attractors embedded in an abstract phase space. These strange attractors have fractal properties, but they do not represent geometrical fractals in real space like those we see in nature.

Id. See also Geu, *supra* note 121, at app., pt. A (providing a more detailed description of fractals, strange attractors, and chaos).

198. John Horgan, *From Complexity to Perpelexity*, SCI. AM., June 1995, at 106. This discussion first appeared at Geu, *supra* note 121, at 276.

ity, such as crystals. On the other hand, completely chaotic systems such as turbulent fluids or heated gases are *too* formless to harness for analytic purposes. "Truly complex things—appear at the border between rigid order and randomness."[199]

Amoebas and bond traders on the edge of chaos are not only *complex* but also they exhibit *emergent* behavior and are *adaptive* to their environment. Complex behavior is simply "a system with multiple agents dynamically interacting in multiple ways, following local rules and oblivious to any higher-level instructions."[200] Emergent complex systems, on the other hand, possess "some kind of discernible macro behavior" from the interaction of those local rules.[201] That is, emergent complex systems are self-organizing. An example of "[e]mergent complexity without adaptation is . . . the intricate crystals formed by a snowflake: it's a beautiful pattern, but it has no real *function*."[202] Therefore, to reiterate Holland's description of CAS, emergence is a by-product of CAS through the property he labels aggregation.[203] While aggregation is necessary for a system to be complex under Holland's formulation of CAS, it is not the property which alone provides adaptability to the system.

An *adaptive* system "learns" through feedback from interactions with other agents. The spontaneous organization of water molecules into an emergent snowflake, therefore, does not have this feedback or learning feature. Therefore, while the snowflake is emergent behavior of a complex system, it is not representative of a complex adaptive system. The discussion of complex adaptive systems, therefore, comes full-circle back to one of Holland's examples of complex adaptive systems quoted previously: ant nests.[204]

As one of the nation's leading ant researchers, Professor Deborah Gordon of Stanford University spends one quarter each year studying harvester ant behavior in the American Southwest.[205] She emphasizes the aggregate and decentralized features of harvester ant colonies that is shared with all emergent complex adaptive systems. Steven Johnson, in his book *Emergence*, explains the organization of Gordon's ant colonies by comparing it to human political decision-making systems as follows:

> Popular culture trades in Stalinist ant stereotypes—witness the authoritarian colony regime in the animated film *Antz*—but in fact, colonies are the exact opposite of command economies. While they are capable of remarkably coordinated feats of task allocation, there are no Five-Year Plans in the ant king-

199. Horgan, *supra* note 198, at 106.
200. STEVEN JOHNSON, EMERGENCE 19 (2001).
201. *Id.*
202. *Id.* at 20 (emphasis added).
203. *See supra* notes 173-180 and accompanying text.
204. *See supra* note 179 and accompanying text.
205. JOHNSON, *supra* note 200, at 29.

> dom. The colonies that Gordon studies display some of nature's most mesmerizing decentralized behavior: intelligence and personality and learning that emerges from the bottom up.[206]

The key to understanding decentralized decision making that may lead to emergence is that it is *local*. In the world of harvester ants:

> They think locally *and* act locally, but their collective action produces global behavior. Take the relationship between foraging and colony size. Harvester ant colonies constantly adjust the number of ants actively foraging for food, based on a number of variables: overall colony size . . . ; amount of food stored in the nest; amount of food available in the surrounding area; even the presence of other colonies in the near vicinity. No individual ant can assess any of these variables on her own. . . . The perceptual world of an ant, in other words, is limited to the street level. There is no bird-eye views of the colony, no ways to perceive the overall system—and indeed, no cognitive apparatus that could make sense of such a view.[207]

Nonetheless the communication between individual ants, which is largely chemical and limited to ten to twenty signs, allows the colony to act as an emergent super-organism. Repeating Holland's distinction between the individual ant and the colony:

> The individual ant has a highly stereotyped behavior, and it almost always dies when circumstances do not fit the stereotype. On the other hand, the ant aggregate—the ant nest—is highly adaptive, surviving over long periods in the face of a wide range of hazards. It is much like an intelligent organism constructed of relatively unintelligent parts.[208]

This "interesting" emergent behavior is a hallmark of a *complex* adaptive system that is poised on "the edge of chaos."[209]

Stated another way, this "edge of chaos" is a special critical state and emphasizes the difference between *chaos* and *complexity*.[210] "[A] chaotic process looks wildly erratic even if the underlying rules are actually quite simple."[211] For example, the molecules of "air" inside a balloon "move according to the law of chaos: give a tiny nudge to just a single molecule, and in much less than a minute every last one will be affected."[212] According to mathematician Ian Stewart: "Chaos is when any system is so . . . irregular that it appears to be random un-

---

206. *Id.* at 31-32. Further, Johnson states:

> We know now that systems like ant colonies don't have real leaders, that the very idea of an ant "queen" is misleading. But the desire to find pacemakers [leaders, centralized control, the historical "great man"] in such systems has always been powerful—in both the group behavior of the social insects, and in . . . collective human behavior [*e.g.*, "human behavior that creates a living city"].

Id. at 33.

207. *Id.* at 74-75.

208. HOLLAND, *supra* note 171, at 10.

209. *See supra* notes 198-99 and accompanying text.

210. MARK BUCHANAN, UBIQUITY 15 (2000); *see generally* ALBERT-LASZLO BARABASI, LINKED: THE NEW SCIENCE OF NETWORKS (2002).

