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January 3, 1996

Robert John Behnke, Ph.D.
3429 East Prospect Road
Fort Collins, CO 80525

Re: Water Appropriations for Instream Flow
Deposition of: **ROBERT JOHN BEHNKE, Ph.D.**
Date of Deposition: December 19, 1995

Dear Dr. Behnke:

Enclosed is a complimentary copy of your deposition regarding the above, including an original signature page and form of Amendment. It was agreed at the time of the deposition that you would read, sign, make changes if necessary, and return the notarized signature page and Amendments, if any, to this office by February 3, 1996.

We trust you will find our work product indicates we are experienced in the terminology of your expertise. Our goal is to produce an accurate transcript, to save you and counsel time when reading and using it.

If you do find that our work product reflects well on our service, perhaps you would consider offering our name to attorneys in the future when they are scheduling your deposition. Out-of-town counsel may not have a reporter connection in Denver and they may appreciate the suggestion of a reporting firm which has your approval. **When you schedule a deposition with us, we will always provide you with a complimentary copy of the transcript.** Enclosed are our Rolodex and business cards for future reference.

We appreciated working with you regarding this matter and would look forward to future occasions.

Sincerely,

Eileen Charles Hyatt

Eileen Charles Hyatt

Enclosures

AMENDMENT TO DEPOSITION

THE DEPONENT Robert J. Behnke, REQUESTS THAT THE
(PLEASE PRINT NAME)

FOLLOWING CHANGES BE NOTED RELATING TO HIS/HER DEPOSITION:

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59:8, 9, 14			
61:24	spacial	spatial	

I found nothing that changed meaning or intent of my deposition

Robert J Behnke
DEPONENT SIGNATURE

THE SIGNATURE ABOVE WAS SUBSCRIBED AND SWORN TO BEFORE ME THIS ______ DAY OF ______, 19____

NOTARY PUBLIC ADDRESS:

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When Rigor Meets Reality

Ecological experiments have become quite good at isolating causes and effects. But there's a debate brewing over whether these results reveal anything about the natural world

Ecologists use many tactics in their attempts to understand how organisms relate to one another and to their surroundings. In the News section of this special issue on ecology, our lead story deals with one of those tactics, experimentation, and an emerging debate over how ecologists design these tests of the natural world. This is followed by stories on how small organisms have large influences, two hugely ambitious conservation plans, and the value of a biological survey in Hawaii.

Articles, beginning on page 324, start with an exploration of the value of large- and small-scale manipulations of ecosystems. Other topics discussed include strategies for assessing climate-driven effects on ecosystems, world biodiversity, the impact of human population growth, land restoration programs, public opinion on the environment, and the effects of environmental discontinuities and synergisms.

When ecologist Andrew Blaustein linked vanishing amphibians to disappearing ozone last year, he made a splash in the popular press. Alarming field studies showing big drops in frog and salamander populations all over the world have had scientists scrambling for explanations. One controversial idea was that a thinner ozone layer—produced by global atmospheric changes—was the culprit. And Blaustein and his colleagues at Oregon State University had what looked like dramatic experimental data suggesting the amphibians are suffering from higher levels of ultraviolet radiation—a result of thinner ozone. The scientists had placed UV filters over some frog and salamander eggs and left other eggs uncovered. Survival rates in the uncovered eggs were markedly lower. And media attention suddenly became higher. *The New York Times* editorialized that "the Oregon team has provided suggestive evidence that wildlife is affected by the thinning ozone layer. Those vanishing frogs are telling us something."

But some of Blaustein's colleagues aren't sure what that something is. "The study was very poorly grounded in long-term, quantitative field data," says Joseph Bernardo, an ecologist at the University of Texas. The Oregon team failed to investigate whether UV levels had actually risen over the last 10 years—the period in which, according to Blaustein, amphibians have become more difficult to find—nor did they test other possible explanations for frog egg mortality, Bernardo says. For instance, a fungus known to be spreading through some frog populations in the Northwest could have killed enough of the eggs to provide a more mundane solution to the mystery of the attenuated amphibians.

Although Blaustein insists that "we've been doing natural history on these animals since 1979," and "we studied UV because we can't find any other reason why they are dying," Bernardo is not impressed. The "inferential chain to what's going on in nature" is weak in this work, he says.

And there are too many such experiments being done, he and others charge. For 3 decades, ecologists have been replacing assumptions about natural systems with testable theories and rigorous statistical analyses, says William Resetarits, an ecologist for the Illinois Natural History Survey. While this effort has been key to the field's progress, Resetarits says it's gone a bit too far, and experiments often reduce nature to oversimplified caricatures that have little to do with the real world. "Experiments can do something for ecology that no other approach can do: establish cause and effect. But they don't tell you what questions to ask, or whether you are testing your questions appropriately," Resetarits says.

UNIVERSITY OF BRITISH COLUMBIA

Natural design? Experiments to test evolutionary theories, such as ecologist Dolph Schluter's artificial fish pond *(above)*, have some wondering if the tests are too artificial.

Now, says Bernardo, "there is a little bit of a backlash from people like me, younger folks who are fed up with that kind of artificiality." And at the annual meeting of the American Society of Zoologists in St. Louis in January, in a 2-day symposium called "The State of Experimental Ecology," these new experimentalists held an organizational rally of sorts. They argued that only by combining careful experimental design with long periods spent observing ecosystems and their inhabitants—what field researchers call "muddy-boots biology"—can ecologists come up with truly meaningful results. "We wanted to provide a framework for the next paradigm in experimental ecology," says Resetarits.

Ecology's evolution

This budding revisionist movement is a reaction to what, 30 years ago, was a revisionist trend of its own: controlled lab and field manipulations. Now comprising at least 60% of the studies published in ecology's three major journals, according to a 1994 survey, such research was rare throughout most of the discipline's history, says Robert Holt, a community ecologist at the University of Kansas Museum of Natural History. "People would observe patterns in nature consistent with their theories, then conclude that this proved the theories right," Holt says. Beginning in the 1960s, however, "ecology went through a very critical phase where it was realized that in order to actually nail down that a particular process is taking place, you have to go out and kick the system."

Trailblazing investigations published by ecologists Joseph Connell in 1961 and Robert Paine in 1966 did much to convince their colleagues of the power of experiment. By removing, enclosing, or transplanting small populations of the barnacle *Balanus balanoides* along the intertidal zone of the rocky Scottish coastline, Connell proved that the distribution of another barnacle species, *Chthamalus stellatus*, was regulated mainly by competition with *Balanus*. Paine, by contrast, was able to show that the removal of a "keystone" carnivore, the starfish *Pisaster ochraceus*, from patches of Washington shoreline allowed its favorite prey, the mussel *Mytilus californianus*, to edge out most other local invertebrates, drastically altering local species diversity (see p. 316). Although ecologists had long suspected the importance of mechanisms like competition and predation in shaping species distribution, never before had these forces been so explicitly demonstrated.

These and similar experiments spawned "an incredible maturation and intellectual momentum" in ecology, says David Tilman, director of the University of Minnesota's Cedar Creek Long Term Ecological Research area. "In the intervening 3 decades, ecology has gone from not even considering the possibility of being able to predict patterns in nature to having an understanding of some broad general principles," Tilman says. Contemporary ecologists conduct experimental manipulations in nearly every accessible habitat and on every practical scale, from Rutgers University ecologist Peter Morin's laboratory investigations of food webs among bottled algae and bacteria to Tilman's own studies of changing species diversity within dozens of square-meter plots, each seeded with up to 54 local plant species, on the Minnesota prairie.

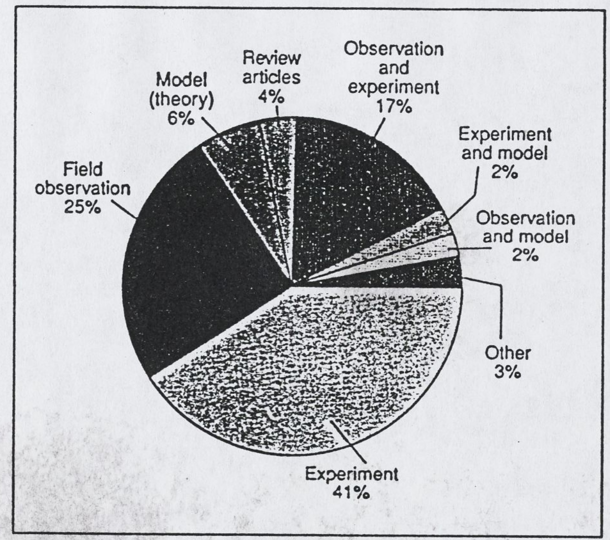
And ecology journals, full of differential equations and multiple regression analyses, are growing more and more difficult to distinguish from their counterparts in "hard" sciences like geophysics or applied mathematics. "The push toward experimentation beginning in the 1960s was the result of 'physics envy,' " says Resetarits. "We wanted to be a hard science."

A disconnect with nature

But this effort to transform ecology into an experimental science has had a downside, say critics. "Now that we've infused people with the need for rigor, we've perhaps drawn them a bit too far from the roots of ecology," says Resetarits. Authors can have difficulty persuading journal editors to include tables of field observations germane to their experiments, he says. And unlike Connell's and Paine's pioneering field experiments, which were based on prolonged observation of local population dynamics, Bernardo argues that many experiments conducted by today's ecologists evidence no such intimacy with nature. "The problem is that ecologists threw out the proverbial baby with the bath water," Holt says.

One instance of this estrangement, Bernardo and other critics say, was the Oregon team's work on amphibians and UV radiation. Blaustein and co-workers found that frog and salamander eggs inside UV-protected enclosures had a much greater chance of developing into tadpoles than those in unfiltered enclosures. They also discovered that eggs from a frog species with high natural levels of photolyase, an enzyme that repairs UV damage to DNA, survived better in all the enclosures than did those with lower photolyase levels. Human activity, they concluded, may be depleting Earth's ozone layer faster than many amphibian species can evolve new defense mechanisms against UV radiation [*Proceedings of the National Academy of Sciences* 91, 1791 (1994)].

Bernardo, however, dismisses Blaustein's study as a "science fair experiment" whose central variable, UV radiation, was chosen with no strong grounding in local field conditions. "Has UV influence over those lakes changed over the same period that frog egg mortality has changed? He has no data," Bernardo states. "Suppose Blaustein had decided to manipulate temperature instead of UV—then the story he's weaving in the press would have been that global warming is causing [the amphibian decline]."



Hard science. Experiments have taken on a dominant role in ecology, indicated by this breakdown of observational techniques used in studies published in the journals *Ecology*, *Oecologia*, and *Oikos*, from 1987 to 1991.

David Reznick, an ecologist at the University of California, Riverside, adds that some amphibian populations—such as one Central American tree frog species that inhabits dense foliage—are declining even though they live beneath UV radiation's reach, indicating that some other mechanism must be at work. Says Reznick, "These global patterns don't lend themselves to a single easy explanation."

Blaustein agrees with this last point, saying "UV is definitely not a universal explanation for amphibian declines," and adds that new experiments are already under way to test for a possible synergism between UV radiation and a fungal disease now spreading quickly through amphibian populations in the Oregon Cascades. But while he admits there are no data showing that UV incidence has increased at the team's field sites, he notes "there are absolutely no long-term data on UV anywhere, let alone in our area ... so that can be a criticism of any UV study." Further, he says his team searched hard for other environmental changes that might be harming amphibians, such as acid rain, heavy metals and other pollutants, and hab[itat] destruction, but found nothing. "Wh[at] we've seen in about 15 different field sites [is] that the eggs that are dying are right out i[n] the open," where they are most exposed t[o] solar UV, Blaustein says.

Bruce Menge, a community ecologist als[o] at Oregon State University, calls the lack o[f] long-term UV data to back up Blaustein['s] findings irrelevant. "If we followed [Bernar]do's] arguments, we wouldn't do much o[f] anything relevant to these pressing prob[-]lems" like ozone thinning, Menge says[.] Blaustein is "an outstanding naturalist" wh[o] "doesn't go out and do experiment[s] without having a natural-history basi[s] to do them," Menge adds.

Designing reality

Whatever the truth of the amphibia[n] puzzle, being disconnected from natur[e] isn't the only factor that can throw o[ff] an ecological experiment, the revi[-]sionists say. Many studies are also un[-]dermined by basic flaws in their design[.] It's on these grounds that Bernardo[,] Resetarits, and University of Pennsyl[-]vania ecologist Arthur Dunham hav[e] attacked an influential study of "char[-]acter displacement" published in *Sci[-]ence* last year. Character displacemen[t] is the theory that competition for a[n] ecological niche can force species tha[t] initially have similar characteristics t[o] evolve in slightly different direc[-]tions—in effect to keep out of on[e] another's way. In the study, Dolph Schluter, an ecologist at the University of British Columbia in Vancouver, filled both halves of each of two divided artificial ponds with "generalist" three-spine stickleback fish (*Gasterosteus aculeatus* complex) that feed both high and low in the water columns of their native glacial lakes (*Science*, 4 November 1994, p. 798). To one half of the pond, he added a second stickleback species that feeds exclusively on plankton near the water's surface.

After 3 months, Schluter began recording the generalists' growth. Fish in the untreated halves of the two ponds grew normally. But in the presence of the top-feeders, he found, the quickest growing generalists were those whose mouths and gill shapes most resembled those of a third, bottom-feeding type of stickleback. Schluter's conclusion: Natural selection was starting to favor the generalists with more bottom-feeding capabilities. If the trend had been allowed to continue through subsequent generations, the initial generalist characteristics would have been be displaced because they are heritable.

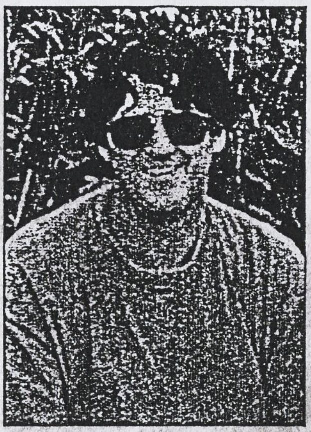
Says Resetarits, "It's a sexy result, and it's gotten a lot of play, but it's a very bad experiment." Resetarits was so skeptical of the results that he, Bernardo, and Dunham challenged them in a recent Technical Comment (*Science*, 19 May, p. 1065). The experiment's fatal flaw, they say, was that Schluter failed to control for the possibility that plain overcrowding in the treated halves of the two ponds—rather than the specific presence of the top-feeders—gave the bottom-feeding generalists a growth advantage over their competitors. One simple way to establish such a control, says Resetarits, would have been to add an equal number of generalists to the untreated halves of the ponds, thus keeping the sticklebacks' densities in the two halves equal.

In addition, the critics point out, Schluter artificially increased the frequency of extreme characteristics among the generalist sticklebacks by using hybrid fish with genes from both top- and bottom-feeding species. As a result the generalists were swimming in a far richer gene pool, so to speak, than could be drawn on by individuals in a natural lake.

Schluter responds that extreme phenotypes are so rare in nature that his experiment could not have been done within a reasonable research budget without priming the genetic pump. "If you wanted to [test character displacement] with purely natural variation in those same traits, you would need a much larger sample size and a greater number of ponds," says Schluter. "It's doable in principle, but in practice it would be very daunting."

He acknowledges that his experiment did not strictly rule out density as a contributor to morphological changes. He says he chose the design described in the *Science* paper over the alternative Resetarits outlines because the alternative design would not have yielded any information about selection pressures.

In this, Schluter has allies. "I strongly respect the call for ecological realism in the design and conduct of field experiments. But Bernardo and his colleagues have argued the hard line a little too strongly," says Peter Grant, an evolutionary ecologist at Princeton University. "Not only does the stickleback experiment demonstrate a phenotype-specific effect of a competitor on individual growth rates of another—in a manner expected from the hypothesis of character displacement—but it is solidly grounded in 30 years' worth of knowledge of the animals in nature."



Hard questions. Ecologists Joseph Bernardo *(left)* and William Resetarits *(right)* have challenged some of their colleagues' methods. Says Bernardo: "There are still plenty of young [ecologists] doing mindless, stupid experiments."

Bernardo, however, says the gospel of good experimental design can never be reinforced too strongly, as "there are still plenty of young [ecologists] doing mindless, stupid experiments." Too many researchers, Bernardo and Resetarits say, fail to identify explicitly the biological questions they are trying to address or to translate these questions into a set of precise, statistical tests that unambiguously distinguish between alternative hypotheses. In addition, they say, too many ecologists let their interpretations stray beyond the theory being tested or the natural system under investigation.

Such experiments carry risks that go beyond ecology, says Dunham. "When you overgeneralize your results—particularly when there is a need for applied ecological principles in conservation and biodiversity protection—then you run the risk of having bad science accepted by resource managers, with potentially disastrous results," he says.

The remedy, says Bernardo, is to "allow more complexity and multiple causality to enter into our designs." The revisionists point to ongoing field studies by James H. Brown, an ecologist at the University of New Mexico, as an example of experimental ecology done right. On two dozen quarter-hectare plots in the Chihuahuan desert of southeastern Arizona (a hectare is 2.47 acres), Brown and colleagues have spent the last 18 years manipulating one factor after another in an attempt to explain predator-prey relationships and species composition among seed-eating rodents, ants, and seed-producing plants (*Science*, 10 February, p. 880). At times Brown has fenced out certain ant species to study the effects of decreased competition; at other times he has fenced out certain rodent species to study resulting changes in grass cover and cascading effects on other species. Says Bernardo: "The experiments have been tedious, costly, and difficult, but very realistic."

The limits of description

Many researchers believe, however, that Bernardo and his fellow critics are setting unrealistic standards. They argue that complex problems like the ecological effects of global environmental change will never be untangled without help from the most reductionist of experiments: computer simulations and lab-based ecosystems. John Lawton, an ecologist at the U.K.'s Imperial College, has used a terrarium-like enclosure called the Ecotron to measure plant productivity and carbon dioxide uptake as functions of species diversity. He advocates such "controlled environment facilities" as "halfway houses between the simplicity of mathematical models and the full complexity of the field" (see p. 316 and Article by Lawton on p. 328). Adds Rutgers' Morin, "There are some ecologists who put down [lab experiments] because we have abstracted things so much. Our response is that if you don't start with a simple system, you won't understand what's going on anyway."

Other ecologists say critics like Dunham, Bernardo, and Resetarits sometimes make too much of the occasional flaws in published experiments. "It's possible to do anything badly," says Nelson Hairston, an emeritus ecologist at the University of North Carolina, Chapel Hill, and author of the 1989 volume *Ecological Experiments*.

But many ecologists not in the thick of the debate, such as Minnesota's Tilman, say participants in the St. Louis symposium are prescribing a necessary antidote to the excesses of experimentalism. Continuing generational change will reinforce this message, he believes. "Twenty or 30 years ago, most ecologists were either theorists or experimentalists or natural historians. But as younger generations are drawn in, an increasing number of individuals are acquiring skills in all three disciplines." Tilman says this has fostered "a trend in the whole field ... toward the realization that ecology will advance most rapidly through a balanced combination."

That advance won't be easy, notes Gary Polis, a community ecologist at Vanderbilt University in Tennessee. Understanding the natural variability in conditions at most field sites and detecting subtle, infrequent, or hidden ecological processes takes studies much longer than the usual timescale of ecological experiments. Restoring natural history to ecological experiments will also mean broadening their spatial scales, Polis says, because many natural processes like mobility, dispersal, and species interactions can create patterns visible only from a macroperspective.

All that will take money, and although funding is scarcer than ever, many ecologists think it's worth the effort to try. "I think we're at a very early, embryological stage in the ontogeny of ecology," says Polis. "There are lots of really neat questions out there for the picking. It's just a question of recognizing them." And asking them in the proper manner.

–Wade Roush

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Information for Contributors appears on pages 112–114 of the 6 January 1995 issue. Editorial correspondence, including requests for permission to reprint and reprint orders, should be sent to 1333 H Street, NW, Washington, DC 20005.
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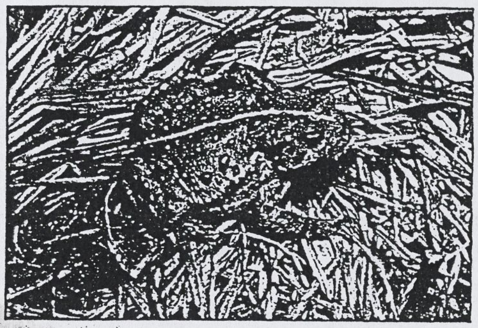
LETTERS

Western toad at high noon?

Field experiments show that ultraviolet (UV) light can damage amphibian eggs. Field observations show a decline in many populations of frogs and toads, such as this threatened toad *Bufo boreas*. But to what degree is solar radiation a factor in the decline? The latter, more complex, question is of a global scale. Many letters praising the UV light experiments of Andrew Blaustein and his colleagues were received in response to the 21 July special section "Frontiers in Biology: Ecology." How the media, including *Science*, report on such experimental findings, and what kind of studies should be done next, are more problematic for these writers.



WILLIAM LEONARD

Ecological Research

Our recent work showing that ultraviolet (UV) radiation can contribute to amphibian egg mortality is criticized by Joseph Bernardo and William Resetarits in a news article for, as Bernardo says, being "very poorly grounded in long-term, quantitative field data" ("When rigor meets reality," by Wade Roush, in a special section: Frontiers in Biology: Ecology; 21 July, p. 313). These criticisms are unfounded. We have collected and published data (including yearly egg mortality estimates) on the ecology of northwestern amphibians for 15 years. Moreover, we have about 40 years of background data on northwestern amphibians from Robert Storm and his numerous students.

With this natural history basis, we became concerned in the mid-1980s when we observed unprecedented mortality of amphibian eggs in the Cascade Range. After systematically analyzing pond water for pollutants, acidification, and many other factors, we found only one factor associated with egg mortality—a pathogenic fungus (*1*). Bernardo ignores relevant issues when he presents the fungus as an alternative to UV for high egg mortality without acknowledging that I proposed this explanation (*1*). We also noted that dying eggs were laid in shallow, open water, an observation consistent with the view that mortality is related to UV radiation. Thus, after 8 years of observing dying eggs, conducting preliminary experiments, and after ruling out many potential mortality factors, we designed field experiments to test the hypothesis that amphibian embryos are sensitive to ambient UV-B radiation.

Eggs of several species were placed in enclosures in a randomized block design at natural oviposition sites. This design allows experimental and control treatments to be conducted simultaneously, side by side, after randomly assigning enclosures to positions along the shore. Each block had three treatments (not just filtered and unfiltered treatments, as stated by Roush): enclosures (i) open to natural sunlight including UV-B, (ii) covered with a UV-B blocking filter, or (iii) covered with a filter that transmitted UV-B (a control for placing a filter over eggs). Each block was replicated four times. To ensure that our results were not unique to a specific site, each species was tested at two sites. Experiments were conducted in both 1993 and 1994. Our published papers (*1*, *2*), those in press, and those in review suggest that in certain species both UV radiation and the fungus contribute to egg mortality, and that is all we have stated in our papers. We do not know how continued egg mortality will affect amphibians at the population level. But we do know that our experiments had the potential to invalidate the view that UV radiation contributes to egg mortality. We have not claimed that UV radiation is the single worldwide cause of amphibian population declines, as is implied in the news article. We have repeatedly stated that habitat destruction is the main cause for the declines (*3*–*5*); that they do not lend themselves to single explanations is a point that we have made in several papers (*3*–*5*). However, this statement is mistakenly attributed to David Reznick, apparently because Reznick paraphrased one of my papers (5) on amphibian declines to Roush (6). It is unfortunate that Bernardo and Resetarits appear not to have read our papers carefully and have criticized us for what some of the popular press has said about our work.

Instead of being poorly grounded in long-term field data, as Bernardo alleges, we believe that our work demonstrates how long-term observations point the direction toward relevant, realistic experiments.

Andrew R. Blaustein
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6. D. Reznick, personal communication.

I wish to express my concern over the quote attributed to me in the article by Roush. The quote (which gives the incorrect impression that I am critical of Blaustein's work) was actually derived from Blaustein's own writings (1). Blaustein is at the forefront of the worldwide investigations into all the potential causes of amphibian decline, including UV radiation. In view of his clear statement of likely multiple causes of the amphibian decline, I interpreted Blaustein's experiment as a test of the plausibility of UV radiation as one of those possible causes. The fact that the experiment was performed without the benefit of prior long-term data indicating an increase in UV radiation should not be a concern because, in a rapidly changing world, it is impossible to foresee what the important changes might be. Rather than criticize the work for not being motivated by such data, I instead view it as contributing to the motivation for collecting such data in the future.

More generally, it is ironic that Roush featured criticism of two such fine papers. Both Dolph Schluter (2) and Blaustein were working on systems for which there are abundant ecological data. Both took these prior observations into account when designing and executing their experiments. Both studies represent novel approaches to a problem and produced interesting results that should be of interest to a general, critical audience such as *Science*'s readership. Both studies incorporated complexities that merit some open debate, so it is not unreasonable that one of them has been discussed in *Science*'s Technical Comments section (3); however, the tone of Roush's news article in no way represents the subtleties of this kind of work or the costs and benefits of alternative experimental approaches to a problem, such as the role of density or the use of hybrids in Schluter's work. In my opinion, Schluter made the right decisions. For all of these reasons, I feel that Roush's article presents an inaccurate, destructive view of the scientific process.

David Reznick
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I am appalled and dismayed by the views attributed to Bernardo and Resetarits in the article by Roush. Experiments in ecology, as in all branches of biology, must be well grounded in an understanding of the natu-

ral world, but to attack Blaustein for not having followed this principle is absurd. The declines in amphibian populations that have recently been observed in many parts of the world are disturbing to many biologists, and increased UV radiation resulting from ozone depletion is an obvious candidate as a cause of at least some of these declines. Blaustein's experiments were a simple, well-designed, and carefully carried out test of this hypothesis, and they yielded strong and persuasive results in its support; they should be judged on their merits as experiments, and it is for the biological community to evaluate their wider significance. They do not solve the mystery of the declines, and Blaustein has never claimed that they do; they do, however, open up important new areas of investigation. Blaustein's decision to study the effects of UV radiation on amphibian eggs may have been a largely intuitive one, but where would science be if researchers ignored their intuition?

*Tim Halliday**

Department of Biology, Open University, Buckinghamshire, MK7 6AA, United Kingdom

*Director, Declining Amphibian Populations Task Force, Species Survival Commission, World Conservation Union

Who would have anticipated 10 years ago that collecting long-term data on UV might be important now? The point of Blaustein's research is that UV exposure *does* affect amphibian egg survival and that changes in UV radiation *have the potential* to contribute to declines in some populations.

Most ecologists recognize that the two approaches to studying ecology are not in opposition, but are complementary. Long-term field experiments of the type advocated by Bernardo and Resetarits have the advantage of retaining some of the complexity of natural systems. Disadvantages include (i) a lack of control of factors that may affect the population under study; (ii) little replication of results; and, in many cases, (iii) little power to prove or disprove inferences about causality. Laboratory or controlled field experiments have the advantage of larger numbers of replicate studies, greater statistical power, and more power to reveal causality. The primary sacrifice made in the latter approach is the elimination of possibly relevant factors.

I agree with Bernardo and Resetarits on the general point that it is critical to articulate biological hypotheses and to collect precise experimental or observational data that distinguish among alternative causes, although I suspect that most ecologists would agree that this should be standard operating procedure.

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Response: Some of the experiments discussed in my news article—studies by Andrew Blaustein and colleagues and by Dolph Schluter—had generated discussion and debate among ecologists well before I wrote about them. The article reflected that debate. It also allowed the scientists to refute the critiques; for instance, Blaustein's initial point in his letter, that he had 15 years of data on his study population, is also made by him in the news article.

The criticisms of Blaustein's work conveyed in the news story focused on a specific paper [A. R. Blaustein *et al.*, *Proc. Nat. Acad. Sci. U.S.A.* 91, 1791 (1994)]. That paper did not include the qualification that a pathogenic fungus might be another source of egg mortality, nor did it contain any reference to the 1991 paper in *Biological Conservation* that Blaustein cites in his letter above. Nevertheless, the news article should have acknowledged that Blaustein himself had raised the fungal hypothesis elsewhere.

The 1994 paper by Blaustein *et al.* did include the statement that "There is no known single cause for the amphibian declines, but their widespread distribution suggests involvement of global agents—increased UV-B radiation, for example." David Reznick, when interviewed by me, noted several alternatives to the view that a global UV increase was responsible. It was not clear in our discussion that his statement, "These global patterns don't lend themselves to a single easy explanation," was derived from Blaustein's own writings. I regret the error, and apologize for the misunderstanding.—*Wade Roush*

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Dioxin and Advisory Board

We take strong exception to Richard Stone's summary of the U.S. Environmental Protection Agency (EPA) Science Advisory Board (SAB) meeting and the accompanying headline, ("Panel slams EPA's dioxin analysis," 26 May, p. 1124), as members of the panel in question. At the conclusion of the meeting, one of us (D.O.) characterized the panel's recommendations as "in no way a repudiation," but rather a judgment that two of the nine chapters (parts of chapter eight and chapter nin[e] the health assessment document ne[eded] "clarification and ripening." No one o[n the] 39-member panel disagreed publicly [with] that judgment, and there were several [con]currences on the record.

As noted by Stone, we did commen[d the] agency for considering dioxins and re[lated] compounds as a class, and many of us [were] highly supportive of the work reflecte[d in] the first seven chapters of the health as[sess]ment document. In particular, we do [not] agree with Stone's assertion that "[S]board members say EPA also ignored [data] that fail to support its conclusion tha[t di]oxin is harmful to human health." The board member Stone cites in this cont[ext,] Michael Gough, a microbial genetic[ist at] the Office of Technology Assessment [of the] U.S. Congress, and we disagree with [him] and think he is not representative of th[e] group. Moreover, his long-held view[s on] this subject are well known.

Finally, we point out that the one p[ublic] comment on the agenda in the 2-day [meet]ing from an organization not represe[nting] industry also commended the EPA [for its] work to date. We think it is likely [that] when the EPA redrafts the health a[ssess]ment document for the molecule TC[DD, it] will maintain the scientific core of th[e]

An Instream Flow Philosophy for Recovering Endangered Colorado River Fishes

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ABSTRACT: Remnant stocks of some endangered Colorado River fishes persist, including Colorado squawfish (*Ptychocheilus lucius*), humpback chub (*Gila cypha*), razorback sucker (*Xyrauchen texanus*), and bonytail (*Gila elegans*). Recovery of these species to a nonendangered status is problematic. Provision of flows to maintain habitats in which the fish are declining may do little to slow their decline or prevent their loss. It is argued that determination of instream flows for endangered fishes should be based on the premise that the fish are not occupying optimal, or perhaps even acceptable habitats, a philosophically different approach than that addressed by prevailing flow methodologies. A recovery rather than survival philosophy is recommended that includes developing instream flow needs through a combination of empirical studies, simulations, and assessments.

KEY WORDS: Endangered species, *Gila elegans*, *Gila cypha*, instream flow, *Ptychocheilus lucius*, stream habitat, *Xyrauchen texanus*.

INTRODUCTION

Severe, long-term, and adverse impacts have changed historic fish habitats and stocks in North America. Populations of native fishes are declining and some are faced with extinction. During the past 100 years, 3 genera, 27 species, and 13 subspecies of fishes have become extinct due to physical habitat alteration and concomitant fish introductions (Miller et al. 1989). An additional 364 rare fishes in Canada, the United States, and Mexico are threatened with extinction (Williams et al. 1989). In a 10-year review of fishes of threatened, endangered, or special concern listed by Deacon et al. (1979), Williams et al. (1989) found that 139 new taxa warranted protection, but not a single species had been removed from the original list by successful recovery efforts.

There are few rivers remaining in North America in which annual flow patterns have not been severely altered. Stream fishes have been particularly affected by this form of habitat deterioration, prompting the American Fisheries Society to state that alteration of streamflows is the major factor in the loss of stream fishery resources in North America (Peters 1981; Tyus 1990). It is unknown whether the rate of loss of these natural faunas can be reduced because community-level disturbances often result from species extirpations. The fate of native Colorado River fishes in the southwestern United States is of particular concern, because widespread and drastic habitat loss has had severe impacts on this unique fauna (Carlson and Muth 1989).

The Colorado River basin, encompassing about $\frac{1}{12}$ of the land mass of the continental United States, is located in extremely arid country (McAllister et al. 1986) and its waters are a precious commodity. Waters of the Colorado River were diverted for agricultural use by Native Americans, but these diversions increased exponentially with subsequent settlement. Many such diversions existed by the late 1800's, and construction of large mainstream projects began in the early 1900's (Fradkin 1981; Carlson and Muth 1989).

The Bureau of Reclamation initiated its major dam construction phase in the Colorado River with passage of the Colorado River Compact and Boulder Canyon Project Act in 1928 and 1929 (Fradkin 1981). By the 1960's, much of the mainstream Colorado River had been converted into a system of dams and diversions. As a result, the timing, duration, and magnitude of flows of most mainstream rivers of the Colorado River basin have been substantially altered. This includes downstream changes in flow, temperature, and channel morphology; inundation of stream habitats; and habitat fragmentation due to stream blockage (Miller 1961; Ono et al. 1983; Carlson and Muth 1989).

Habitat change in the Colorado River has been associated with the proliferation of nonnative forms introduced by man and the decline of native species (Minckley 1982; Carlson and Muth 1989). The disappearance of native fishes from greatly altered habitats indicates that habitat change, including invasion by other species, has occurred too quickly for native forms to adapt and recover (Minckley and Deacon 1968; Molles 1980). It is more difficult to determine causes for declines of endangered fish stocks that occupy less-altered habitats.

Changes in riverine habitats and endangerment of native fishes has been of concern to the U.S. Fish and Wildlife Service (FWS). The FWS has consulted with other federal agencies in the upper Colorado River basin under provisions of the Endangered Species Act of 1973 as amended (16 U.S.C. § 1531 et seq.), and has issued more than 100 Biological Opinions pursuant to Section 7 of that Act (Rose and Hamill 1988). In general, the FWS determined that water depletion and dam operation would likely jeopardize the endangered fishes. However, FWS opinions on flows that are required by the fish may conflict with water rights of various states as well as Interstate Compacts and other agreements (Rose and Hamill 1988; Wydoski and Hamill 1991). An interagency Recovery Implementation Program was established in the upper Colorado River basin in an effort to recover the listed fishes to a nonendangered status, and to seek ways to provide streamflows for them under existing state and federal water agreements (Wydoski and Hamill 1991).