211. BUCHANAN, *supra* note 210, at 17.

212. *Id.*

less you know a lot of hidden information about it. Chaos is lovely, it is absolutely wonderful. It is full of all sorts of intriguing forms and behaviors."[213] It is nonlinear but the "processes are only superficially chaotic; underneath there is a deep, if irregular order."[214] Chaos is an example of systems following "simple rules to do very complex things"[215] and "[r]esearchers have discovered chaos at work in the fluctuations of things ranging from lasers to rabbit populations."[216]

Complexity, on the other hand, is the study of nonlinear systems at the edge of chaos where complex interactions among the players (e.g., molecules and bond traders) "produce their own kind of order."[217] Complex systems typically have three ideas or features absent in chaotic systems which are familiar from the discussion of Holland's work herein:[218] feedback, emergence and self-organization.[219] It is self-organization that provides the *critical state* at the edge of chaos that is "characterized by a tendency towards sudden and tumultuous changes." Unlike the systems represented by the molecules inside the balloon which are in rough equilibrium (a closed system); complex systems are forever out of equilibrium (open systems).[220] Thus, unlike the chaotic air inside the balloon, the earth's "atmosphere is very much out of equilibrium" because "it is being continually stirred and agitated and energized by the influx of light from the Sun."[221]

The openness of the atmospheric system results in "the rich and ever unfolding history of the weather and climate:" complexity is based on "out-of-equilibrium physics."[222] It could also be called "historical physics" because of the importance of feedback as feedback builds upon and amplifies historical changes in the system.[223]

"Natural" forest fire ecology is an example of a system self-organized to a critical state at the edge of chaos. Forest fire ecology represents complexity because a relatively simple pattern of the area burned by each fire over time emerges even though there are a multitude of factors involved in any given fire.[224] The pattern that emerges from "data for 4,284 fires on U.S. Fish and Wildlife Service lands between 1986 and 1995 reveals a remarkably strong . . . geometric pattern: double the area of the fire, and it becomes about 2.48 times as

213. RICHARD KOCH, THE NATURAL LAWS OF BUSINESS 155 (2000).
214. *Id.* at 156.
215. *Id.* at 162.
216. BUCHANAN, *supra* note 210, at 15.
217. KOCH, *supra* note 213, at 167.
218. *See supra* notes 172-186 and accompanying text.
219. KOCH, *supra* note 213, at 167-8.
220. BUCHANAN, *supra* note 210, at 16.
221. *Id.*
222. *Id.*
223. *See* BUCHANAN, *supra* note 210, at 17.
224. *See id.* at 67-69.

rare, and the pattern holds for fires varying in size by a factor of a million."[225] This kind of geometric pattern is known as a power law and scientists believe that power laws might be the mathematical signature for the critical state of complex systems far from equilibrium.[226]

Interestingly, the U.S. Bureau of Land Management "has acknowledged that, despite determined efforts to suppress naturally ignited fires, wildfires have in recent years become more numerous, severe, and difficult to control."[227] Researchers at Cornell University, using actual data, have developed a computer model which suggests that human fire fighting intervention and the U.S. Forest Service's policy for "zero tolerance" for fires may have altered the self-organized critical state of forests by pushing the system into "an even more unstable state, a super critical state"[228] by allowing the build-up of an enormous forest-wide fuel load.[229] These researchers called this effect the "Yellowstone Effect," in honor of the 1988 Yellowstone fire which burned 1.5 million acres.[230] The bottom line is that "[f]ires of intermediate size remove some of the dangerous deadwood [and other components of fuel load] from the forest . . . . and so make it more difficult for a tiny disturbance to trigger large-scale disaster."[231]

> The U.S. Federal Wildland Fire Policy hit the nail squarely on the head in concluding that "wildland fire, as a critical natural process, must be reintroduced into the ecosystem." It may take years to redress the balance, and even then large fires will, of course, still break with a fair frequency; this is unavoidable in the critical state. But at least terrific conflagrations would be less likely than they would be in the supercritical situation.[232]

The small and intermediate sized fires simply represent natural "constant re-adjustment" to the forest ecology: "[P]reventing such adjustments merely makes matters worse."[233] The same kind of power law geometry and catastrophic supercriticality has been suggested for grasshopper pest management in Idaho, Montana, and Wyoming;[234] city size worldwide;[235] income distribution;[236] and a wide array of

225. *Id.* at 68. For a recent popular description of the application of these "power laws" (Zipf's Law), see Rauch, *supra* note 163, at 40.

226. *See, e.g.*, David Post & Michael B. Eisen, *How Long Is the Coastline of the Law? Thoughts on the Fractal Nature of Legal Systems*, 29 J. LEG. ST. 545 (2000). *Cf.* BUCHANAN, *supra* note 210, at 68.

227. BUCHANAN, *supra* note 210, at 71.

228. *Id.*

229. *Id.*

230. BUCHANAN, *supra* note 210, at 70-1.

231. *Id.* at 72.

232. *Id.*

233. *Id.* at 209.

234. *Id.* at 74.

235. *Id.* at 169.

236. *Id.* at 171.

other economic data and even economies themselves.[237] Like forest fires, all of these systems are subject to an almost inconceivable number of detailed and complicated interacting influences; but also like forest fires, the result of these influences is a relatively simple, *naturally* occurring, power law pattern.

Recall, however, that these patterns emerge from the complex interaction of individuals in something akin to a web or network of interactions wherein the action of one individual or agent affects other individuals or agents and, ultimately the system at large. It is this interaction, coupled with feedback, that can be said to *allow* the system, through adaptation, to learn. In Holland's CAS computer model, adaptation also creates diversity. In turn, diversity creates systemic resilience:

> Roughly, each kind of agent fills a niche that is defined by the interactions centering on that agent. If we remove one kind of agent from a system, creating a "hole," the system typically responds with a cascade of adaptation resulting in a new agent that "fills the hole." The new agent [, assuming the entire environment has not changed and that the niche still exists on the fitness landscape,] typically occupies the same niche as the deleted agent and provides most of the missing interactions.[238]

It is this conception of *resilience*, as understood in the context of critical state systems far from equilibrium that has led another commentator to suggest an evolutionary model for the system of justice expressly within a CAS framework. As her abstract summarized: "In contrast to Plato's substantial 'fail-safe' view of justice and its ideal of stability, contemporary science suggests a procedural 'safe-fail' model of justice that takes change as fundamental and seeks to promote resilience rather than stability."[239] Professor Robert Artigiani was one of the first authors to suggest that the United States Constitution established a complex adaptive system.[240] And, of course, the more general idea that law is an adaptive evolutionary system (or at least that evolution is an appropriate metaphor for law) is not new and has been the subject of quite extensive study and comment.[241]

---

237. *See generally*, Geu, *supra* note 121, at 177-190.