The need for annual flow regimes for the endangered fishes in the upper Colorado River basin has been identified by the Recovery Implementation Program, but various cooperators disagree on the methods used to determine their magnitude, timing, and duration (unpublished reports on file at the FWS office in Denver, Colorado). Management and recovery of endangered fishes is a relatively new concept, and recovery methods are not well developed (Williams et al. 1989). Future management of endangered Colorado River fishes will require the development of recovery goals in which instream flow needs are clearly identified, and innovative approaches will be required to meet the flow needs of the fish within water constraints.

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The objectives of this article are to: (1) report the status of the endangered, big-river Colorado River fishes, (2) contrast two philosophies guiding the determination and implementation of instream flows, and (3) recommend an approach for determining instream flow needs of endangered Colorado River fishes that will promote their recovery and lessen the likelihood for decline of other native fishes.

STATUS OF COLORADO RIVER FISHES

A long period of geographic isolation and extreme climatic and hydrologic conditions have resulted in a unique and insular Colorado River fish fauna (Miller 1959, 1961; Molles 1980). This fauna can be separated into three categories: (1) fishes inhabiting high or intermediate elevations that either share, or have closely allied forms in, adjacent drainages; (2) species endemic to small streams at low to intermediate elevations; and (3) big-river fishes, commonly called the Colorado River fishes, that are mostly species endemic to mainstream rivers (Minckley et al. 1986). Native big-river fishes, consisting of cyprinids (minnows) and catostomids (suckers), were widely distributed in mainstream habitats of the historic Colorado River basin (Jordan and Evermann 1896). Four of the big river fishes, Colorado squawfish (*Ptychocheilus lucius*), razorback sucker (*Xyrauchen texanus*), humpback chub (*Gila cypha*), and bonytail (*Gila elegans*), are now threatened with extinction due to the combined effects of habitat loss (including regulation of natural flow, temperature, and sediment regimes), proliferation of introduced fishes, and other man-induced disturbances (Miller 1961; Minckley 1973, 1982, 1983; Minckley and Deacon 1991). Stocks of these four fishes have declined to the point that all are federally listed as endangered species. That this decline continues is evidenced by the recent listing of razorback sucker, a species first proposed for federal listing as threatened in 1980, which has deteriorated to the point that only relict stocks of nonrecruiting fish prevail (FWS 1991).

Conversion of the mainstream lower Colorado River into a system of dams and diversions has been accompanied by a significant change in river fauna. Change in the natural flow regimen, stream blockage, and conversion of many miles of warmwater stream habitat to reservoirs and cold tailwaters have been accompanied by stocking a plethora of nonnative fishes. Native fishes there have been largely extirpated and replaced by a new fauna of about 44 forms (Minckley 1982), many of which were introduced from more mesic environments. Of these, 20 species are abundant either locally or regionally (Minckley 1982). In the lower basin, Colorado squawfish has been extirpated; relict populations of bonytail and razorback sucker remain in some impoundments, but neither species is presumed self-sustaining; and humpback chub reproduction is restricted to the Little Colorado River in the Grand Canyon (Minckley 1973, 1983; Kaeding and Zimmerman 1983).

Recovery prospects for most of the endangered fishes may be greatest in the upper Colorado River basin because about 2,000 km of occupied habitat remains. The native fish fauna there includes six species that are endemic large-river cyprinids and catostomids, and six headwater forms that also occur elsewhere. Although 42 introduced fishes are presently reported, less than 10 are considered abundant (Tyus et al. 1982). Colorado squawfish persists in the Yampa River, the Green River below its confluence with the Yampa River, the upper Colorado River mainstream, and the lower San Juan River (Tyus et al. 1982; Platania et al. 1991). The humpback chub is reproducing successfully in the Yampa and upper Colorado rivers (Kaeding et al. 1990; Karp and Tyus 1990a). The razorback sucker persists in the lower Yampa and Green rivers, the mainstream Colorado River, and the lower San Juan River (McAda and Wydoski 1980; Tyus et al. 1982; Platania et al. 1991), but there is no indication of recent recruitment in these remnant populations (FWS 1991). The remaining endangered large-river fish, the bonytail, is extremely rare in the upper Colorado River basin (Valdez and Clemmer 1982; Kaeding et al. 1986) but it occurs elsewhere only in hatchery or relict reservoir stocks.

CONTRASTING PHILOSOPHIES

Past efforts to determine instream flows for the endangered Colorado River fishes have been based on two different philosophies: (1) flows required for population survival (Beecher 1990), and (2) flows needed for recovery. The first one attempts to maintain populations of endangered fishes at their current levels and recommends flows based on current habitat use information. In this case, emphasis is placed on preventing extinction. The second would increase standing crops of fishes and numbers of reproducing populations to the point that the species could be delisted under the Endangered Species Act (16 U.S.C. § 1531 et seq.), a goal that would presumably require improvement of existing conditions; that is, nondegradation of suitable habitats and restoration of others (Beecher 1990). In the upper Colorado river basin, most efforts have been directed at determining survival flows, even though this goal is seldom identified.

Survival Flows

The goal of most habitat and streamflow protection efforts for endangered fishes has habitat formation. ie. No Process

been to prevent extirpation due to water resources development, pursuant to provisions of Section 7 of the Endangered Species Act. This level of protection may be interpreted as maintaining population survival (or viability), and it is based on the premise that the numbers of individuals in a population are sufficient to maintain genetic diversity and that the environment will be suitable. However, population size is not known for Colorado River fishes and their habitat requirements are not well understood. The determination of survival flows needed by these fishes has been based on recent habitat use even though present habitats are presumably suboptimal. Provision of existing conditions for these imperiled species is intuitively incorrect and ostensibly may further their decline.

As suggested by Prewitt and Stalnaker (1982), careful consideration and a structured approach are required to determine flow requirements of endangered Colorado River fishes. Because of river-system complexity, habitat changes, and fish community alteration, a careful and structured approach has been difficult. As an example, Miller et al. (1982) provided flow recommendations for survival of Colorado squawfish stocks and noted that flows exceeding survival flow levels were necessary to maintain fish habitats. Determination of such flows was constrained by the limited availability of habitat use information. More recently, Tyus and Karp (1989) used empirical data and professional judgment to recommend flow regimes needed for maintaining habitats of the endangered fishes and noted that other management practices would be needed to arrest population declines. To date, no study has identified the specific measures that will recover local stocks of these fishes to a nonendangered status.

Instream flows have been determined by standard setting or incremental methods (Wesche and Rechard 1980; Trihey and Stalnaker 1985). Standard setting methodologies usually involve the determination of one specific flow, such as a low flow that would occur at some exceedence value based on the historic flow record. Incremental methods include some modeling techniques that are useful in evaluating tradeoffs between developmental alternatives. Some of the most valuable assessment tools, the Instream Flow Incremental Methodology (IFIM) and Physical Habitat Simulation (PHABSIM) system (Bovee 1982; Gore and Nestler 1988), have had wide application. The IFIM was developed as a water management tool; PHABSIM is useful in relating flow changes to the availability of certain habitats.

In PHABSIM, the relationship between fish habitat use is usually determined by generating "weighted usable area" (Bovee 1982) to represent certain physical parameters (usually water depth and velocity, and stream substrate) used by the fish. In the application of the method, alternative flow scenarios that provide a larger amount of such "physical habitats" are judged more acceptable than those that do not. PHABSIM does not determine whether or not a valid relationship exists between physical habitats and standing crops of fishes, and its utility has been widely debated (Condor and Annear 1987).

Some workers have established relationships between fish abundance (i.e., usually 1 species and life stage) and physical habitats in small, coldwater streams with 1 to 10 fish species (Nestler 1990). Little relationship has been found in large warmwater streams and other such complex biological systems that may have 30 or more fish species (Orth and Maughan 1982; Mathur et al. 1985; Baltz et al. 1987; Layher and Maughan 1987). It has been difficult to establish a positive linear relationship between standing crops of warmwater fishes and physical parameters that are often used in habitat simulation models (e.g., water depth and velocity and stream substrate type) (Mathur et al. 1985; Nestler 1990). The relationships between flow, habitat, and fish production are not well understood (Reiser et al. 1989).

Instream flow requirements for endangered Colorado River fishes can only be determined by the integration of life history information with instream flow needs. Life history information can be used to identify habitat use by various life stages, and flow requirements determined by using different techniques in such diverse habitats as main river channels, backwaters (little or no water flow), and seasonally flooded bottomlands. Recent attempts to determine flows for certain life history stages of the endangered Colorado River fishes using PHABSIM have been judged inappropriate because certain habitats used by the fish were not easily simulated, microhabitat parameters used were not accepted as the only factors required by the fish, and conflicting flows have been obtained for different species and life stages in the same location (Valdez et al. 1990; unpublished FWS reports on file in Grand Junction, Colorado). Because microhabitat availability is not the only factor limiting fish populations (Orth 1987), the IFIM or any other method cannot be accepted as valid for determining flow needs of endangered fishes unless the ecosystem is well understood and the relationship between flows and standing crops of target organisms is established.

Many western states now acknowledge fisheries resources as a beneficial use of water (Reiser et al. 1989) and set standards to protect these resources based on minimum flows (McKinney and Taylor 1988). Because minimum flows are usually defined as those needed to protect the environment to a reasonable degree (e.g., Col. Rev. Stat. § 37-92-102[3]), state water boards and other water development interests are hesitant to endorse use of empirical fish habitat data for instream flows without the use of some model that allows them to choose minimum flows. For this reason, agencies have spent much time and money developing minimum flow methods that are acceptable for water appropriation.

Stalnaker (1990) argued that "minimum flow is a myth," when minimum flows have been the basis for reserving water for stream fisheries. He points out that as water is appropriated, the minimum flow becomes the management target. This practice means that the minimum becomes the average flow, and resultant low flows are undesirable for stream communities. Only instream flow regimes that provide wet, average, and dry years will meet life requirements of most fishes (Stalnaker 1981) and this includes endangered Colorado River fishes.

Thus, recovery of Colorado River fishes is problematic given the survival flow philosophy because: (1) habitats are presumed marginal, (2) there is insufficient information on the life history of the fishes, and (3) water managers tend to consider only minimum flows.

Recovery Flows

Recovery of endangered Colorado River fishes to a nonendangered status requires a guiding philosophy that is different from the philosophy that prevails in commercial and sport fisheries management. Instead, a conservation ethic (Soulé and Wilcox 1980; Frankel 1983) must be developed to perpetuate natural systems. Management practices must be developed to achieve adequate distribution, abundance, and relative numbers of species, not mere "status quo." Thus, effective recovery of the endangered fishes will require new research and management methods to protect and restore stream resources as the highest goals (Beecher 1990) for instream standards.

In identifying such standards, it is necessary to determine the ecological requirements and specific habitat needs of the fishes. These requirements and needs would be best evaluated in least-altered systems in which the fish are most abundant. The need to evaluate endangered species in least-altered systems is based on the assumption that conditions in which a species evolves are also those in which it is most likely to maintain an adaptive advantage over other forms. However, habitats used by endangered fishes in the upper Colorado River basin continue to change, and an evaluation of *optimum* habitat requirements is problematic.

YAMPA. → 15 + 18 Mile Reach

Habitat changes that have resulted in the endangerment of Colorado River fishes are unknown, but they are due in part to human-induced change. As an example, early operation of Flaming Gorge and Fontenelle dams on the upper Green River in the 1960's eliminated most of the native fishes in 128 km of river above Dinosaur National Monument (Baxter and Simon 1970; Vanicek et al. 1970) and recent operations have not provided acceptable flow and temperature conditions for native fish populations for many kilometers downstream (Vanicek et al. 1970). Standing crops of endangered fishes in the Green River below its confluence with the Yampa River are presumably being maintained by the more natural flow and temperature regimens of the latter system (Holden and Wick 1982; Tyus and Karp 1989). Successful reproduction of Colorado squawfish in the lower Green River continues because of mitigating effects of tributary flows and ambient warming of the river with increased distance from Flaming Gorge Dam.

Flows that were associated with various life history needs of endangered fishes in the Green River basin were evaluated by FWS and used in part as a basis for a Draft Biological Opinion on the operations of Flaming Gorge Dam pursuant to Section 7 of the Endangered Species Act and for recommending flow needs for fishes in the Yampa River (unpublished FWS report on file in Denver, Colorado). However, only instream flows that are the minimum amount needed can be protected under Colorado water law (Col. Rev. Stat. § 37-92-102[3]), and in other states as well. Although general flow needs have thus been established, it is difficult to determine minimum flows because the system is no longer natural; flow, temperature, and other physical features are changing in response to water management. In addition, endangered fishes are exposed to a myriad of introduced forms, and these introductions have resulted in a new, more complex fish community, whose structure and attributes are poorly understood (Minckley 1982).

Habitat requirements of the endangered Colorado River fishes have been determined in areas that are occupied by the many introduced fishes, and their habitat use has presumably been affected by them. For example, predaceous northern pike (*Esox lucius*) and channel catfish (*Ictalurus punctatus*) occupy habitats of adult Colorado squawfish (Wick and Hawkins 1989; Tyus and Nikirk 1990). Habitats used by young Colorado squawfish are dominated by introduced fishes (Haines and Tyus 1990) and aggressive behavior of some of these toward Colorado squawfish (Karp and Tyus 1990b) suggests adverse interactions for food and space. Juvenile Colorado squawfish have been consumed by introduced fishes (Coon 1965; Hendrickson and Brooks 1987; Osmundson 1987). Populations of humpback chub may be adversely affected by channel catfish in the Green River basin (Karp and Tyus 1990a). The apparent lack of recruitment in razorback sucker has been related to predation by common carp (*Cyprinus carpio*) and other nonnative fishes (Marsh and Langhorst 1988; Marsh and Minckley 1989).

It is common practice to determine flows that would provide habitat for a target fish species. However, the Colorado River system has been permanently modified by the introductions of so many nonnative fishes (Minckley 1982) that recovery efforts for the endangered fish must include evaluations of flow needs of all inhabitants. In this context, instream flow needs must not be considered in a vacuum, but should be incorporated in a comprehensive program that involves evaluating the limiting factors, propagation and genetics management options, and field testing of alternative management practices, including different flows. Because project compliance with agreed-upon instream flows is often lax, it is important to monitor specified flows to ensure that they are provided (Hubert et al. 1990) and to evaluate effects of such flows on fish populations (Deacon 1988).

Another issue associated with flow recommendations involves the importance of seasonally flooded lands to the survival of the Colorado River fishes. The role of bottomlands for fish production has been documented in warmwater, floodplain rivers worldwide (Welcomme 1979). Many such areas in the upper Green River have been lost by river regulation (reductions in the magnitude and duration of high spring flows) and by impoundment (removal of fish access) for agriculture, waterfowl production, and other purposes. Large bottomlands along the upper Green River are examples of these, and they are under evaluation for their role in endangered fish management. These lands should be further studied for the relationship between fish use and various types of spring flooding events. HEC-2 analysis

It is not known whether the Colorado River fishes can be recovered in the remaining habitat. To accomplish this requires adoption of a recovery philosophy that relies on the interpretation of empirical data and ecological perspectives. As demonstrated by others (e.g., Murphy et al. 1990), the persistence of threatened animal populations depends on genetic, demographic, environmental, and other factors, some of which may act synergistically to affect population viability. Although it may not be possible to construct and validate population models for the complex Colorado River system, water management for endangered fishes can proceed using combinations of empirical studies, analytical models, computer simulations, and subjective assessments to assist the decision-making process (Maguire 1986; Soulé 1987).

CONCLUSIONS

Instream flow requirements for endangered fishes should be determined with respect to their recovery, not survival. This is particularly true in the Colorado River where habitat change has been severe and widespread, and is continuing. Survival is too often synonymous with "status quo," and this may ultimately lead to extinction in declining populations. In the past, streamflows for fisheries resources have been provided on a minimum flow basis, and the utility of this approach is questionable (Stalnaker 1990).

Although much progress has been made in developing analytical methods for assessing streamflows, the relationship between physical parameters and fish production is complex and not well understood. New approaches for assessing streamflow requirements of fishes are needed if endangered fish recovery is to become a reality. Rather than providing endangered fish with the same habitats in which they are declining, alternatives might include studies that would test fish community response to various flow scenarios. These could include appropriately designed laboratory studies, reclamation of stream sections, or construction of new stream sections in which such things as flows and species compositions could be manipulated to test specific hypotheses concerning fish response to flows. The goal of these studies should be to determine if flows are limiting the recovery of different life stages of the endangered fishes and to evaluate the role of "nonflow" impacts. Because experimental approaches are complex and costly, they will not become a reality unless managers are better informed about shortcomings and potential dangers of using some instream flow methods.

Although most of the interest in determining and protecting Colorado River fishes has been associated with the need to protect federally listed endangered species, the "fundamentally insular" (Molles 1980) nature of the fauna suggests that other species may also become endangered or extinct in the near future. As each species disappears, it is anticipated that recovery of the remaining forms will become increasingly more difficult as perturbations in the native ecosystem increase.

Successful recovery of the Colorado River fishes to a self-sustaining status will require the efforts of many individuals with varied interests concerning multiple uses of water. Because some of these interests will differ, progress will be made only by concentrating on the consequences of water management decisions. Such decisions must be based on a recovery flow philosophy grounded in sound ecological principles and solid biological information.