238. HOLLAND, *supra* note 171, at 27, quoted in Geu, *supra* note 121, at 176.

239. Juarrero-Roque, *supra* note 181, at 1745 (article abstract).

240. Robert Artigiani, *Chaos and Constitutionalism: Toward a Post-Modern Theory of Social Evolution*, 34 WORLD FUTURES 131 (1992).

241. *See, e.g.*, E. Donald Elliot, *Law and Biology: The New Sythesis?*, 41 ST. LOIUS U. L.J. 595 (1997); Owen Jones, *Evolutionary Analysis in Law: Some Objections Considered*, 67 BROOK L. REV. 207 (2001); Craig La Chance, *Nature v. Nurture: Evolution, Path Dependence and Corporate Governance*, 18 ARIZ. J. INT'L & COMP. L. 279 (2001); William H. Rodgers, *Where Environmental Law and Biology Meet: Of Panda's Thumbs, Statutory Sleepers, and Effective Law*, 65 U. COLO. L. REV. 25 (1993). Indeed, there is a professional organization called "Society for Evolutionary Analysis in Law." *See* www.sealsite.org (last visited June 20, 2002).

C. "Harnessing" Complexity and CAS in Adaptive Management

Harnessing complexity really involves two related themes: (1) motivating individuals to exhibit behavior that allows for the possibility of emergence through adaptation and (2) attempting to structurally design organizations (whether real or artificial) that are complex adaptive systems. Both themes have at their core the concept of pushing the system toward "the edge of chaos"[242] where novel and "interesting things" happen.

Gordon's harvester ant studies suggest "five fundamental principles" that need to be followed to build a system where macrointelligence and adaptability derive from local knowledge."[243] The principles correspond roughly in a conceptual way to the features that Holland delineates as properties of a complex adaptive system and which he illustrates by referencing ant nests.[244]

Gordon's fundamental principles include (1) "more is different"—meaning that there must be a "critical mass" of agents interacting in a statistically relevant way; (2) "ignorance is useful"—meaning that the densely connected component agents do not each assess their environment on the global level but on the local level only; (3) "random encounters are encouraged"—meaning that decentralized solutions emerge from novel and unusual network connections; (4) patterns are discerned from the signs given by the individual agents such that emergence is probably a search for patterns in the signs; and (5) "the primary mechanism of . . . [CAS] logic is the interaction between neighboring [local agents]. . . ."[245]

Pushing a system toward "the edge of chaos," given the features and properties of a CAS, first requires a careful assessment and identification of the agents and properties within an existing system, and then attempting to coax the system to contain the features of a CAS.[246] Thus, a book entitled *Harnessing Complexity* suggests design principles to take advantage of CAS—focusing on encouraging variation and interaction and assessing selection of good ideas, techniques, and good starts on which to build further feed back loops.[247] Several

242. *See supra* note 198 and accompanying text.

243. JOHNSON, *supra* note 200, at 77.

244. *See supra* notes 163-203 and accompanying text. Holland's properties are (1) networks of many agents acting in parallel; (2) many levels of organization; (3) use of models that anticipate the future; and, (4) the existence of specific niches for agents. Stated differently, Holland reiterated and modified the properties slightly as diversity, aggregation, nonlinearity and flow.

245. JOHNSON, *supra* note 200, at 78-79.

246. *See* ROBERT AXELROD & MICHAEL D. COHEN, HARNESSING COMPLEXITY: ORGANIZATIONAL IMPLICATIONS OF A SCIENTIFIC FRONTIER 154-55 (1999).

247. *See id.* at 152-158.

of the most relevant suggestions for purposes of designing a CAS follow.

One of the suggestions is to tie "processes that generate extreme variation to processes that select with few mistakes in the attribution of credit" which is illustrated by the way the Linux operating system is designed by using the internet "to increase massively the variety of proposed improvements to the software" while maintaining the software's integrity by imposing "appropriate and mutually agreed upon performance criteria" (e.g., "execution speed and crash-resistance").[248] This suggestion clearly marries the ideas of variation and its many "agents" (programmers) with order and structure (execution speed and other performance criteria) which might be expected at the edge of chaos between randomness and inflexible rigidity. Another suggestion is to "encourage effective neighborhoods" because "there can be tremendous gains from helping would-be cooperators interact more frequently."[249]

Selection of solutions, or parts of solutions, is integral to establish feedback. Selection, however, is also used in the sense of encouraging appropriate behavior that is critical to find appropriate solutions. One suggestion to promote the latter behavior is to "[u]se social activity to support the growth and spread of valued [behavioral] criteria."[250] This suggestion is illustrated in the business setting by the use of prize competitions. Summarizing a longer discussion in *Harnessing Complexity*, the authors recount:

> Our example of prize competitions revealed that the processes of refining prize criteria, selecting judges, recruiting nominees, and publicizing winners can all serve to disseminate the underlying goals that motivated the creation of the prize. The result of such activity is to increase the use of the criteria embodied in the prize, which can sometimes be far more effective than direct advocacy of the criteria.