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Management of Aquatic Resources in Large Catchments: Recognizing Interactions Between Ecosystem Connectivity and Environmental Disturbance

J.A. Stanford and J.V. Ward

Abstract

Management within catchment basins must be approached with an empirically based understanding of the natural connectivity and variability of structural and functional properties of riverine ecosystems. Rivers are four-dimensional environments involving processes that connect upstream-downstream, channel-hyporheic (groundwater), and channel-floodplain (riparian) zones or patches, and these differ temporally. Natural and human disturbances, including biotic feedback (such as predation, parasitism, and other food web dynamics), interact to determine the most probable biophysical state of the catchment ecosystem. Human disturbances can be quantitatively determined by deviations from an observed biophysical state (baseline), but usually this requires long-term ecological data sets. A case history of the Flathead River-Lake system in Montana (USA) and British Columbia (Canada) is summarized to illustrate how disturbances interact at the catchment level of organization. Owing to the natural complexities of catchment ecosystems and the cumulative effects of human disturbances, the rationale and logistics of obtaining long-term data often seem intractable and excessively expensive. The naive alternative is to derive and implement simplistic procedures that are agency specific and often result in management actions that interfere with each other. We argue that integrated management at the catchment level is needed and propose some simple principles, beginning with broader based collegiate training for prospective managers.

Key words. Ecosystem, river, catchment, drainage basin, management, disturbance, natural resources, watershed, Flathead River, Montana.

Introduction

Professor Noel Hynes first synthesized the concept of ecological connectivity in the context of river systems in his Baldi Lecture at the 19th Congress

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Watershed Management.
Springer-Verlag, New York
(1992).

of the International Society for Pure and Applied Limnology (Hynes 1975). He eloquently described how rivers are a manifestation of the biogeochemical nature of the valleys they drain, and he proposed that understanding the inherent connectivity between terrestrial and lotic biotopes would lead to important predictions about the future structure and function of river ecosystems.

In the nearly two decades since that seminal lecture, several paradigms (reviewed by Cummins et al. 1984) emerged from scores of studies that examined spatial and temporal aspects of geomorphic, hydrologic, thermal, and riparian influences on biotic attributes (e.g., diversity, zonation, food web associations, bioproduction) of rivers. The river continuum concept (Vannote et al. 1980, Minshall et al. 1985) provided a template for examining how biotic attributes of rivers change within the longitudinal gradient from headwaters to ocean confluence. The serial discontinuity concept (Ward and Stanford 1983*a*) provided a construct for the propensity of rivers to predictably reset biophysical attributes in relation to distance downstream from on-channel impoundments. Comparison of organic matter budgets in streams in different biomes provided the basis for the riparian control concept and demonstrated the extreme importance of allochthonous debris (wood and leaves) in lotic systems (Cummins et al. 1984, Harmon et al. 1986, Webster and Benfield 1986, Ward et al. 1990, Gregory et al. 1991). The nutrient spiraling concept (Webster and Patten 1979, Newbold et al. 1983) led to an understanding of how plant growth nutrients are transformed from dissolved to particulate states during translocation from upstream to downstream reaches. Lastly, the ecotone concept (Naiman and Décamps 1990, Holland et al. 1991) has fostered greater understanding of the extreme importance and potential predictive power related to transformations and fluxes of materials that occur within boundaries between functionally interconnected patches that form the riverine landscape. In many ways the ecotone concept integrates the other paradigms by emphasizing the functional connectivity inherent in all ecosystems.

Studies articulating these paradigms and other syntheses of stream ecology (Lock and Williams 1981, Barnes and Minshall 1983, Dodge 1989, Stanford and Covich 1988, Yount and Niemi 1990), plus a great number of other research projects, have largely verified Hynes's proposition that the streams are tightly coupled with catchment characteristics. Drainage basins or catchments (i.e., the river valley in Hynes's context) may indeed be characterized as ecosystems composed of a mosaic of terrestrial "patches" (Pickett and White 1985) that are connected (drained) by a network of streams. Of course, the lotic environment itself is a smaller scale patchwork or mosaic of habitats in which materials and energy are transferred (connected) through dynamic, biodiverse food webs. In most catchments, on-channel lakes and floodplain aquifers dramatically increase the complexity of the ecosystem, in contrast to the contemporary view of rivers as dynamic channels bounded by a riparian corridor (Sedell et al. 1989).

In this chapter we discuss the catchment in ecosystem terms (Lotspeich 1980, Naiman and Sedell 1981), stressing the ecological coupling that characterizes aquatic components of catchments, and discuss natural and human disturbances that influence biophysical connectivity. We describe how management actions can work at cross purposes when the interactions of natural and human disturbances are not considered from a catchment ecosystem viewpoint, and we discuss the difficulties of assessing cumulative effects of human perturbations. We use the Flathead River (British Columbia, Montana) as an example of a large river ecosystem influenced or partly uncoupled by a myriad of anthropogenic effects and competing management bureaucracies and interests. Finally, we propose an alternative general approach to natural resource management—an approach that begins with revised college curricula for training resource managers as conservators of ecological connectivity in river ecosystems.

Habitat Dimensions, Ecological Connectivity, and Natural Disturbance within River Ecosystems

In the United States, the term *watershed* is often misused in the context of river basin research and management. By proper definition, the watershed is the ridgeline or elevation contour that delimits drainage basins or catchments. The catchment is bounded by the watershed, and since water flows downstream from the watershed through the catchment, thereby integrating influences of natural and human disturbances within the catchment, we use the watershed as the natural ecosystem boundary.

Obviously, in these terms an ecosystem may be very small, such as a first-order catchment (sensu Strahler 1957), or it may be very large, encompassing entire river systems (e.g., the 671,000 km^2 catchment of the Columbia River, USA). Choice of ecosystem dimension (i.e., catchment size) is logically determined by the question being examined or the resource being managed.

The time frame encompassing the research question or management problem is of course also important. In geologic time, as a result of orogeny and erosion, watersheds were bisected and catchments reorganized, clearly having enormous zoogeographic consequences (Stanford and Ward 1986). In a much shorter time frame, engineering projects artificially connected catchments via transwatershed diversions of rivers in many areas (Stanford and Ward 1979, Davies and Walker 1986), allowing differently adapted organisms to commingle (Guiver 1976) or greatly accelerating immigration of

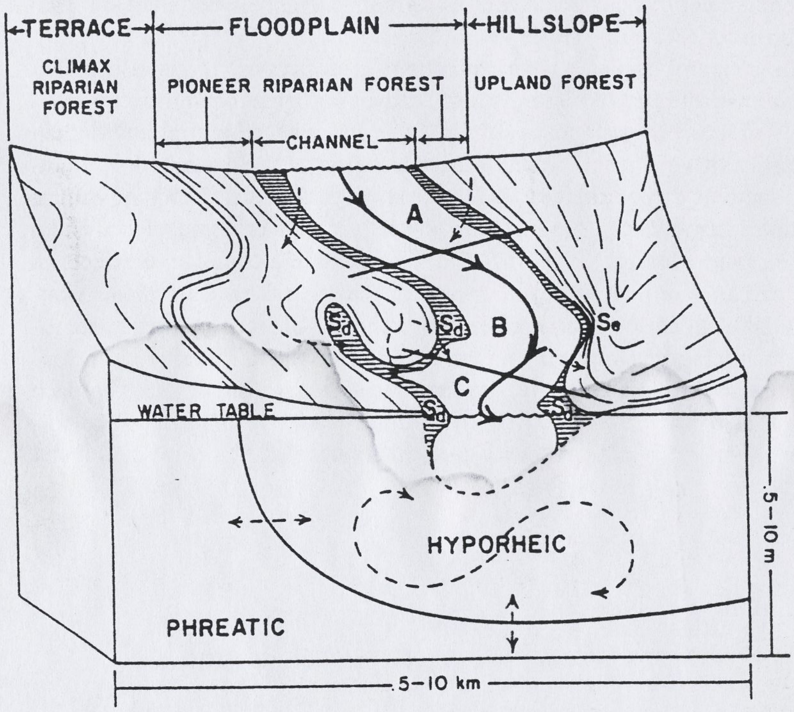
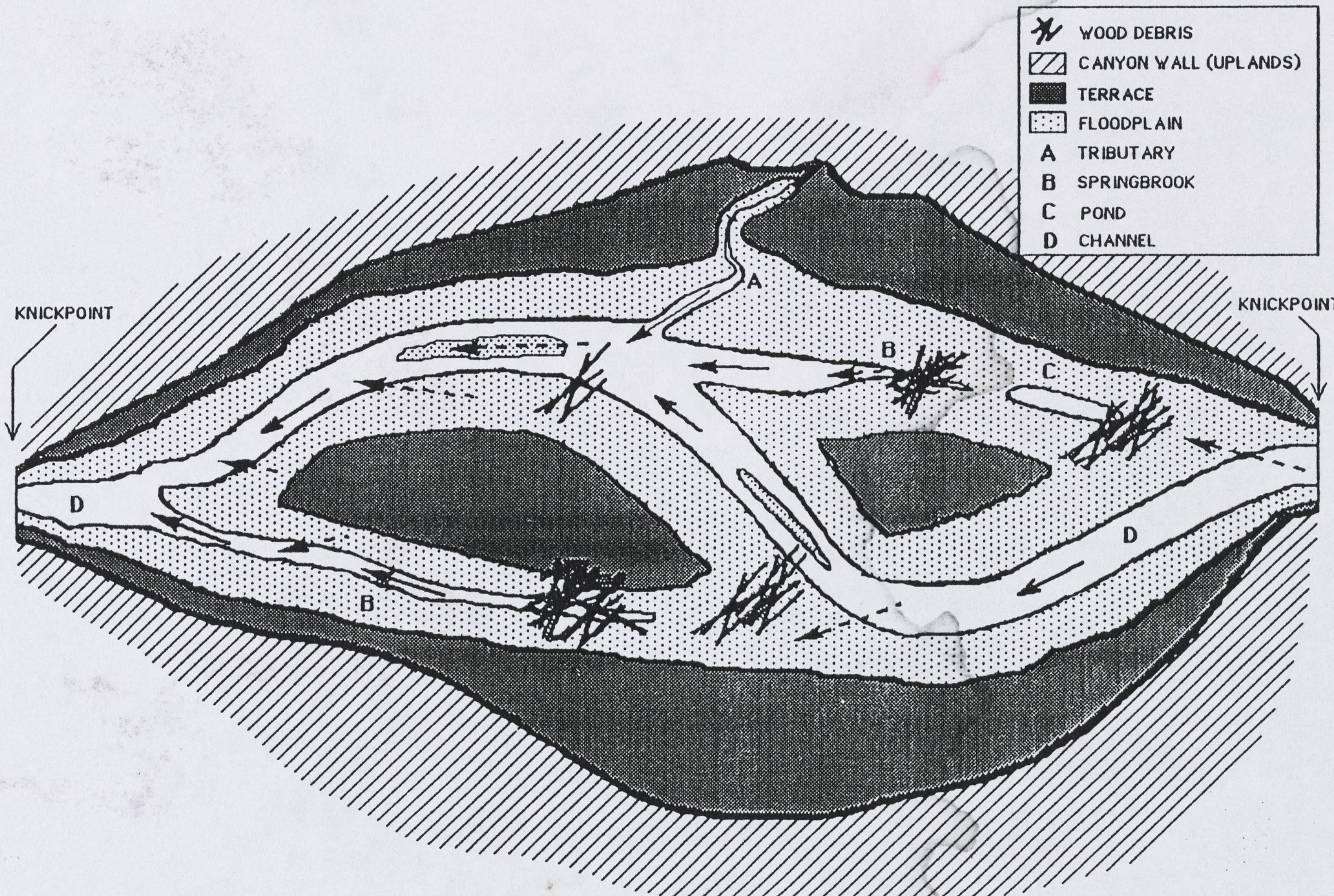


FIGURE 5.1. Major landscape features of the Kalispell Valley of the Flathead River, Montana, USA, showing the three primary spatial dimensions (lateral, longitudinal or altitudinal, and vertical) which are dynamically molded through time (the fourth dimension) by fluvial processes. Biota may reside in all three spatial dimensions: riparos (streamside or riparian), benthos (channel), hyporheos (river-influenced groundwater), and phreatos (true groundwater). The hatched area is the varial zone, or the area of the channel that is periodically dewatered as a consequence of the average amplitude of the discharge regime. Major channel features include a run (A), riffle (B), and pool (C); Sd refers to sites of sediment deposition and Se refers to a major site of bank erosion. The heavy solid line is the thalweg, and broken lines conceptualize circulation of water between benthic, hyporheic, and phreatic habitats.

nonnative biota introduced by other means (Stanford and Ward 1986, Mooney and Drake 1986).

Given that catchments may be referred to as ecosystems and that the ecosystem is dynamic in time and space as well as in its relation to environmental problem solving, it is fundamentally important to recognize the major structural features and dimensions of river ecosystems (Figure 5.1). Ecologists have appreciated for many years the importance of microhabitats encompassed by the run-riffle-pool sequence as influencing the distribution and abundance of biota within the river channel. Zonation of biota within the longitudinal continuum has long been recognized as a fundamental feature of the lotic environment (Hynes 1970), although explanations of specific distribution patterns often remain contentious (Alstad 1982, 1986; Thorp et al. 1986). Within the last decade, the connection between riparian zones, including the surficial floodplain dynamics, and ecological structure and function has been clearly demonstrated (see reviews in Décamps and Naiman 1989, Dodge 1989, Gregory et al. 1991). The importance of microbial transformation and transport of solutes in groundwaters has been shown in relation to plant growth nutrients for channel biotopes in streams (Stanford and Ward 1988, Ford and Naiman 1989, Dahm et al. 1991, Stream Solute Workshop 1990, Grimm et al. 1991, Valett et al. 1991); and penetration of groundwaters (i.e., the hyporheic zone, Figure 5.1) by amphibiotic stream biota has been documented (Schwoerbel 1967, Stanford and Gaufin 1974, Williams and Hynes 1974, Bretschko 1981, Danielopol 1984, Pugsley and Hynes 1986, Stanford and Ward 1988). But the presence of large-scale hyporheic zones, and the critical importance of groundwater – surface water interchange as a major landscape feature of catchments, have only recently been demonstrated (Stanford and Ward 1988, Danielopol 1989, Gibert et al. 1990).

River floodplains are often, if not always, penetrated by interstitial, subterranean flow (Figure 5.2). Water penetrates (downwells) at the upstream end of the floodplain, flows through unconfined aquifers at rates determined by the porosity of the substrata and the slope of the floodplain, and eventually upwells to the surface some distance downslope. Location of aquifer discharge is often related to bedrock outcrops or encroaching canyon walls (knickpoints in Figure 5.2). Effluent groundwaters may enter the channel directly or emerge as floodplain springbrooks that exhibit seasonally dynamic hydrology controlled by flow entering the floodplain from the river and from tributaries. These springbrooks usually occur in abandoned meander channels blocked at the upstream end by natural deposition of alluvium and woody debris. They have been referred to as wall-base channels in locations where they erupt from the substratum of old channels originally constrained by contact with the terrace or canyon walls (Peterson and Reid 1984). However, variations on this general theme may occur, depending on floodplain geomorphology and catchment hydrology (Amoros et al. 1982). Since spates frequently may overflow these springbrooks (in the Flathead River, Montana, these systems are flooded on about a ten-year return frequency; J. Stanford et al., unpublished), woody debris often accumulates, providing structurally complex lotic habitat. Moreover, relative to the main river channel, these springbrooks are characterized by fairly stable flows, moderated temperature regimes, high water clarity, and elevated concentrations of plant growth nutrients, particularly nitrate and soluble reactive phosphorus. As a result, standing crops of attached algae and zoobenthos can exceed biomass in the channel by several orders of magnitude. Juveniles of native cutthroat trout (*Oncorhynchus clarkii)* are abundant (J. Stanford et al., unpublished).


WOOD DEBRIS
CANYON WALL (UPLANDS)
TERRACE
FLOODPLAIN
A TRIBUTARY
B SPRINGBROOK
C POND
D CHANNEL
KNICKPOINT
KNICKPOINT
A
B
C
D
D
B

Therefore, it appears that these springbrooks are "hot spots" of bioproduction, although this relation has yet to be thoroughly documented.

Wall-base streams are known to be critically important as spawning and rearing habitats for salmonids in Pacific Northwest streams (Peterson and Reid 1984); and recent analyses suggest that aggraded floodplains and upwelling groundwaters historically were key production areas for anadromous salmonids (*Oncorhynchus* spp.) and resident bull charr (*Salvelinus confluentus*) in the Columbia River system (James Sedell, U.S. Forest Service, pers. comm.). In the Flathead River, Montana, native bull charr adults migrate upstream from Flathead Lake to spawn in specific habitats of fourth-order tributaries (Figure 5.3; see also Fraley and Shepard 1989). Juveniles remain in riverine habitats for two or three years before migrating downstream to Flathead Lake, where they mature. This phenology is termed *adfluvial*. Primary bull charr spawning sites are the groundwater upwelling zones of aggraded floodplain segments, which usually occur downstream from major altitudinal transitions (knickpoints) in the river continuum. Bull charr select only fourth-order streams that are not regulated by on-channel lakes, apparently in response to temperature criteria (J. Stanford, unpublished).

These observations emphasize that the riverine ecosystems are truly four dimensional, with longitudinal (upstream-downstream), lateral (floodplain-uplands), and vertical (hyporheic-phreatic) dimensions (Figure 5.1); since these spatial dimensions are transient or dynamic over time as a consequence of relativity, temporality is the fourth dimension (Ward 1989). Within a given stream reach, distribution and abundance of organisms form a multivariate function of the structural and functional attributes of channel (fluvial), riparian (floodplain, shoreline), and hyporheic (groundwater) habitats as they interact within time and space with the geomorphology and hydrology of the catchment. Clearly, catchments may be characterized as patch-dynamic systems (Pringle et al. 1988, Townsend 1989), and ecological connectivity of patches is a fundamental feature.

Many riverine organisms may traverse all three spatial dimensions in the process of completing life cycles (high connectivity), whereas others may be relatively stationary (low connectivity). For example, in the Flathead River, Montana, a gravel-bottom system with expansive intermontane floodplains characterized by substantial interstitial flow (Figure 5.2), certain specialized stoneflies (Insecta: Plecoptera) reside within floodplain groundwaters during the entire larval stage. Indeed, hundreds of these crepuscular stoneflies have been collected in single samples taken from groundwater monitoring wells 2–3 km from the river channel, demonstrating the enormous volume of the

FIGURE 5.2. Simplified plan view of an intermontane floodplain of a gravel-bed river on the Middle Fork of the Flathead River, Montana, USA. The floodplain is formed on the aggraded slope between bedrock constrictions (knickpoints) of the river channel. Riparian forests are well developed (mature) on the terrace, intergrade into upland forests, and are in various successional stages on the floodplain.

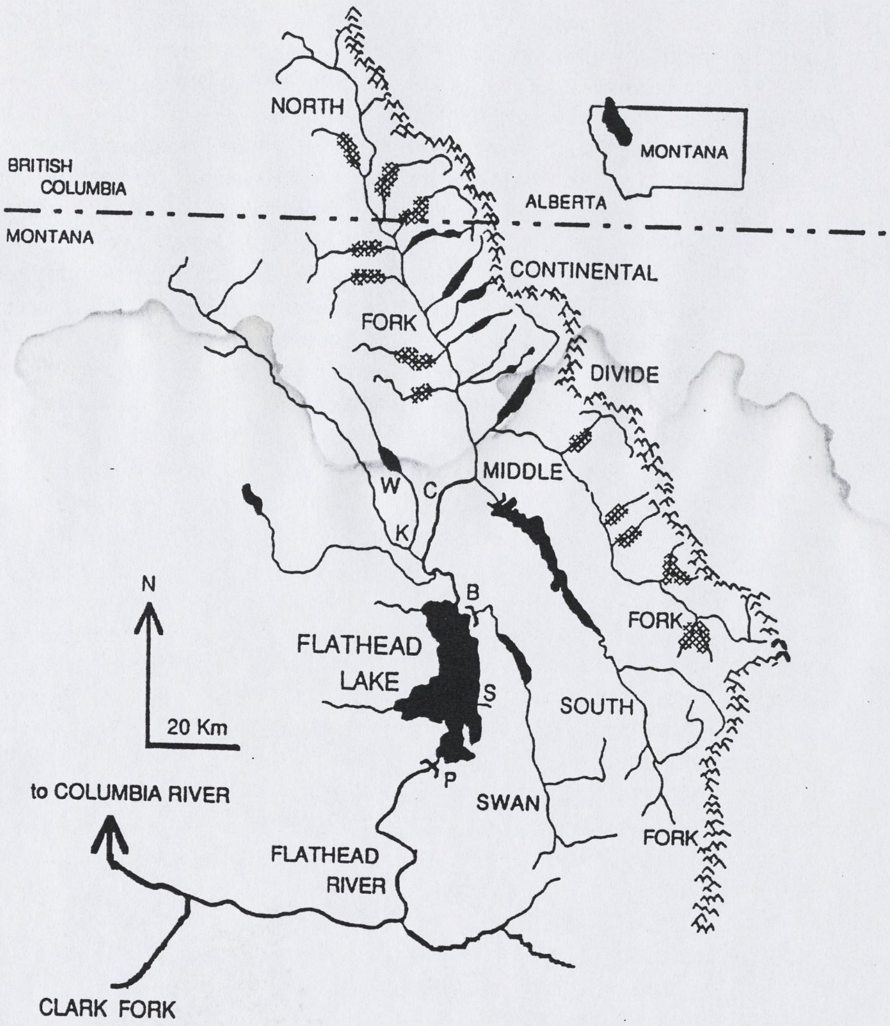


FIGURE 5.3. The Flathead River catchment basin in Montana, USA, and British Columbia, Canada. Primary spawning sites for adfluvial bull charr (*Salvelinus confluentus*) from Flathead Lake are shown on tributary creeks of the North and Middle Forks by cross hatching. Towns include Kalispell (K), Whitefish (W), Columbia Falls (C), Bigfork (B), and Polson (P). The Flathead Lake Biological Station (S) is on the east shore of the lake. The hydroelectric dam on the Swan River near Bigfork is a small run-of-the-river facility, whereas the other two dams in the system are much larger. See text for further explanation.

hyporheic zone in this river. They are the top consumers in a speciose (80+ species) groundwater food web. Yet these stoneflies emerge as winged adults from the river channel and fly into the riparian vegetation to mate and produce eggs. The eggs are deposited in the river channel, followed by larval immigration into the hyporheic zone (Stanford and Ward 1988). Many other riverine insects, which commonly characterize the rhithron (cold, swift-flowing, gravel-cobble substratum) habitat of western USA rivers, also depend on riparian vegetation during the flight period, but the larval stage is completed within the channel. Most noninsect zoobenthos and periphyton (attached algae) are essentially obligate channel inhabitants, although they, like most fish species and insect larvae, are often distinctly segregated by temperature, flow, substratum, or behavioral criteria within the altitudinal gradient of the stream continuum (e.g., bull charr distribution in Figure 5.3; see also Resh and Rosenberg 1984, Matthews and Heins 1987).

Biodiversity and bioproduction in rivers are related to a plethora of factors that interact bioenergetically (Figure 5.4) to determine reproductive success of individuals (e.g., the P and C compartments of Figure 5.4) attempting to coexist. Phenologies (life histories) are highly evolved and sensitive to environmental change. Consequently, disturbance events (e.g., floods, droughts, fires, disease epidemics, invasions by exotic species) reduce reproductive success and, hence, bioproduction; thus connectivity of lotic food webs is naturally decreased (Figure 5.5). Our main point is that for a particular species to survive, either as a resident of the catchment or as an immigrant, enough individuals must realize a net energy gain to meet phenological requirements which permit conservation of the gene pool (i.e., net positive contribution to riverine bioproduction). Bioproduction at the ecosystem level of organization is controlled by the same plethora of environmental factors; although in the case of riverine fishes, especially anadromous species, harvest by humans often is more pervasive than other environmental disturbances.

The degree of structural (Figures 5.1 and 5.2) and functional (e.g., flux of organic and inorganic materials and energy between consumer groups, Figure 5.4) connectivity determines the most probable biophysical state of the ecosystem at any given time. For many scientists this implies that tightly coupled ecosystems are highly evolved, undisturbed, and essentially in equilibrium. However, circumspection of equilibrium concepts is waning in contemporary ecology (Murdoch 1991), owing to the realization that natural and anthropogenic disturbances occur too frequently in most catchments to allow equilibrium models at any level of organization to be realistic (Resh et al. 1988; Naiman et al., this volume). Disturbance events alter structural and functional connectivity (Figure 5.5); the instantaneous biophysical status of ecosystems is usually more analogous to a quasi-equilibrium (sensu Schumm and Lichty 1956; see also Huston 1979).

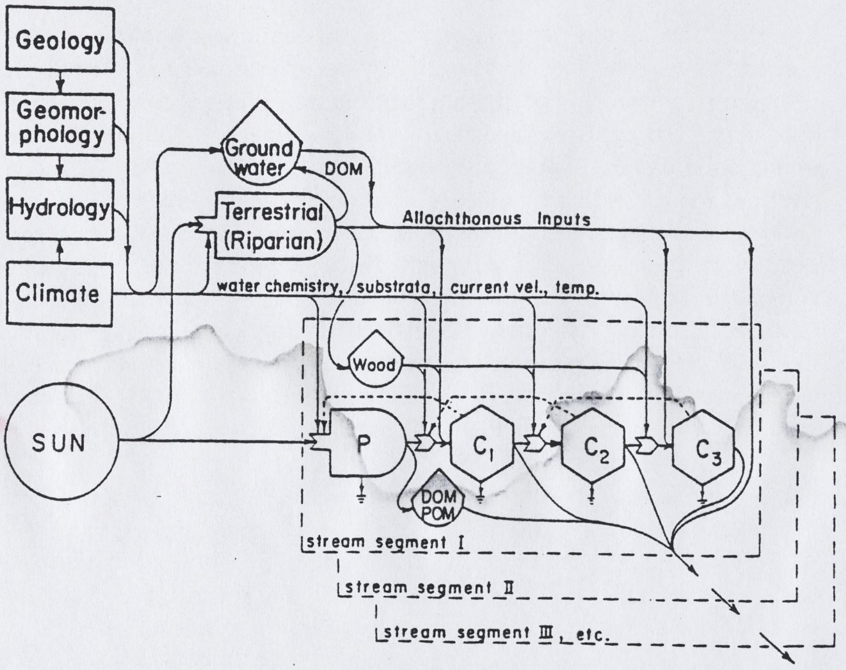


FIGURE 5.4. Energetics of successive segments of a stream ecosystem (from Benke et al. 1988). Solar energy provides energy for primary production in both the terrestrial ecosystem and the stream. Climate, geology, geomorphology, and hydrology have interdependencies, and all directly affect both the terrestrial and stream systems. The terrestrial system, with indirect input through the groundwater, provides allochthonous resources for the stream consumers, including important substrata (wood) and food (leaf litter, DOM, organisms). P = primary producer module. C_1, C_2, C_3 = consumer modules. Symbols after Odum (1983). Solid arrows are energy flows or energy regulators. Dashed lines are biotic feedback regulators.

Human Disturbances and Loss of Ecological Connectivity

How much disturbance can occur in a catchment before ecosystem resilience (i.e., the ability to recover from disturbance, Odum et al. 1979) is exceeded and ecosystem structure and function are permanently altered (Yount and Niemi 1990)? How much is attributable to natural interannual variation? That such questions were articulated years ago but remain largely unanswered is, of course, problematic for researchers and especially for managers attempting cumulative impact assessments at the catchment level.

We have argued (Ward and Stanford 1983*b*) that natural interannual variation in catchments is encompassed by Connell's (1978) intermediate disturbance hypothesis. Connell suggested that biodiversity is maximized by

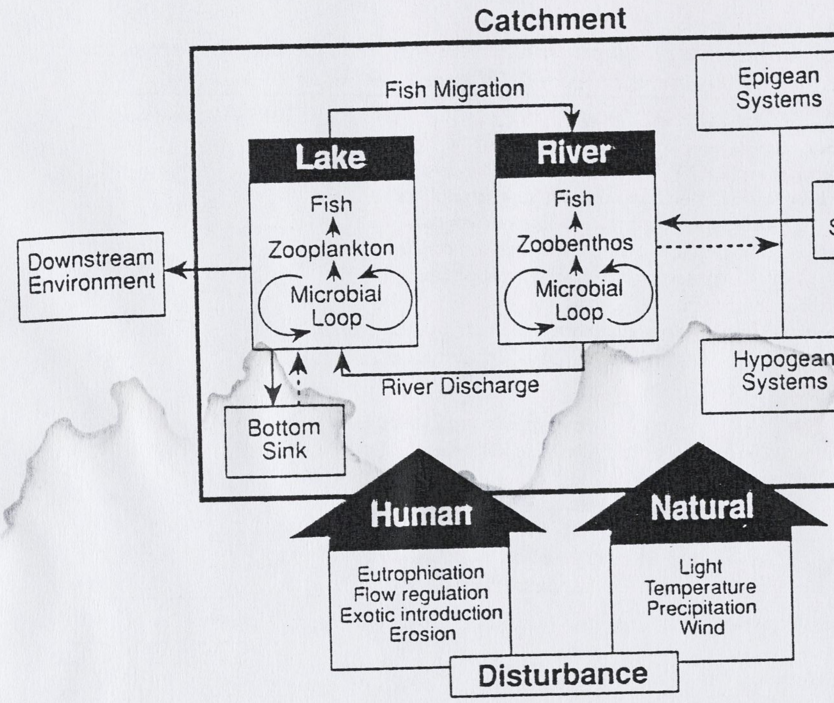


FIGURE 5.5. Ecological connectivity of the Flathead River-Lake ecosystem.

ecosystems that are "adapted" to disturbance events of intermediate intensity and duration. Intermediate might be loosely quantified in catchment terms as less than a 100 year flood event and more dynamic than constant flow, for example, from a spring or a storage reservoir. In other words, it is intuitive that a most probable state of quasi-equilibrium can be maintained by natural, intermediate disturbances until the occurrence of a major disturbance event on the scale of a volcanic eruption or hurricane. Events of that magnitude can completely restructure ecosystems. However, recovery is more rapid than once thought (e.g., recovery of streams following the 1980 eruption of Mount St. Helens in the Cascade Range, USA, is occurring decades sooner than expected).

In many ways the idea of natural disturbance controls on stream ecosystem structure and function—however intuitive—remains hypothetical for lack of long-term data to test inferences. Indeed, the National Science Foundation decided nearly a decade ago to support long-term ecological research (LTER) at a variety of sites in different biomes so that accurate data describing interannual variation and ecosystem responses to environmental change could be evaluated quantitatively. The objective was to initiate work on hypotheses requiring data sets of five years or more and, at the same time, set up a

Table 5.1. Some pervasive human disturbances that uncouple important ecological processes linking ecosystem components in large river basins.

STREAM REGULATION BY DAMS, DIVERSIONS, AND REVETMENTS: *uncouples longitudinal, lateral, and vertical dimensions*
Lotic reaches replaced by reservoirs: loss of up-downstream continuity, migration barrier, flood and nutrient sink, stimulates biophysical constancy in downstream environments
Channel reconfiguration and simplification: loss of lateral connections, removal of woody debris, isolation of riparian and hyporheic components of floodplains
Transcatchment water diversion: abnormal coupling of catchments, dewatering of channels, immigration of exotic species, import of pollutants
WATER POLLUTION: *alters flux rates of materials, uncouples food webs*
Deposition of pollutants from airshed into catchment: eutrophication, acidification
Direct and diffuse sources of waterborne waste materials from catchment: toxic responses, eutrophication
Accelerated erosion related to deforestation and roading: sedimentation of stream bottoms, eutrophication
FOOD WEB MANIPULATIONS: *induces strong interactions that alter food webs*
Harvest of fishes and invertebrates: biomass and bioproduction shifts
Introduction of exotic species: cascading trophic effects

network of sites where basic biophysical data would be systematically gathered for decades (Likens 1989, Franklin et al. 1990). These studies have already greatly contributed to understanding ecosystem connectivity, although data are not yet of sufficient scope to resolve many of the landscape- and patch- specific hypotheses proposed in the LTER program (Swanson and Sparks 1990). Moreover, these data are very site specific and tied to falsification of hypotheses that are clearly of great scientific importance but may be rather narrow in scope from the point of view of many managers.

Even though the scientific community has a long way to go before ecosystem response to natural environmental changes is fully understood, the human disturbances of catchments are often more extreme than natural events in frequency, intensity, and duration. In case after case, ecosystems in the catchment sense presented herein have been essentially uncoupled by the cumulative impacts and interactions of human disturbances (Table 5.1) (see also Ward and Stanford 1989). Perhaps the most pervasive disturbance is encompassed by the combined effects of channelization, revetment, and harvest of riparian timber within major river corridors. It has often been written that we may never know the true nature of channel-floodplain connectivity of large (> eighth order) rivers in the temperate latitudes because cultural development of the industrial nations was so dependent on these rivers as commercial waterways and because the attendant effects were so ecologically devastating (cf. Regier et al. 1989). In most, if not all cases, precious little information about the connectivity of these large rivers was recorded before major human disturbances took place. However, several carefully researched case histories provide insightful syntheses of the interactive effects of human and natural disturbances on the ecology of river systems (reviewed in Davies and Walker 1986).

Rather than attempt to summarize the important inferences of these and many other studies chronicling human disturbance in catchments, we present below a single case history of a large catchment that retains numerous pristine attributes but is threatened by a variety of interactive effects. In this case an ecosystem-level understanding might be very productive in fostering a new management ethic. The goal is to sustain the natural ecological connectivity of the system. We use this example to set the stage for articulation of some new approaches to that goal that may be useful elsewhere.

A Case History of Interactive Effects on Ecosystem Connectivity

Background

The Flathead River-Lake ecosystem in northwestern Montana provides a good example of a tightly coupled system where natural and human disturbances are clearly interactive. Understanding of this catchment is based on ecological studies by scientists at the Flathead Lake Biological Station (a field station of the University of Montana), where biophysical data have been routinely collected since 1896, and a wide variety of management-oriented research has been conducted by tribal, state, and federal agencies (reviewed by Stanford and Hauer 1992). Salient points are summarized here.

This 22,000 km^2 catchment is dominated by runoff from the myriad tributaries that feed the sixth-order Flathead River (mean annual discharge = 340 m^3/s), which flows through 496 km^2 Flathead Lake (Figure 5.3). Water quality in this river-lake system is extremely good; solute concentrations and bioproduction are uniformly low (oligotrophic); waters are usually highly transparent (Secchi disc readings in Flathead Lake routinely exceed 15 m autumn and winter); and native fisheries are healthy. Fewer than 80,000 people reside in the entire catchment, and no major industrial or agricultural sources of pollution currently exist. The Flathead River dominates the inflow of solutes and particulate materials that influence water quality, structure food webs, and drive bioproduction in the lake. For example, the river provides 65% of the annual load of bioavailable phosphorus reaching the lake. Six of the ten native fishes in the lake are adfluvial; that is, they reside in the lake but migrate upstream into tributaries to spawn (cf. bull charr in Figure 5.3). Hence the fishes constitute an upstream feedback loop and enhance the ecological connectivity of the ecosystem (Figure 5.5).