Finally from *Harnessing Complexity*, CAS requires its agents to gain experience and for the system to assess that experience in order to *adapt*. Here, the authors of *Harnessing Complexity* suggest the organization:

> *Look for shorter-term finer-grained measures of success that can usefully stand in for longer-run, broader goals.* By examining the use of simulation in military and business affairs, we found that there can be severe shortages of experience to drive adaptation of Complex Adaptive System. Although it pays to be alert to . . . risks . . . , it can sometimes be valuable to find ways to get more experience quickly, even if it is of lower validity. Simulations can do this. So can short-run proxy measures. . . .[251]

248. *Id.* at 156.
249. *Id.* at 157.
250. *Id.* at 157.
251. *Id.* at 158.

Notice that the quote encourages simulation as a second-best alternative to real experience. The central importance of mental modeling and feedback from application of those mental models directly infers a corollary principle of developing a complex adaptive system already inherently recognized by CAS and by general management theory. Simply put, the system must be designed to allow, or perhaps even encourage, and then learn from, *failure*.

Thus far the lessons from and for CAS have been derived from the observation of existing systems with inherent goals. One of the earliest authors adapting CAS to business organizations, Professor Preismeyer, however, clearly discussed the importance of missions, visions and goals of an organization as components of its purpose. His definitions are also consistent with suggestions elsewhere in this Article. Specifically one of his suggestions dealing with goals and purpose expressly acknowledges that the future performance of complex adaptive systems "emerges incrementally from its current state" and, therefore, it is possible to affect the end-state of the system at many decision points, both large and small, over time.[252] As a result, Priesmeyer suggests that "[r]ather than trying to estimate all the forces that act on a system in order to forecast the future behavior of a system, we can vision the future and then act on the forces to create the visioned condition."[253] Visions are not mission statements, nor are they goals: "Visioning, which identifies a future state of a system, can be integrated into a strategic planning process to quantify a broad mission statement. Visions differ from goals or objectives because they are multidimensional.[254]

Illustratively:

A Mission:	To provide quality medical care to the population in the district.
A Vision:	To attain a bed capacity of 300 and a budgeting surplus of $100,000 by [a specific date].
Goals:	To remodel the East Wing within eighteen months. To reduce utility costs by 15 percent this year.[255]

252. H. RICHARD PREISMEYER, ORGANIZATIONS AND CHAOS: DEFINING THE METHODS OF NONLINEAR MANAGEMENT 187 (1992).
253. *Id.* at 177.
254. *Id.* at 196.
255. *Id.* This vision seems very similar to the "Commander's Intent" in Army doctrine, which is a "concise expression of how you visualize the operation, and it is always written by the commander personally. In the absence of specific orders, it could be used as operating guidelines." TOM CLANCY WITH FRED FRANKS, JR. (RET.), INTO THE STORM: A STUDY IN COMMAND 14 (1997). The Commanders Intent allows for adaptive management because the smaller unit leader may react to unforeseen consequences in furtherance of the ultimate objective. This is directly related, although the converse of, the saying "what goes around, comes around"

The book *Complexity and Creativity in Organizations*, by Professor Ralph Stacey is another source of advice for designing complex adaptive systems. Professor Stacey suggests several organizational sources of stability and instability which might be adjusted by design to encourage the organization to operate as a complex adaptive system. His sources of stability include: "(1) constraints that clamp down change, (2) cooperation, and (3) protection from creative tension by dominant schemas, or maladaptive learning."[256] The book explains the relationship between the formal decision making process and the informal political decision making process as a source of stability (or as a constraint on change). The following quote seems to have direct application in cases like Missouri River management:

> Where objectives conflict and/or it is not clear what actions will lead to the realization of objectives, then the technically rational decision-making process must be supplanted by an overtly political one. Choices between objectives and trial actions will be made on the basis of support from the most powerful coalitions—the current leaders of the legitimate system. . . . Overt politics will then maintain current vested interests . . . and not threaten existing coalitions and leadership structures. . . . Political decision making and control will then be further sources of stability in the system; they too take on a negative feedback form in which deviations from the current political program are damped down.[257]

As a result of these stabilizing factors, therefore, control of the decision making apparatus is retained in an informal political way by the "legitimate" (formal) organization and its leadership. In the case of Missouri River Management this control would seem to rebound to the Corp and to the existing status quo. While it may be possible to be creative in a process labeled "consensus," Professor Stacey reminds the reader that the "creative process involves competition" and that the creative process in human systems . . . is inevitably messy:"[258]

---

which emphasizes behavioral choice in circumstances where the consequences are uncertain. The latter is applied and illustrated in one of the "Harry Potter" books:

> "But—I stopped Sirius and Professor Lupin from killing Pettigrew! That makes it my fault if Voldemort comes back!"
>
> "It does not," said Dumbledore quietly. "Hasn't your experience with the Time-Turner taught you anything, Harry? The consequences of our actions are always so complicated, so diverse, that predicting the future is a very difficult business indeed . . . ."
>
> "This is magic at its deepest, its most impenetrable, Harry. But trust me . . . [ellipses in original] the time may come when you will be very glad you saved Pettigrew's life."

J.K. ROWLING, HARRY POTTER AND THE PRISONER OF AZKABAN, 426-27 (1999).

For a more detailed analysis of the literature concerning "complexity and business," see Geu, *supra* note 121, at 177-190.

256. RALPH D. STACEY, COMPLEXITY AND CREATIVITY IN ORGANIZATIONS 195 (1996).

257. *Id.* at 197-98.

258. *Id.* at 15.

> [The creative process] involves difference, conflict, fantasy, and emotion; it stirs up anger, envy, depression, and many other feelings. To remove [too much of] the mess by inspiring us to follow some common vision, share the same culture, and pull together is to remove the mess that is the very raw material of creative activity.[259]

The design task, it seems, must provide stability by fostering competition within defined constraints without allowing shadow politics to "damp down" creative action ideas. Without constraints it appears only the status quo is reasonably possible.

Stacey lists the features of instability that work within "the space for novelty" (which are bounded by stability) as "(1) the process for amplifying small changes [through feedback], (2) the operation of competition and the use of unpredictability as a survival strategy by other interconnecting systems, and (3) exposure to creative tension set up by . . . cross-fertilization and flux."[260] These sources of instability should

---

259. *Id.* A recent business book, James F. Moore has expressly adopted the business-biology analogy as its thesis. JAMES F. MOORE, THE DEATH OF COMPETITION: LEADERSHIP AND STRATEGY IN THE AGE OF BUSINESS ECOSYSTEMS (1996). Rather than adopting evolutionary biology as a base of comparison, Moore uses ecology and eco-systems as his model. Recall that Professor Holland inclusively listed ecology as an example of an "adaptive complex system." Moore explains both the title of his book and the metaphoric use of ecology as follows:

> Not that competition is vanishing. In fact it is intensifying. But competition as most of us have routinely thought of it is dead—and any business manager who doesn't recognize this is threatened . . . . The problem [with the traditional competition model] . . . is that it ignores the context—the environment—within which the business lies, and it ignores the need for coevolution with others in that environment, a process that involves cooperation as well as conflict.

Id. at 3. To illustrate the ecosystem analogy, Moore says "[a] good restaurant in a failing neighborhood is likely to die." *Id.*

To illustrate competition we suggest that if two better restaurants serving the same type of food for the same price move in next door the good restaurant might fail even if the neighborhood is good because there is more competition for the same ecological niche.

260. STACEY, *supra* note 256, at 205. Another aspect of this "creative space" that also address feedback loops (which are necessary in CAS) is that assessing the outcomes from the creative space is "safe" on some level. The analogue, here, might be to the "morbidity and mortality conference in medical education":

> The deeper problem with medical-malpractice suits, however, is that by demonizing errors they prevent doctors from acknowledging and discussing them publicly.
>
> . . . .
>
> There is one place, however, where doctors can talk candidly about their mistakes, if not with patients, then at least with one another. It is called the Morbidity and Mortality Conference—or, more simply, M&M—and it takes place, usually once a week, at nearly every academic hospital in the country. This institution survives because laws protecting its proceedings from legal disclosure have stayed on the books in most states, despite frequent challenges. Surgeons, in particular, take the M&M seriously. Here they gather behind closed doors to review the mistakes, complications, and deaths that occurred on their watch, determine responsibility, and figure out what to do differently next time.

be used within the organizational design in those areas where novelty and creativity are desired.

Finally, as a matter of theoretical design, Professor Ruhl observed that the current and general environmental law notions of sustainable development, adaptive management, and biodiversity are consistent with the theoretical application of complex adaptive systems to the design of environmental law:

> Thus, Gerald Emison's exploration for complex systems as a model of environmental law reaches a similar set of conclusions as to the direction of reform through which he advocates a system designed to: (1) get accurate, detailed information; (2) challenge sources to achieve measurable goals for sustainable progress; (3) use all parts of the environmental management system; (4) use incentives to promote responsible behavior; (5) pay close attention to implementation; (6) make innovation a priority; and (7) emphasize flexibility.[261]

Ruhl's prescription is somewhat general and, therefore, difficult to apply in any specific micro-organizational context. Nonetheless, his prescription for macro-environmental law design is consistent with the more specific suggestions for organizational design by other commentators whom do not necessarily address environmental regulation and whose suggestions have been discussed previously. Ruhl's work also stands for the proposition that many different parts of the legal environmental process seem to be converging toward complex AM techniques.

Beyond suggestions, analogy and musings by business consultants, the world of complex adaptive systems has been explored and mined and applied in a more realistic and practical way on the Web. Rather obviously the Web and, more generally, Internet is very interactive. Examples of such interactivity include "a button that lets you e-mail a response to a published author; a tool that lets you build your own home page; even a collection of interlinked pages that let you follow your own path through them—these are examples of interactivity."[262] Nonetheless, these examples do not represent systems that evolve to the edge of chaos where systemic properties might emerge from a dynamical mix of control and freedom.

Atal Gewande, *When Doctors Make Mistakes*, *in* THE BEST AMERICAN SCIENCE WRITING 2000, at 9 (James Gleick ed.).

Obviously the procedure in other spheres need not be secret. On the other hand, at least good faith decisions that do not "work" need to be protected to encourage creativity. Perhaps a decision-making model based on decisions made by corporate boards of directors would be appropriate. *See, e.g.*, WILLIAM E. KNEPPER & DAN A. BAILEY, LIABILITY OF CORPORATE OFFICERS AND DIRECTORS (6th ed. 1998).

261. Ruhl, *supra* note 5, at 1000 (citing Gerald Andrews Emison, *The Potential for Unconventional Progress: Complex Adaptive Systems and Environmental Quality Policy*, 7 DUKE ENVTL. L. & POL'Y F. 167, 192 (1996)).

262. JOHNSON, *supra* note 200, at 158.

In the past few years, however, a "control" tool seems to have developed to tweak categories of electronic interaction to both adapt to a kind of democracy and to allow for emergence. The control, simply, is a level of user feedback beyond the mere number of hits on a Web page; Amazon, eBay, and others have been early adopters.[263] The new level of feedback is allowing users of "reviews" to rate them:

> Amazon had long included user rating for all the items in its inventory, but in 1999 it began to let users rate the reviews of other users. An ingenious site called Epinions cultivates product reviews from its audience and grants "trust" points to contributors who earn the community's respect. The online auction system of eBay utilizes two distinct feedback mechanisms layered on top of one another: the price feedback of the auction bids coupled to user ratings that evaluate buyers and sellers. One system tracks the value of stuff; the other tracks the value of people.[264]