Ecological connectivity of the Flathead system is of course maintained in a quasi-equilibrium status by natural disturbance events (Figure 5.5). For example, the catchment is naturally disturbed by floods. Catchment hydrology is annually dominated by spring snowmelt, and in that sense the hydrograph is very predictable. But the magnitude of the spring spate is highly unpredictable, based on a 90 year period of record. Climatic events alternately juxtapose either continental (cold, dry) or Pacific maritime (warm, wet) air masses over the catchment, determining precipitation patterns. Infrequently and under the extreme moisture conditions in the Pacific front, the two air masses collide directly over the catchment, resulting in intense precipitation. Intermediate levels (10–20 x mean annual flow) of flooding occur on about a 10 year return pattern and almost always during spring; but high magnitude (20–50 x mean annual flow) floods have occurred 17 times during the historical record. The timing and duration of high magnitude floods and other extreme climatic events (Figure 5.5) are stochastic. Another example concerns the occurrence of wildfires caused by lightning strikes during dry periods. Mosaics of successional stages in forest stands characterize the uplands of the catchment as a result of these randomly distributed burns over many decades. Thus natural disturbance is a fundamental feature of this ecosystem and, coupled with the zoogeographic history of the area, is responsible for the generally high biodiversity of plants and animals by preventing dominance by a few species.

However, four generalized classes of human perturbations clearly have affected the natural attributes of this catchment: (1) stream regulation, (2) eutrophication, (3) food web manipulation, and (4) erosion (Figure 5.5). While localized effects may vary and the magnitude of the impacts has not been so severe as to completely compromise ecosystem connectivity, anthropogenic disturbances have degraded natural structure and function.

Stream Regulation

Two large hydroelectric and flood control dams partly regulate flows in the mainstem river and volume in Flathead Lake (Figure 5.3). The spring flood pulse of the Flathead River is predominantly stored behind these dams and discharged during the baseflow period. Owing to the presence of a natural bedrock sill at the outlet, the backshore of Flathead Lake historically was inundated up to about 882.5 m above sea level (masl) during the spring spate; however, the lake returned to base level (878.8 masl) by mid-July. Kerr Dam was built downstream from the sill in 1937 and extends the full pool (881.8 masl) period into late October to facilitate hydropower production. Hungry Horse Reservoir was first filled in 1953 and stores runoff from the entire South Fork subcatchment. Hydropower operations currently cause both flow and temperature problems in the river segments downstream from the dams. The varial zone of the river channel (Figure 5.1) is alternately inundated and dewatered by fluctuating flows related to power production below the dams. As a consequence, the varial zone is quite large and is essentially devoid of aquatic biota. Sluicing of the substratum by clear water flows has removed the smaller particles, leaving larger rocks and cobblestones firmly implanted on the river bottom (a phenomenon of regulated rivers known as armoring; Simons 1979). Capture of flood flows has partly or totally eliminated the natural fluvial disturbances on the floodplains of regulated river segments, thereby allowing senescence or other alteration of riparian plant communities. Since Hungry Horse Dam discharges from the bottom of the reservoir, nutrient concentrations are elevated relative to the free-flowing river segments, and algal mats coat the armored substratum in the minimum flow channel below the varial zone. Stream regulation has reduced the biodiversity in the dam tailwaters by about 80%. Spawning, juvenile recruitment, and growth of resident and adfluvial fishes have also been seriously compromised by extension of the varial zone in both regulated river segments; and cold (5–8°C) summer temperatures in the effluent water from Hungry Horse Reservoir compound the problem in the mainstem river upstream from Flathead Lake (Stanford and Hauer 1992).

Eutrophication

Plant growth in most of the lakes and streams of the Flathead catchment is limited by a general lack of labile nutrients. Most of the waters appear to be phosphorus limited or co-limited by paucity of both nitrogen and phosphorus (Dodds and Priscu 1989). Many alpine and subalpine lakes contain no measurable soluble reactive phosphorus and <20 mg/L nitrate, owing to the lack of these minerals in the Precambrian argillites that dominate the bedrock of much of the catchment. Therefore, bioproduction in these waters is very low (Stanford and Ellis 1988, Stanford and Prescott 1988).

Consequently, abnormally accelerated algal production associated with anthropogenic nutrient enrichment (i.e., eutrophication) is a primary concern, particularly as it relates to degradation of the high quality water in Flathead Lake. Of the total bioavailable phosphorus load entering Flathead Lake annually, 17% is derived from sewage treatment plants in the catchment and 30% is atmospheric deposition. Smoke from homes heated with wood burning stoves and from slash burning may be the primary source of labile phosphorus measured in bulk precipitation samples. In 1983 a lakewide bloom of the noxious blue-green alga *Anabaena flos-aqua* occurred for the first time in Flathead Lake since records began in 1902. The bloom was not severe and it has not recurred, but it did suggest that conditions were near a threshold beyond which major changes in the autotrophic community of the lake might be expected. Recent nutrient bioassays and analyses of long-term mass balance data have supported this inference (Stanford et al. 1983, 1990).

Food Web Manipulation

Since the turn of the century, 17 fish and 2 crustacean species have been purposely introduced into the Flathead catchment, primarily by fishery managers. Most fishes and both crustaceans established viable populations and gradually immigrated widely within the catchment. Today only a very few lakes in Glacier National Park have entirely native food webs, because of their remote localities and the presence of cascades, falls, or other migration barriers that prevented invasion by nonnative species from waters downstream.

These introductions had major impacts on native populations and dramatically restructured food webs in the lakes and streams throughout the catchment. Often effects cascaded through the food webs in ways that were unanticipated and sometimes involved both terrestrial and aquatic species.

For example, the kokanee salmon (*Oncorhynchus nerka*) fishery has undergone extreme fluctuations since the species was introduced into Flathead Lake in 1916. The population expanded rapidly and gradually replaced the native cutthroat trout as the dominant planktivore. Adfluvial kokanee from Flathead Lake spawned primarily in the outlet of McDonald Lake in Glacier National Park (Figure 5.3), where they attracted large numbers of migratory bald eagles (*Haliaeetus leucocephalus*). When the kokanee spawners were abundant (>150,000), so were eagles (>700).

In 1981 the nonnative crustacean *Mysis relicta* immigrated to Flathead Lake from intentional plants made in lakes upstream. Within six years, numbers exceeded 125/m^2. *Mysis* feed on zooplankton near the lake surface at night and rest on the lake bottom during the day. They have reduced zooplankton biomass in the lake by almost an order of magnitude. Kokanee are also dependent on zooplankton, but they prefer to stay near the lake surface, perhaps to avoid predation by piscivorous lake trout (*Salvelinus namaycush*, a nonnative species) and native bull charr. Thus *Mysis* created a trophic restriction for kokanee, and the fishery collapsed in 1987–88. Since 1989, only incidental kokanee spawners have been observed in McDonald Creek and the bald eagles have dispersed elsewhere (Spencer et al. 1991).

Erosion

Soil and other mineral substrata are naturally eroded by fluvial processes within the Flathead catchment, as in all river basins. Owing to the porous nature of the bedrock substrata and extensive tills of glacial origin, very little overland or sheet flow occurs except during extreme precipitation events or during periods of intensely accelerated snowmelt. Streams originate primarily as springbrooks fed by waters that percolate into substrata from precipitation at higher altitudes. Springbrooks coalesce to form the drainage network of the catchment. Therefore, most of the sediment loads carried by the streams and rivers are derived from erosion of stream channels and banks.

The rate of erosion is determined by channel morphology, slope, relative erosiveness of streambank substrata, and the intensity and duration of spates. Most of the sediment load in the system is derived from Tertiary shales deposited as valley fill and Quaternary tills and alluvium. These soils contain nitrogen and phosphorus either within the organic debris or associated with the clay lattice of the mineral particles. Therefore, as much as 60% of the annual riverine nutrient load of the Flathead River may be associated with sediment particles that are transported for short periods, most years during spring runoff, when the rivers and streams of the catchment are flooding. Only about 10% of the nutrients associated with particles can be assimilated by the biota (i.e., only about 10% of the particulate phosphorus is labile or bioavailable; Ellis and Stanford 1986, 1988), and much of the load is deposited either on the river floodplain or into the lakes as a short-term pulse event. In spite of the low nutrient bioavailability, the fertilization effect of the particulates eroded and transported by fluvial processes is significant owing to (1) the oligotrophic nature of the water bodies and (2) the dominance of the hydrograph and nutrient mass balance of both rivers and lakes in the catchment by spring runoff.

Clearly, erosion is a natural process that both shapes the catchment landscape and to some extent fertilizes patches within the landscape. Natural (e.g., lightning-caused fire, insect epidemics, beaver [*Castor canadensis*] and other large herbivore influences) and human (e.g., road building, clear-cutting) deforestation increases the seasonal and annual variation in water yield, particularly during spring snowmelt (Hauer and Blum 1991), thereby accelerating erosion of streambanks and increasing sediment loads. Erosion of road surfaces and berms or stream crossings is of particular concern, because unstable roads are known to be major sources of fine particles in some streams in the Flathead catchment, as elsewhere (see Megahan et al., this volume). Accelerated erosion, locally associated with logging and road building, has increased the volume of fine particles within the channel of disturbed streams, clogging interstices and reducing interflow and aeration of the substratum. Speciosity and biomass of zoobenthos may be reduced by 80% in highly sedimented areas compared with adjacent cobble substratum (Spies 1986), and survival of bull charr eggs and juveniles decreases markedly when fines (particles <6.35 mm) exceed 40% of the substratum volume (Weaver and Fraley 1991). Moreover, recent work has shown a clear correlation between sedimentation rates in on-channel lakes and road building activities in the McDonald and Whitefish subcatchments (Spencer 1991). Inflowing riverine sediments apparently fertilize the water column of Flathead Lake in the spring, based on the observation that phytoplankton productivity is highest in years of high runoff and high sediment loading from the catchment (J. Stanford and B. Ellis, unpublished); however, the sediment load has not been apportioned in terms of natural versus human disturbances.

Interactions Between Natural and Human Disturbances: Management Considerations

Many different management jurisdictions exist within the Flathead River Basin. Seventy-two percent of the basin is federally administered, involving the Flathead National Forest (U.S. Department of Agriculture), Glacier National Park (National Park Service), national wildlife refuges (U.S. Fish and Wildlife Service), and the Flathead Indian Reservation trust lands (U.S. Bureau of Indian Affairs). Large areas of state and tribal (Confederated Salish and Kootenai Tribes of the Flathead Indian Reservation) lands exist, with the remainder of the basin primarily in privately held tracts. Hungry Horse Dam is a federal project operated by the U.S. Bureau of Reclamation. Kerr Dam is located within the Flathead Indian Reservation and operated by a private corporation, Montana Power Company, Inc., on the basis of a rental agreement with the Tribes as mandated by the Federal Energy Regulatory Commission. Many other federal, state, and local agencies have statutory authority to manage specific resources in the catchment. Since the headwaters of the North Fork are in British Columbia (Figure 5.3), many provincial and Canadian federal agencies are involved. For example, the authority of the International Joint Commission (organized under the U.S.-Canada Boundary Waters Treaty of 1909) was invoked during 1986–88 to quantify and reference the potential impacts of a large open-pit coal mine (International Joint Commission 1988) proposed by a Canadian subsidiary of an American corporation in Canada (Figure 5.3). This maze of management jurisdictions and associated interactions between natural and human disturbances complicates resource management within the ecosystem.

The threat of deteriorating water quality in Flathead Lake from urban sewage, the proposed Canadian coal mine, and burgeoning road building and clearcutting on federal and private forest lands stimulated management actions designed to implement conservation of natural conditions in the tributaries and to reduce nutrient loading in the lake by about 20% (i.e., to near natural conditions). Actions included a ban on the sale of phosphorus-containing detergents (mandated by the Montana state legislature), construction of new sewage treatment plants to allow phosphorus and nitrogen removal from all urban effluents in the catchment, and voluntary imposition of best management practices (BMPs) to reduce nonpoint sources of nutrients, especially those associated with accelerated erosion in the catchment (mandated by the State Water Quality Bureau, which has statutory authority to enforce water quality laws).

During 1983–90, annual nutrient loads into the lake decreased (least squares regression, $P<0.1$, J. Stanford and B. Ellis, unpublished); and, as noted above, *Anabaena* blooms did not recur. This, of course, suggested that initial management actions were successful. However, construction of a new sewage treatment plant for Kalispell, Montana, which has been the largest point source of bioavailable nutrients in the past, is not yet complete. Moreover, very little, if any, of the reduced nutrient load can currently be related to voluntary BMPs, because their utility in improving water quality has not been quantified empirically in the Flathead Basin. The apparent reduction in nutrient loading and lack of recurring *Anabaena* blooms may be due to at least three other interactive linkages.

First, catchment precipitation has been below average since 1983. Natural loading rates of water and nutrients have been generally lower on an annual basis than occurred earlier in the period of record. However, average concentrations in the river did not change significantly.

Second, operations at Hungry Horse Dam changed from primarily midwinter to summer and fall discharges, in response to economic considerations for hydropower production as related to demands for higher summer flows in the lower Columbia River to more effectively flush smolts of anadromous salmon out to sea (discussed below). Owing to thermal stratification in the reservoir and the hypolimnial (bottom) release mode of the dam, the high volume water masses from Hungry Horse Reservoir are cold (4–7°C) and dense relative to ambient temperatures (unregulated, natural) in the river below the dam and within the epilimnion (surface) of Flathead Lake, which is also thermally stratified in the summer (22°C surface, 4° bottom). Thus summer discharges from Hungry Horse Dam essentially dilute the pollutants entering from the urban and argricultural areas in the Kalispell Valley. Moreover, these cold waters and the nutrient load immediately sink to the lake bottom (underflow) upon entry into Flathead Lake. Since the lake is maintained at full pool during the summer for ease of access by boaters, Kerr Dam must discharge water volumes equal to the inflowing volumes. But Kerr Dam releases water from the surface layers of the lake, owing to its location below the natural outlet sill. The net effect on the limnology of the lake appears to be (1) a significant reduction in the heat budget, (2) cooler surface temperatures during the plant growing season, (3) stripping of plankton and nutrients from the surface by the Kerr withdrawal current, and (4) deposition of a large portion of the summer and fall nutrient load far below the upper portion of the water column that is penetrated by sunlight. Therefore, conditions favorable for sustained algal biomass, especially forms like *Anabaena*, in the epilimnion of the lake may have been compromised by hydropower operations.

Third, food web shifts caused by the collapse of the kokanee fishery may have influenced grazing rates on the algae. Owing to intense predation by *Mysis*, zooplankton biomass decreased almost an order of magnitude in the peak *Mysis* years, 1987–88, compared with pre-*Mysis* measures. During 1988–90, *Mysis* numbers decreased from 125/m^2 in 1987 to 30/m^2 in 1989 (Spencer et al. 1991) and 35/m^2 in 1990 (Spencer 1991), owing to predation by bottom-oriented fishes (whitefishes [*Coregonus* spp.], lake trout, and bull charr). Phytoplankton primary production was the highest on record in 1988 and decreased during 1989–91 in concert with declining *Mysis* numbers. At the same time, cladoceran zooplankton have recovered during periods of thermal stratification. Apparently, large numbers of *Mysis* do not penetrate the thermocline and enter the epilimnion during summer. This thermal refugia from *Mysis* and the lack of kokanee or other surface-dwelling planktivores apparently allowed *Daphnia thorata* to increase, and the inference is that grazing on phytoplankton has also increased (Stanford et al. 1990). These interpretations are based on preliminary analyses of long-term trends in the various data bases for Flathead Lake. Our main point here is simply to reinforce by example the idea that food web dynamics in lakes can be strongly interactive in response to both bottom-up (nutrient supply) and top-down (*Mysis* introduction) effects (see also Carpenter 1988).

Interactions between dam operations, natural circulation patterns, and shoreline erosion in Flathead Lake are also noteworthy. It is exceedingly difficult to move large water masses through Flathead Lake while also maintaining it at full pool elevation. Often the lake exceeds the full pool owing to lack of coordination between the dams coupled with the complexities of wind and temperature-driven internal circulation events and patterns. Flathead Lake is an extremely large, deep lake and therefore its hydrodynamics are profoundly influenced by Coriolis and density currents and circulation patterns in addition to volume regulation by the dams. The lake has a 30 km wind fetch on the long axis, and storms and shoreline erosion rates exceed 2 m per year (lineal cross section) at the north end of the lake where the shoreline is dominated by deltaic sand substratum. Surface and internal seiches are common after storms and may influence the pattern of sediment transport from eroding shorelines. As a consequence of these natural (wind) and human (lake level regulation) disturbances, the 970 ha depositional delta of the Flathead River has entirely eroded into the lake within the last 50 years; littoral and riparian communities of the lakeshore have also been vastly altered, if not partly uncoupled from processes in the main (pelagic) part of the lake (Bauman 1988, Hauer et al. 1988, Lorang et al. 1992).