It is the rating of the reviewers, at the second level of feedback, that gives the system its control component and which organizes and reigns in what otherwise would be just more and more individual reviews. It is the mechanism which allows, in the case of the Amazon, for example in, a mystery fan to choose to read only the most trusted reviewers opinions on a new mystery. In turn, that reader could rate the review herself thereby communicating both the value of the individual review and, over time, the worth of all this *reviewer's* reviews (and thus the reviewer herself). While the foregoing represents a "bottom-up" interactive and adaptive control system, it certainly does not assure the system will have emergent properties because it might simply result in a tyranny of the majority by quashing, *inter alia*, the diversity necessary for a complex adaptive system. Therefore, it seems that the "control" system itself would need to be adjustable to allow for the appropriate mix of freedom and control. Slashdot.org (hereinafter "Slashdot") might have found a way to adjust the "control" function.[265]

Slashdot is a discussion group that fosters discussion on a broad range of technical and electronic gaming topics which featured a moderator rating various contributions. As Slashdot grew, the volume outstripped the ability of a single moderator to read and rate each contribution. Ultimately a system of selecting short-term moderators based on the ratings given their contributions developed resulting in highly ranked participants serving as moderators who, in turn, ranked the contributions of others from –1 to 5. A new post from a past participant is ranked based on her past contributions unless the moderator "adjusts" the ranking for that entry. The moderator is assigned a fixed number of points to assign to other posts and when all those points are allocated the system selects a new moderator based on the value of her past postings.

263. *Id.* at 157.
264. *Id.* at 157.
265. *See* JOHNSON, *supra* note 200, at 152-62.

The moderators, however, are not supposed to rate postings on whether they agree with the postings but rather on the overall "quality" of the post.[266] Nonetheless, there is a danger, if not a propensity, for "average" majoritarian conceptions of what is a good post to drive out diversity at least at the highest rank of 5. Of course, it is possible for a user to enter a wildly diverse world of reading only those given a low ranking. And therein lies the mechanism to push the Slashdot discussion system to the edge of chaos:

> While its true that Slashdot's filtering software creates a heavy center, that tendency is not inherent to the Web medium, or even the subset of online communities. You could just as easily build a system that would promote both quality *and* diversity, simply by tweaking the algorithm that selects moderators . . . whose contributions have triggered the greatest range of responses. . . . The cranks would still be marginalized, assuming their polemics annoyed almost everyone who came across them. But the thoughtful minorities—the ones who attract both admirers *and* detractors—would have a place at the table.[267]

V. CONCLUSION: APPLYING ADAPTIVE MANAGEMENT TO THE MISSOURI

The Master Manual Review as Linear Decision-Making. When in the late 1980s the Corps agreed to rewrite the Master Manual for the Missouri River it was looking toward a classic "linear" process which, according to the rules then in place, would follow a reasonably certain trajectory. It would plan for a revised Manual, to be agreed upon firmly at some set time in the future. Along the way it would do enough research and data collection to satisfy the requirements of NEPA, and make such adjustments in its operations as were necessary to avoid further jeopardy to the several species listed under the ESA. It would build an administrative record sufficient to satisfy a reviewing court.

While this is nowhere written, it is fair to assume that as a highly competent engineering agency, capable of bringing tremendous resources to bear on difficult issues, the Corps was confident that it could move through this process to a final decision without bringing harm to any of its principal constituencies on the River. In fact, the goal for the Corps was to use the linear process to bring reservoir recreation within the management objectives of the river, thus quieting the concerns of the upper basin states which had been vocal since the time the 9-foot navigation channel first became a reality. In this sense, the process would enhance the Corps' control over the river by bringing upper basin states within the group of satisfied "customers," along with hydropower, navigation and flood control.

266. *See id.* at 160.
267. *Id.* at 161.

For the Corps the most significant uncertainty in this process was the potential for judicial review of the final decision on a revised Master Manual. Even there, however, the process itself was predictable, well-understood, and the standard of review stated in advance. Thus, while this linear process complicates life in a large resource planning agency such as the Corps, it brings the element of predictability and the promise of a final resolution.

The linear process was also attractive to existing stakeholders on the River. They would go into the process with their traditional priority and reliance interest fully recognized; for them, it was a familiar decision-making setting. It was also attractive, however, to newer players such as fish, wildlife, conservation and environmental groups which hoped to use the process to advance new issues, and to integrate consideration of new science and altered conditions into river policy. Such interests were to have the full opportunity of participation, something which had been unavailable under the old order of river operations. For the first time, Missouri River decision-making would be brought into the open, a prospect which was quite inviting in the late 1980s.

Master Manual Review: Critique of Linear Decision-Making. In the year 2002—with this process still very much incomplete—we can look back and conclude that the Master Manual Review appears to have developed along two lines. The first line is the linear planning process led by the Corps which has brought to light an enormous and valuable amount of information and scientific knowledge concerning the River while also providing a forum for a lively public discussion about the River's future. The second line is what amounts to a critique of linear decision-making processes, leading gradually to an active interest in AM guided in that direction by general concepts of ecosystem management. Thus, the discussion now is not only about reforming river management, but about reforming management processes in general.

Critics of the linear process are quick to point-out that it dammed and channelized the river for the benefit of vast irrigation schemes which were impossible from the outset, and for a navigation industry which has failed to materialize; that under it, a great river has been allowed to deteriorate. With the exception of flood control, which was planned, and reservoir recreation, which was accidental, the linear process has caused the River and most of the plans made for it to suffer. They urge that the rigidity of the linear process should be replaced by AM. But this leads necessarily to an inquiry into the potential consequences for legal process when an agency elects to implement an ecosystem management/AM alternative.

Let us assume, as a simple example case, that after much planning, including public participation and a complete EIS process, a fed-

eral agency announces, in a final record of decision, that a large and complex natural resource—river, national park, or national forest—will be managed by an AM system. Assume also that the resource is relied upon by many users whose interests frequently collide, but who have agreed to assemble in an inclusive stakeholders group. A science advisory panel is appointed, supported by a respectable scientific monitoring capacity. Procedures governing both the science panel and the stakeholder group are adopted informally. What are our concerns?