The negative effects of both Kerr and Hungry Horse operations have been carefully documented (see review by Stanford and Hauer 1992), and a mitigation plan for hydropower impacts (e.g., fluctuating flows and lake levels, temperature changes, migration barriers, habitat and production losses, accelerated lakeshore erosion) on fish and wildlife resources has been proposed to regulatory authorities. In this case, two different regulatory authorities exist. The Federal Energy Regulatory Commission is currently considering a plan related to Kerr Dam, since it is operated by private concerns. Owing to Hungry Horse Dam's operation by a federal agency, mitigation of impacts falls under the mandate of the Northwest Power Planning Act of 1984 for the entire Columbia River Basin, which involves the Northwest Power Planning Council (planning) and the Bonneville Power Administration (research and implementation). The mitigation plans were jointly developed by the state (Montana Department of Fish, Wildlife and Parks), the tribes, and the entities that operate the dams, with input from university scientists and other agency biologists. Proposed actions include: retrofitting Hungry Horse Dam to allow selective withdrawal to facilitate more natural temperature regime downstream; construction of re-regulation dams or operational changes to moderate flow fluctuations from Hungry Horse and Kerr dams; reducing the full-pool level of Flathead Lake to reduce shoreline erosion; revetment of some shorelines to curtail erosion and enhance wetland development for waterfowl; habitat restoration in damaged fish and wildlife production areas; and hatchery supplementation of fishes as replacement for losses associated with hydropower operations at both dams (Fraley et al. 1989, Fraley et al. 1991, Jourdonnais et al. 1990, Stanford and Hauer 1992).

Differences of opinion remain as to whether the various mitigation actions are appropriate or whether they will work as proposed, primarily because the statutory authorities of the two processes are independent and mandate solution of impacts on fish and wildlife without in-depth consideration of other ecosystem interactions, such as influences on timing and magnitude of nutrient loads and connectivity between riverine processes and food web dynamics (Stanford and Hauer 1992). However, the pervasive effects of stream and lake regulation were thoroughly documented and an interagency consultation and public information transfer was effective. This was fostered by forums coordinated by a public information and oversight group called the Flathead Basin Commission. This commission was legislated by the state to bring together agency heads and informed citizens in a manner that stimulated interagency cooperation to fund research, effectively monitor ecosystem indicators (e.g., catchmentwide water quality and population dynamics of important indicator organisms, like the bull charr), and facilitate interactive discussion of results and proposed management actions in a nonstatutory fashion.

The natural ecological connectivity of the Flathead catchment remains largely intact. It is a high priority area for conservation and effective resource management, since large areas are designated as national parks, wildlife refuges, wilderness areas, and tribal lands. Environmental problems exist but they have been quantified, articulated, and periodically reassessed in the process of understanding how this large catchment is influenced by natural and human disturbances. More information is needed, but the presence of a legislated commission to coordinate monitoring of ecosystem conditions by the many different management agencies has proved to be an effective and empirically based forum for considering and implementing alternative actions to protect and enhance ecological connectivity in this large catchment.

Interference Management and the Illusion of Technique

The Flathead experience illustrates the travail of contemporary resource management. Interactive and cumulative effects become seemingly intractable in large and ecologically complex catchments. Managers often want simplistic methodology that will explicitly satisfy an increasingly circumspect public. Unfortunately, in the absence of practical and conceptual understanding of ecosystem structure and function, management actions often produce results significantly different from what was expected. Usually this happens because management questions are not posed in an ecosystem (whole-catchment) context and actions evolve as interferences with the natural ecosystem connectivity. The introduction of *Mysis* as a forage stimulus for sport fishes in a very tightly coupled system interfered with the quasi-equilibrium of the Flathead Lake food web and produced a trophic cascade that ultimately displaced a critically important population of bald eagles.

On a larger scale, influences far downstream may have unanticipated effects on the operations of the two large dams in the catchment. In particular, we are concerned that efforts to increase the runs of Pacific salmon and steelhead downstream in the middle and lower reaches of the Columbia River may interfere with mitigation efforts in the Flathead Basin and other headwater reaches that, because of natural barriers, never contained anadromous fishes. The plight of the anadromous salmonid fishery involves overharvest, continually increasing dominance of runs by cultured stocks (apparently at the expense of naturally reproducing runs, owing to genetic introgression and increased harvest), predation of wild and cultured smolts by resident fishes, highly variable oceanic survival, and passage problems created by the nine mainstem dams (Ebel et al. 1989). Prominent in this discussion is the fact that early summer flood crest of the Columbia River has been eliminated by storage of the spring spate in four large reservoirs (Hungry Horse, Dworshak, Libby, and Mica) in the headwaters. Historically, the flood pulse of the river not only flushed smolts along on their outmigration, it also stimulated bioproduction in the estuarine food web which sustained the fisheries (Simenstad et al., this volume). Recovery plans for the fisheries call for a water budget for the river that mandates "fish flows" that will very likely interact with the economics of hydropower production and the need for flood control in a manner that will introduce a large measure of uncertainty in operations of the headwater dams. Unless the needs of resident fishes directly influenced by these dams have equal priority with downstream objectives, mitigation of resident fish and wildlife in the headwater segments may be compromised by actions for anadromous fishes.

A related problem is the tendency of today's managers to use a standardized methodology that often relies on little or no empirical data, or data that have little or no predictive power at the ecosystem level. Because of the natural complexities of river ecosystems, the intractability of cumulative effects in large catchments, and the cost of long-term data acquisition, managers too often tend to seek simple answers to complex problems. Often this involves nothing more than a formalization and synthesis of "best professional judgment" with no ecological rationale that is empirically based.

For example, one approach in current vogue is to assemble groups of professional hydrologists, biologists, engineers, silviculturists, and foresters to assess or "audit" forest practices (BMPs) as they relate to observed, but not empirically quantified, impacts on water quality. Specific sites are visited, and each person simply provides his or her qualitative judgment as to whether the logging activity has had any impact on the streams draining the area. Again, audit values are apportioned among BMPs on an areal basis and summed up to allow inferences about levels of disturbance to be drawn (Ehinger and Potts 1990).

In the Rocky Mountains and Pacific Northwest, including the Flathead, another popular approach for assessing the impacts of forestry on water and sediment yield is to assemble a series of impact or "risk" values and recovery rates for various land disturbance activities (e.g., roads, skid trails, site preparation, logging method). These values are then apportioned on an areal basis for the catchment and summed to provide a measure of cumulative effects (Klock 1984, United States Forest Service 1988, Coboum 1989). This approach can be greatly improved when formalized as a true risk analysis (Cairns and Orvos 1990) or Markovian simulation, in which the impact values are based on catchment-specific experiments and the results are expressed in terms of specific forest dynamics such as the mass transfer of water, sediment, or nutrients (Pastor and Johnston, this volume).

Unfortunately, subjective methods or model results are often never verified in terms of actual impact measured *in situ* (e.g., increase in fine sediments, decrease in fish production), and inferences and recommendations can be misleading to those seriously interested in minimizing negative instream effects associated with anthropogenic land disturbances. Clearly, these methods will identify pervasive effects, such as severe sedimentation resulting from roads collapsed into streams or skid crossings that are not bridged. But it is virtually impossible to detect chronic effects (e.g., accelerated water yield and bank erosion, slow reduction in woody debris accumulation, changes in water chemistry and bioproduction, fish habitat alteration) via nonempirical audits. The value of the judgment is lost in formalization of the approach unless the audit result can be verified by temporal and spatial ecological measures obtained within appropriate experimental designs.

Too often standardized techniques or mathematical models are used to evaluate impacts when they have little or no predictive power in terms of ecosystem connectivity. This amounts to an "illusion of technique" (R. Behnke, Colorado State University, unpublished).

A prime example of the illusion of technique is the very popular incremental method (IFIM) that is recommended by the U.S. Fish and Wildlife Service to determine minimum flows to protect fisheries from the effects of stream regulation. The method is based on field surveys that determine the area of the varial zone that is inundated at different instream volumes (i.e., wetted usable area, WUA), along with other physical habitat components (e.g., velocities). These data are then used to drive a sophisticated simulation model involving target species and different flow scenarios to determine minimum flows required to sustain fisheries (Nestler et al. 1989). The model does nothing more than predict physical habitat availability for various life stages of specific fishes, and in some cases it does not appear to do that very well, among other problems (Mathur et al. 1985, Orth and Maughan 1982, Scott and Shirvell 1987, Shirvell 1989, Gan and McMahon 1990). However, the IFIM clearly is a refined and standardized technique and its use has in some instances prevented chronic dewatering of rivers. Our point is that this and other models are not responsive to processes that ultimately determine variability of bioproduction and other important aspects of ecosystem connectivity (Figures 5.4 and 5.5). In spite of warnings to the contrary by the authors of IFIM (and other standardized approaches), the illusion for naive users in this case is that WUA is deterministic, when in fact complex interactions of abiotic and biotic components of a river are naturally stochastic. This is precisely why the ecosystem exists in a quasi-equilibrium state. Naive managers and administrators easily confuse quantification, objectivity, and sophistication with biological reality, and such illusions should not be fostered (R. Behnke, Colorado State University, unpublished; Lee, this volume).

A more rationale approach is to recognize and appreciate the complexities of river catchments and utilize standardized tools and models in the limited sense for which they were designed. It is not likely that any model or other deterministic construct will ever accurately predict ecosystem structure and function at the catchment scale. But model building is one very effective way to plan and articulate the need for collection of long-term ecological data that will ultimately explain observed variability caused by natural and human disturbances. In almost all assessments of cumulative impacts at the catchment level, long-term empirical data describing ecosystem structure and function are required as baselines to firmly quantify environmental change.

Integrated Management

In this age of desktop computer power and electronic communication, it is paradoxical that interference management should occur. However, as communication power has burgeoned, so have agency bureaucracies. For example, the Bureau of Reclamation has run out of dam sites and is now attempting to add supervision of fish and wildlife resources of western rivers to its official mandate (our observation). Indeed, we think that many state and federal agencies are purposely fostering an insular approach to resource management. Each wants to do ecological research, develop and follow standardized management criteria and procedures for ecological resources, and, most important, minimize influence of other agencies. Local and regional fragmentation of management authority is guaranteed to result in interference management, which in turn fragments catchment ecosystems.

The structure and function of catchment ecosystems and the cumulative effects of human disturbances are in fact intractable without an integrated analysis based on long-term data (Magnuson 1990). No single agency can effectively deal with the plethora of management/research problems on a large catchment scale. Yet the bureaucracies and their individual mandates are firmly entrenched, as are the public groups that are increasingly sensitized by the negative effects of interference management and the illusion of technique.

What should be done? If human disturbances are to be managed for the purpose of maintaining natural ecological connectivity at the catchment scale, management agencies must cooperate to minimize interferences. Cooperation is needed for collection of long-term data that will allow BMPs and other management actions to be quantified and adjusted before they interfere with each other. That level of cooperation requires effective information transfer, continual education, and independent coordination.

State-of-the-art ecology almost always originates from research at the university level or in agency research centers closely allied with universities. Although university-based research is also often very insular, we note a recent trend toward interdisciplinary work at the ecosystem level. The long-term research initiatives of the National Science Foundation described above have greatly fostered this trend. It may therefore be expected that university research will provide guidance for a new integrated management ethic.

However, we note three fundamental problems. First, creative research is currently compromised by dwindling funding at the national level and particularly at the state level. Part of the problem is rooted in the growing tendency of agencies to attempt their own basic and applied research in opposition to cooperatives with universities. Second, we perceive a growing gulf between agencies and universities because it is often university scientists who point out flaws and interferences in agency management actions (see also Marston, this volume). Third, universities are not currently producing management specialists in the natural resource arena who are astutely attuned to ecosystem connectivity. Graduates are trained primarily to do basic research, and in most cases that training is highly specialized. We should not be surprised that agencies are becoming insular in their approach to management. Moreover, we should not be surprised that agencies tend to attempt ecological manipulations (e.g., introductions of exotic species, hatchery supplementation of wild populations) rather than focusing management on public education and regulation of human disturbances.

Conducting research and managing resources should be distinguished as separate but complimentary activities. The successful manager must understand ecosystem connectivity and must be able to translate research findings into holistic resource management. It is also the manager's job to involve the public in the decision-making process by communicating how proposed actions relate to the whole and will thereby serve to reconnect severed interactive pathways.

Because those making high-level management decisions must (1) comprehend ecosystem connectivity at the catchment level, (2) be familiar with the relevant primary literature, (3) determine when additional problem-oriented research is needed, and (4) translate all of the above into appropriate managerial decisions while effectively communicating with the public, their proper training is indeed a formidable task. University curricula in natural resource management need to be revamped to foster an understanding of such matters as economic and environmental sustainability, cultural needs and influences, demography and political change, and conservation ethics (Marston, this volume) in addition to traditional biology and ecology. Moreover, high level management jobs (e.g., forest supervisors, park superintendents) require more rigorous training. Doctoral programs typically train either researchers or managers. We argue that to properly protect and manage our valued natural resources requires a solid grounding in research plus managerial expertise. We believe that contemporary management problems at the catchment scale are so complex that nothing less than a Ph.D. degree accompanied by a postdoctoral internship program will suffice to train conservators of ecological connectivity in river ecosystems.

This cannot be done by the universities alone. Agencies must return to the university environment for basic research and cut down wasteful duplication of space, equipment, and effort. University scientists must accommodate managers by doing innovative applied research and by providing educational forums that articulate management problems and potential solutions to students and agency personnel. Some of the cooperatives between a few universities and regional research units in the National Park Service, U.S. Forest Service, and U.S. Geological Survey have been somewhat successful in this regard. However, we envision formal cooperatives at the level of local Forest Service districts and state fish and game regional offices and involving many, if not all, research universities.

We emphasize that education and effective management of natural resource issues also must formally involve the public. Many management interferences and failures could have been avoided simply by the quality control afforded by an *a priori* public forum. A template for success in this regard is a state legislated catchment commission composed of all pertinent agency heads (e.g., forest supervisor, park superintendent, local land use planner, fish and game agency, tribal resource administrator, county commissioners) and at least an equal number of informed citizens who equitably represent the various publics (e.g., industry, agriculture, urban development, conservation). University scientists should be used as advisers or sources of basic information in analyzing and guiding the process. One fairly successful example is the Flathead Basin Commission described above.

In summary, we propose several important principles of integrated management at the catchment level.

1. *The major objective should be to conserve and enhance ecological connectivity*. Processes and disturbances within the catchment are interconnected biophysically in time and space.

2. *The key management questions should define the catchment scale*. However, for very large catchments (e.g., the Columbia River Basin) no

good formulas for success currently exist. Coordination and representation can become quickly fragmented or politicized because there are too many participants at the same table. We suggest that, if possible, the focus should be areas more the size of the Flathead catchment, as described above. The inference is that if ecosystem connectivity can be conserved in all subcatchments of very large drainage basins, the ecological integrity of the entire system should remain stable. Or, at least, an approach to problem solving in very large catchments should be forthcoming from an integration of subcatchment data and knowledge.

3. *A research and monitoring agenda should be established that will provide long-term data bases that may be used to separate variability due to natural and human disturbances (e.g., precipitation, discharge, nutrient loading, primary productivity, population trends of indicator organisms such as the bull charr in the Flathead case history).* University scientists should be utilized independently and in cooperatives with agency research and management personnel to plan monitoring programs and collect and interpret data. If planned properly, monitoring programs can be both an ongoing evaluation of BMPs and an assessment of environmental change at the catchment level. The latter may be expected to provide insights into the effects of regional or global influences on the catchment.

4. *Management actions should be examined from an ecosystem point of view.* A formal evaluation is needed of the risks that management actions portend and alternatives should be developed that can be activated if monitoring or research data suggest that interferences are manifested.

5. *A mechanism (we recommend a commission) should be provided that brings managers, researchers, and public groups into a forum for open debate.* The objective is education and information transfer before management actions are implemented.

Conclusion: Reconnecting Catchment Ecosystems

Ecology as a science has evolved into an understanding of landscapes as interconnected patches that vary in scale from a single rock in a stream to whole catchments (Gillis 1990; Naiman et al., this volume). Research is focused on processes, time frames, and disturbances that control the transfer of materials and energy through catchment landscapes. Management in this context refers to actions that limit interference of human disturbances to the extent that catchment ecosystems are sustained in a natural quasi-equilibrium.

In many catchments, human disturbance has eliminated or severely compromised natural connectivity. Catchment management in the future may logically involve reconnecting patches into landscapes. One example might be reestablishing floodplain springbrooks as functional patches (e.g., as important rearing areas for salmonids). This may involve removing revetments and allowing flood-pulse events to reconnect the channel and the floodplain

(Figure 5.2). Integrated forests, agricultural lands, and urban management can provide many other avenues to allow damaged catchment ecosystems to recover.

Threats to catchments usually manifest measurably in aquatic habitats as problems related to stream regulation, eutrophication and other forms of water pollution, food web changes, and accelerated sedimentation. These phenomena can be used as benchmarks that integrate the environmental health of the catchment if the data are gathered systematically over long periods. Analysis of trends in such data can reveal how leaky or unconnected the system may be and provide clear insights where management actions can be effective in reconnecting the system. This effort can best be accommodated by insightful, integrated management.

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In The Matter Of:

Applications A-17329 through A-17333
Department of Water Resources, Nebraska

Robert John Behnke, Ph.D.
December 19, 1995

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STATE OF NEBRASKA
DEPARTMENT OF WATER RESOURCES

In the Matter of Applications A-17329 through A-17333 for Water Appropriations for Instream Flow Filed by the Game and Parks Commission.

DEPOSITION OF ROBERT JOHN BEHNKE, Ph.D.

December 19, 1995

Pursuant to Notice taken on behalf of the Applicant at Denver International Airport, Concourse A, 8700 Pena Boulevard, Denver, Colorado at 3:25 p.m., before Sharon R. Dobson, Registered Professional Reporter and Notary Public within Colorado.