The first concern is that the process may be so vague as to evade meaningful legal review. Ruhl has observed that "[t]he beauty of expressions like ecosystem management, sustainable development, and environmental justice is that they shortcut the need to define in detail the underlying concept while the business of spreading the idea is underway."[268] So we face the question of whether the decision to adopt AM will receive final approval pursuant to the linear processes required by the Administrative Procedure Act and NEPA, and if so, whether subsequent adaptations or manipulations are subject to review and satisfy due process.[269] The AM process will be a continuing series of reports from stakeholder, monitoring and science panels followed by adaptive manipulations of the resource. Does this mean, as one river lawyer reacted informally, "[t]hat the Corps can do whatever it wants?" Is the "final decision" that is subject to review the decision to adopt AM initially, or is it each and every adaptation? Will AM assure that the Corps controls the river so long as it can keep the stakeholders reasonably satisfied and, therefore, at the table of discussion?

To the lawyer who represents environmental and wildlife interests, the advocate's warning flags are unfurled immediately at this suggestion, because she is being asked to relinquish a well-understood and moderately successful process for one that is incomplete, vague and not subject to any clear oversight. It is one thing to agree that reform of environmental law based on complex AM is a good idea in theory, and quite another thing to accept it in a situation where one represents specific clients and interests whose relative position in the process may be compromised in the elusive AM game.

Of particular concern to the lawyer is the issue of how to gain adequate review of the science being applied. In recent years federal courts have "raised the bar" for admission of expert scientific testimony,[270] but an AM process can, at least arguably, make that exper-

268. J.B. Ruhl, *Ecosystem Management, the ESA, and the Seven Degrees of Relevance*, 14 NAT. REOURCES & ENV'T 156, 157 (2000).

269. This issue is examined in Timothy H. Profeta, *Managing Without a Balance: Environmental Regulation in Light of Ecological Advances*, 7 DUKE ENVTL. L. & POL'Y F. 71, 96 (1996).

270. *See* Daubert v. Merrell Dow Pharm., Inc., 509 U.S. 579 (1993).

tise elusive, because it will take the form of a relaxed consultation with stakeholders groups rather than the more structured scientific inquiry to which most are accustomed. Is a scientist who merely consults with a stakeholder group concerning AM proposals rendering expert advice?

The advocate who is being asked to advise on the issue of AM will encounter further issues. For example, are AM stakeholders and science consultation committee meetings open to the public? There is no particular requirement unless it is concluded that the Federal Advisory Committee Act applies.

The Role of Hard Science in AM Decision-Making. If proposals to replace linear decision-making with AM create concerns among legal and policy advocates, they must also raise concerns among the community of traditional scientific investigators who will question the place of science in this process. If the purpose of AM is to bring science to the resources management table, will science be at the head of the table or somewhere off at the side? If science is to test by hypotheses, will it alone be in charge of defining the appropriate scientific questions? The outline of AM, as it is presented, filters decisions through some sort of science review committee, comprised of individuals who may (or may not) be independent. This committee will either present its findings to decision-makers or, alternatively, review proposals made by a stakeholder group. The underlying issue, however, is how the AM process works when the decision-makers decline to follow the advice of the science community, or choose to ignore what appear to be valid conclusions based upon accepted scientific methodology. Is this the end of the matter?

The *Biological Opinion on Missouri River Operations* does not tackle questions of this type; it proposes an action committee comprised of the Corps, the USF&W Service and "other parties with biologic or engineering expertise."[271] The emphasis appears to be on sound scientific monitoring as the central evaluation and response tool.[272] Nothing is said expressly about the independence of science.

The Corps' EIS on the Master Manual Review does not add to this in any considerable way. It proposes an agency coordination team of federal biologists which will review monitoring data and determine if operational changes are required. Although its science panel will be biologists, they will be agency employees and not, therefore, independent.

The NRC Committee report is somewhat more specific concerning the role of science in Missouri River AM, although it too fails to prescribe a specific place for science in the process. There is an emphasis

271. BIOLOGICAL OPINION, *supra* note 63, at 239.
272. *Id.* at 237.

on the capacity of science to guide decision-makers by constructing informed simulation models "and to help identify uncertainties."[273] AM is to enlist scientists to initiate necessary programs and to interpret and communicate scientific findings.[274] The NRC report proposes that a scientific committee exist, but that its role will be merely persuasive, serving to help get the basin's stakeholders to agree on the science and what it says; to convince the stakeholders that something needs to be done. This suggest that while the scientists who are involved may (or may not) be independent, they will play an advocacy role persuading the decision-makers and stakeholders of the advisability of certain experiments and the range of risks involved.

The vagueness and variety of these descriptions of the role of science in AM leaves us with little to rely on. In theory, AM intends to use science as a source of neutral principles, but no proposal is willing to require allegiance of an agency or stakeholder to the conclusions of the science advisors. The nature of the issue is highlighted by the following statement from an NRC report which describes AM at the Glen Canyon Dam on the Colorado River.

> [AM] ultimately involves trade-offs among competing objectives. The Strategic Plan concentrates on quantifying physical, biological, cultural, and conventional financial consequences of dam operations. It sidesteps the final, equally essential step of articulating scientific criteria for guiding choices among competing objectives that "protect, mitigate, mitigate adverse impacts to, and improve the values" identified in the Grand Canyon Protection Act. . . . [T]he Strategic Plan should include strategy for scientific evaluation of management alternatives . . . .[275]

It seems that the AM contemplated at Glen Canyon relegates science to the task of advancing the solutions and compromises arrived at by the stakeholder group. A stripped-down interpretation is that the stakeholder group will consider the comments of the science panel, but not be bound by it. There is little in the reports and proposals coming out of the Missouri River processes to suggest that any alternatives are being considered.

The very dynamics of the operations of a government agency such as the Corps bear heavily in favor of the results which satisfy the stakeholders and minimize conflict. For the agency to grant to a science panel, in advance, the authority to disrupt or delay an otherwise satisfactory settlement is an outcome not to be anticipated. In fact, the effectiveness of ESA, as applied to date, is that it requires agencies to pay real respect to hard science, even when the result is a disruption of normal agency functions. Viewed from the Corps' perspective,

273. NRC REPORT, *supra* note 98, at 90.
274. *Id.* at 91.
275. NAT'L RESEARCH COUNCIL, COMM. ON GRAND CANYON MONITORING AND RESEARCH, DOWNSTREAM: ADAPTIVE MANAGEMENT OF GLEN CANYON DAM AND THE COLORADO RIVER ECOSYSTEM 8-9 (1999).

to grant decisive authority to an independent science panel as part of an AM process is to suggest the possibility of an in-house ESA!

Sound Science or Dispute Resolution Technique? For those who are trained in the tradition of scientific inquiry, there must be a hesitancy to recognize AM as a sound methodology for achieving optimum management of complex natural resources systems. Readers of texts or government reports on AM may be excused if they perceive AM as an attempt to convert hard biological science into a social science. Alternatively, they may be inclined to see AM not as an attempt to build sound science into decision-making, but rather to use the format of scientific inquiry as a method of dispute resolution, similar to arbitration or mediation. Are scientists to be the new "facilitators" of stakeholder groups, or are they to be given a true lead role in formulating creative and adaptive remedies? Is AM always about stakeholders groups and their need to achieve resolution, with scientists simply serving to provide information when called-upon? Or, are scientists in the lead, with stakeholders groups accepting the reality of scientific conclusions and then achieving a settlement built around the science?

The Essential Place of Stakeholders in AM. It now seems to be clear that while most of the parties who are involved in reconsidering Missouri River operations are prepared to accept AM in general, none have been willing to state specifically what AM is. Our interpretation is that absent full acceptance of recovery efforts by stakeholders there will not be the opportunity to undertake brave and risky experiments, and "there is the high risk of litigation and further gridlock."[276] Stakeholders are to be at the center because they represent the social system, which is an integral part of the ecosystem for which recovery is sought. Stakeholders are to be involved because AM by its very nature requires risk-taking, and the burden of those risks will usually fall upon stakeholders.

Viewed in this way it is apparent that the role of science in AM is to serve stakeholder's groups. In the past, scientific experimentation occurred in isolation from human groups or, if it did involve humans it did so in small and informed control groups. Now, however, we need to experiment in the largest river basin in the United States, amidst a complex and diverse human society. Just as we would not expose an individual human to a medical experiment absent proper agreement in advance, so we cannot undertake risky experiments in the Missouri basin absent some analog to consent, and that is why a stakeholders group is central to the science of ecosystem management and the institutional change now being named AM. Recognition of this core reality about AM defines the role of science in the process, and provides an

276. NRC REPORT, *supra* note 98, at 112.

ultimate definition of AM as presently conceived by management agencies.

What Characteristics of AM Are Required by Chaos and Complexity Theory or Suggested by Chaos or Complexity Theory? It is clear that the agencies involved with the Missouri River are reluctant to be specific about the AM system which they contemplate. The NRC Report is equally vague but recommends that before AM is applied on the river Congress should enact specific authorization. The question that begs a response, however, is what does complex adaptive systems theory suggest of an AM process if it is to fulfill its full potential? The revised system which emerges will represent the tension between the established linear process and the emerging but poorly defined AM process. Whether a revised system constitutes a significant advance will depend, in one part, on the extent to which it satisfies the legitimate concerns raised by defenders of the existing linear process and, in another part, on whether it adopts the essential elements of CAS theory.

Many of the lessons and potential of *complex adaptive systems theory* are consistent with suggestions from the general literature and cases on adaptive management. What CAS theory and its component parts of *chaos* and *complexity* add is an analytical framework for a decision making infrastructure design that pushes the system to the "edge of chaos." Perhaps counter-intuitively the *first lesson* is that limits and structures are as important as flexibility. Thus, true minimum requirements for each constituency must be established so there is less political and economic risk for each.

The *second lesson* is to establish the minimum requirements such that there is "space" for adaptation and experience, that is, the resources cannot be so fully allocated so that there are no resources with which to experiment. This space importantly, also reduces what might be a very fragile supercritical systems state in which catastrophes are regularly courted.

In turn, the focus of the *third lesson* is again on constraint and form but in this lesson the constraint is on the internal decision making mechanism rather than on outside minimum parameters. This structure regards the standard of scientific evidence, the kind of science, and the appellate review standard for adaptation. To experiment is to fail and, thereby, learn. Therefore these standards need to be forgiving. Nonetheless the existence of the "fail-safe" outside parameters (minimums) should help insulate, again, against most stakeholder catastrophic loss.

The *fourth lesson* is that of the necessity of an overarching vision or mission; stated in terms of CAS, it would be the penultimate "mental model" toward which successive adaptations seek to approximate.

Finally, the *last lesson* involves a number of design features that all complex adaptive systems seem to exhibit. Many of these features will require changes in the typical linear models of decision making and they include diversity of "agents" to find existing opportunities; agents acting in parallel recognizing that there is no single "best way" and creating a kind of competition; and, a hierarchy such that the best ideas (not compromises) are tried and the results broadly disseminated.

The level of development on the Missouri is high, and the interests of those who rely upon the *status quo* are well-established; many rest firmly on either case or statutory law. These represent constraints—the minimum requirements to be satisfied by any revised system. In other words, AM will find its "space" to operate in those river resources that are not yet committed, or that are committed but which can be recaptured in one way or another. Within this "space" of uncommitted resources an AM structure can be constructed. Whether it is an advance will depend on whether the fundamentals of CAS are adopted and secured.