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APPEARANCES:

RODNEY M. CONFER, Attorney at Law, from the Law Firm of Knudsen, Berkheimer, Richardson & Endacott, 1000 NBC Center, Lincoln, Nebraska 68508, appearing on behalf of the Applicant.

JAMES E. DOYLE, IV, Attorney at Law, from the Law Firm of Cook & Kopf, P.C., 115 West 6th Street, Lexington, Nebraska 68850, appearing on behalf of the Objectors Coalition.

STEVEN G. SEGLIN, Attorney at Law, from the Law Firm of Crosby, Guenzel, Davis, Kessner & Kuester, 134 South 13th Street, Suite 400, Lincoln, Nebraska 68508, appearing on behalf of the Lower Platte Interests.

MARK L. LAUGHLIN, Attorney at Law, from the Law Firm of Laughlin, Peterson & Lang, 11306 Davenport Street, Omaha, Nebraska 68154, appearing on behalf of the Platter River Whooping Crane Trust.

Also present: J. Larry Hutchinson.

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WHEREUPON, the following proceedings were taken pursuant to the Nebraska Rules of Civil Procedure:

ROBERT JOHN BEHNKE, Ph.D., having been first duly sworn to state the whole truth, testified as follows:

EXAMINATION
BY MR. CONFER:

Q: State your full name, please.
A: Robert John Behnke. That's B-e-h-n-k-e.
Q: And what is your address, Dr. Behnke?
A: My home address is 3429 East Prospect Road, Fort Collins, Colorado. Zip code is 80525.
Q: Do you have a curriculum vitae that you brought with you?
A: (Deponent handing.)
Q: Dr. Behnke, you teach part-time at Colorado State University; is that correct?
A: That's right.
Q: Were you ever full-time on faculty there?
A: No. I originally came there in 1966 and was working for the U.S. Department of Interior, the Cooperative Fishery and Wildlife Unit. I was full-time then. And then since 1975 — 1974, actually, I started doing consulting work, and then continuing at CSU as

part-time professor.
Q: What percentage of your time — or how many courses do you teach at the present time?
A: I've been teaching — well, three courses in the fall semester. I'm been doing a course called conservation biology and then a fishery seminar. And then in the spring I have a course called advanced ichthyology.
Q: And what is the nature of your consulting business?
A: I do scientific editing. Most of this is translations of Russian literature that were published — John Wiley Publishing Corporation publishes English versions of foreign literature. And I do two in the field of fisheries and aquatic ecology.
Q: Do you do other consulting activities as well such as —
A: Like today.
Q: — this one? How frequently do you do these types of things?
A: Oh, I'd perhaps say — water law, you might say, involves most of my consulting for the past 20 years. Just last year I finished — I worked for maybe since the early 1980s, '81, '82 through '94 for

the Salt River project in Arizona as an adviser on instream flow issues.
Q: Have you also consulted on other instream flow matters?
A: Yes. I started, I guess, in 1975, I believe, with the Colorado River Water District which was — wanted to — they were building a hydroelectric plant in the Yampa River, and they had an endangered species problem. And I worked several years with advising the water district there.
Q: What other instream flow matters have you worked on?
A: Let me see.
Q: You can — I don't know if they're on your resume or your curriculum vitae or not.
A: Not much of the consulting work is in there. I did work for the — one of the early instream flow ones was the justice department was filing a suit for a wild and scenic river flows called the Red River in New Mexico. And that was one of the early applications of IFIM, or at least the PHABSIM part of it. And that was when I went down there and found that the model had predicted rainbow trout where — it should be dominant over every life stage over the brown trout. We found out the brown trout was completely

dominant. The only rainbow trout in the river came out of a hatchery four miles upstream. So my advice was if you ever go to court with this, you have to make it site-specific. Make sure the brown trout come out over the rainbow. And yet I remember that was one of the — I notice in Dr. Hardy's testimony pointing out the successes of IFIM. And that was one that was often published in the literature to say it was resolved because IFIM was used. And in those early years, it had what I call the illusional technique about it. But the resolution came about because it was not a very contentious issue and the stream was supplemented by groundwater flow that you couldn't really stop anyway. So it was resolved, you might say. But it really had nothing to do with the IFIM or the PHABSIM part of it, predicting the rainbow trout dominance when, indeed, the other species was completely dominant fish.
Q: Have you —
A: That's what led my — I think I developed the term the illusional technique after that experience.
Q: Have you worked on other instream flow matters other than — you've told us about a couple of them. Are there more?
A: Yes. Well, I don't know if I wrote them

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all down. I do remember five or six years ago when the EPA vetoed the Two Forks Dam project in Colorado. The — was that the — there's a law institute at the University of Colorado/Boulder that does wildlife law. It's funded by the National Wildlife Federation. They were the environmental defense fund, the Sierra Club. There was a coalition that was fighting the Two Forks. They sent, I remember, women attorneys down. They spent a day with me, and I showed them lots of data, talked to them, answered questions. And I remember that final opinion. When the veto came out, one of the official US Government positions, EPA, was that the position of the Denver water board that they could replace the trout habitat loss by the IFIM method by substituting weighted usable areas in one place or another was based on faulty or unsound science.
Q: Were you involved in that conclusion?
A: Well, yes, I spent — I might use the lawyer term called pro bono. I do pro bono work for environmental groups.
Q: You were working for the environmental group in that instance?
A: I do that. I didn't get any pay for that. I've done this quite a bit for the Sierra Club, Environmental Defense Fund.

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Q: So you've testified in —
A: I haven't testified. If it's going to cost me money, then they have to pay me money. But if it's just advice, I'll give them advice.
Q: Okay. What about other instream flow cases? Have you testified in any instream flow cases?
A: Trying to think. As an expert witness in court?
Q: Yes.
A: I think those situations had not so much to do with instream flow. Somewhat habitat related, fish growth, movement, things like that. It wasn't specifically flow related.
Q: You yourself do not use the instream flow incremental methodology; is that correct? Or do you do that?
A: No, I've never been a practitioner — when I say — you might be aware that the instream — well, it was formerly the Fish and Wildlife Service that developed the instream flow, the IFIM. They give their courses at CSU. And we can — I know most of the people involved. And we can have — we can sit in on them and learn from them. We can — our students can attend them. The only stipulation was that we have a graduate committee in our department, and it was

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actually coming from our own fish and wildlife co-op unit people, that we would not allow university credit for IFIM modeling courses. We consider that one of the vocational educations.
Q: Have you taken those courses yourself?
A: No.
Q: And that's not your area of expertise?
A: The mechanics of the course, that was Dr. Payne — or Tom Payne's expertise.
Q: Um-hum. What have you been asked to do in this case?
A: Let me see. Do we have something that would explain that? I'm not sure. I think — was it Jim Doyle? I met him here only one time before. And just what we went over, I told him what my background was mainly, you might say, in the area of theories and principals, the assumptions that underlie. You might use this. This is a course I hand out for the students in the course. You know, it's a final statement. It's what we discuss. Not the vocational, education, or the technical training aspect, but how do you understand the principals, the theories which your assumptions rest upon?
Q: So you're an expert in the scientific method apparently underlying the analyses here?

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A: I really don't — I try to avoid the use of "science," "scientific," "scientist" myself. It's simply a matter of observing patterns in nature, and then developing a hypothesis to test.
Q: Okay. Let me ask you this, Did you bring a file with you on the work that you've done on this case?
A: I've — just what I reviewed. Papers that I have — most I think you already have on record.
Q: Okay. Why don't I read these into the record.
MR. DOYLE: While you're looking, do you have your answers to interrogatories that I —
THE DEPONENT: Okay. They should be in one of these envelopes.
Q: (BY MR. CONFER) We have a November 1995 report from Chadwick Ecological Consultants, Inc., on fish monitoring studies Platte River, Nebraska, 1994. We have a letter from Mark Czaplewski dated November 30, 1995, enclosing — he's filing to FERC his May 9, 1995, "Regarding New Evidence and Comments on NPPD on
Recent Agency Filings." U.S. Department of Interior's filing to FERC dated October 17, 1995, responding to NPPD's May 9, 1995 FERC filing. Fish monitoring study, the one that we've just identified. An updated list of

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Nebraska Cooperative Conservation, parentheses, Coalition Contacts. Studies of Channel Catfish in the Lower Platte River by Peters and Holland, April 1992. Are those all the materials that have been provided to you —
A: Let's see.
Q: — by Mr. Doyle or his clients?
A: These also I've been provided.
Q: Fanin and Nelson Habitat Suitability Index Curves, dated December 3, 1986. And I identified that one.
MR. DOYLE: That's 1989 Peters study.
MR. CONFER: Yes.
Q: (BY MR. CONFER) Hardy & Associates report November 25, 1992, Instream Flow Analyses of the Central Platte River. The Nebraska Game and Parks Commission report which is Exhibit No. 1. Nebraska Game and Parks report, which is Exhibit No. 2 and which is Exhibit No. 3.
Q: Are those the materials —
A: That's all the materials —
Q: — that have been provided?
A: — Sent to me.
Q: Have you prepared some notes and so forth of your work?

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A: Very rough. No, just this very quick — they'd really have to be redone to make any sense out of them. I would go through the — this one's getting a little more coherent. I did this. I would — as I would go through these, I would jot little notes down the first time through. I think this might be the second time through here. I got to that point. But it won't make sense to anyone except me probably.
Q: I think you might be right, at least from my standpoint. Let me approach it in a different way then and ask you, first, have you done any prior work on the Platte River in Nebraska?
A: Only at Lake Ogallala, which is part of the North Platte really, I imagine. Larry would remember what the details of that were from several years ago. But it had to do with a FERC licensing, oxygen standards.
Q: Who was your client in that case? Do you recall?
A: I was sort of advisor working with Chadwick Associates there. And they were in turn working for who? Nebraska Public Power and Irrigation, NPPID, I think.
Q: Central Nebraska Power and Irrigation?
A: Yeah.

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Q: And you were a consultant for them in that case; is that correct?
A: Yes. That was mainly a — trout were the major species there. As a trout expert, I was called in to advise on that.
Q: Is that the primary area of your expertise?
A: I'm most widely recognized when the word trout comes to mind.
Q: That's what I thought. What about Platte River species? Have you worked with them in the past, or the species that are identified as being in the Platte River by Dr. Peters?
A: Most of them occur in the South Platte in Colorado. And that was my very first graduate student project when I came to Colorado in 1966. I realized that we had not a good account of the present — from a historical time to the present of what the Platte River fishes were. So that was my very first graduate student thesis project I supervised with the fishes of the South Platte of Colorado. Later another student did a Ph.D. Might have seen the reference to David Propst. Dave was in early 1980s. He did his Ph.D. and brought it — after about a 15-year period, revised it and had a lot more data at that time.

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Q: What about your familiarity with the river in Nebraska? Have you been on the river in Nebraska?
A: No. Well, on the river — I've done no personal collecting. I just remember years ago I had come out here and we toured some of the Platte River. I think it was mainly the North Platte. Monty Madson and some of the fellows showed us around some of the projects that were going on there.
Q: Have you — are you familiar with the Platte River below Lake McConaughy, for example?
A: That's North Platte below McConaughy and it joins at — North Platte, Nebraska is where the two come together to form the Platte.
Q: Um-hum.
A: What I had familiarized myself — because I was going through the — all the data sent to me. And I saw there's often reference, especially in the Fish and Wildlife Service, about ecosystem management, about the flows that should be designed for — I was wondering what are they talking about? So I did check to familiarize myself with the historical change in the Platte. This was an article — I've seen it cited in Hardy's work, but without — just saying the Platte used to be different or historically changed. And this fellow worked with the USGS, Williams. You might

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see — you know, it's a — what ecosystem are you talking about, the original Platte or the one — there's some from South Platte, North Platte, and Platte River. This is a sort of a condensed version of Mr. Williams' U.S. Geological Survey paper on the subject that contains more data.

Q: You're referring to Historical Perspective of the Platte Rivers in Nebraska and Colorado by Garnet P. Williams?

A: Yes.

Q: Dated —

A: I said in all of my —

Q: — 1978; is that correct?

A: Yes. That all comes out in a larger version as a USGS circular paper. I said I've never seen any — in my mind, I said, What do we want to restore to the Platte River system? Well, do you want the hundred years ago or do you want in the last 50 years? It's a very different system.

Q: Okay. Let me get back to the question of whether you — other than reviewing Mr. Williams' article, have you familiarized yourself with the Platte River, say below North Platte?

A: Only what I read.

Q: Okay. Who contacted you about testifying

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in this matter?

A: Mr. Doyle.

Q: That was the first contact that you received?

A: Yeah.

Q: And what has he asked you to do to testify?

A: I don't think I've — well, they were clarifying what I was going to do, sort of advise on instream flow issues perhaps. I said we had a phone call about, oh, September. I said yes, I would be interested. But I made it clear that once I reviewed — send me what you have on the case, and if I looked it over and I thought that the state and federal agency perspective, they made a good case, did a good job, I said, "I'm not going to be a hired gun." If I think they've made mistakes, I would say yes. I would certainly do that. I was very interested, because in my teaching, we try to find, How do you resolve natural resource conflicts? I thought this would be a good learning experience for me. What went wrong here?

Q: And we'll get into your opinions in just a little bit. What have you done other than review the studies that have been sent to you by Mr. Doyle and Mr. Czaplewski in order to prepare yourself to

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testify?

A: I don't think I've done anything more than reading the — sorting through and going back over second or third times. And then I do, you know, try to support points of view by — I just brought a few examples. This come into my desk yesterday. And shows an article, "The Relationship Between Habitat Availability in a Short-Term Carrying Capacity of a Stream Reach for Small-Mouthed Bass." Well, when I saw this, it has an amazing similarity to the situation at Platte River with channel catfish where — and exactly what — my critique of what went wrong with the Platte River, there was no experimentation or testing. And I said, This is an article that I think everyone should read, and you'd understand some of the — my complaints about what went wrong in the Platte River.

Q: What went wrong on the Platte River?

A: Well, as I went through these and I said I made — I was looking for was it simply after all these years — must go back about 15 years this controversy started. Was there ever an effort to do more than a cookbook method of coming up with flow recommendations.
And I said, there's some examples here of what — I consider more using IFIM as more than a cookbook. And as Mr. Payne was trying to explain that, IFIM itself,

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the instream flow incremental methodology, part of it is — go through the whole sequence is a conflict resolution course. It's supposedly to resolve, to keep parties from getting polarized. Get together. And I said obviously something went wrong here that didn't occur.

But what we wanted to do is test. One of the driving forces of the driving the fish flows up was the channel catfish, which somehow came out as a high velocity species, which is completely wrong. Probably because of the depth. They like — the deeper the water is better for channel catfish, six or seven feet. Of course, higher flows give you higher velocities, give you deeper water, and that raises their weighted usable area. The mixed channel catfish — it was very — it was obviously apparent to me that this is not so, because channel catfish — ask any fisherman, where do they go? They thrive in reservoirs and ponds with no velocity. They don't like velocity. They avoid it, even in the pools where you could measure.

Because the way the PHABSIM model was carried out, the habitat part of it was carried out in the Platte, you measure 6/10 of the water column. That's your velocity that goes into your model. The

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fish themselves are down on the bottom at zero velocity. That's what this paper did. They took small-mouthed bass and, indeed, you do have weighted usable area for small-mouthed bass increases with flow. But they tested that assumption. It was somewhat suspicious. They tested it by stocking some of these small-mouthed bass in an area and following them, and you see an inverse relationship between flow, called carrying capacity, and weighted usable area. I'm sure the same thing would have turned up in the Platte if this was done 10, 12, years ago. And we could have been moving on towards a resolution.

Q: How did you — how am I supposed to determine that channel catfish like slow water as you have said? I mean, what do you rely on for that?

A: Well, if you look back at one of the documents — did I bring that one here? It's the 1980 something Fanin. They did the professional judgment review. And you'll notice, channel catfish — and the fish and wildLife service also has the HSI, habitat suitability index, booklet for channel catfish. You see zero velocity is their preferred velocity.

Q: So you would rely on the fish and wildlife service's —

A: My personal experience of where do you

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catch catfish? You throw your bait on the bottom where there's zero velocity. Velocity brings food into that pool, but the fish themselves stay — or prefer to stay in zero velocity. They don't like to expend energy unnecessarily.

Q: And Fanin and Nelson agree with that as well?

A: Yes.

Q: And your analysis of what the problem was with Dr. Peters' collections was that he assumed because they were in deep water, that had a higher velocity, they were in high velocity water?

A: I would have to go back and check that again. But I think also the way those electric grids — which could really only sample the main channel. You can't get into complex habitat with electric grid. Maybe Larry knows more detail. But, then, a lot of juvenile channel catfish turned up on these grids, I believe.

THE DEPONENT: Is that right?

Q: He can't answer questions, but go ahead.

A: Okay. Again, this would be an artifact of movement because they're fairly fussy in their spawning requirements. And they'll move — the adults will move up and down the river until they usually find a hold

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onto a bank. And they produce lots of young, and they guard the young so there's good survival. As the juveniles start to grow, they start to move out going down the channel. And they're likely to be picked up in these grids by sporadic sampling. It might be in an area of fairly good velocity. And you're being mislead to say that they need that velocity. In other words, there's a difference between what's necessary and what's sufficient. Sufficient to move them, but it's not necessary.

Q: So you discount the collections as being accurate, at least with regard to catfish?

A: I would say any model that says catfish need high velocities is highly in error.

Q: What else went wrong on the Platte River?

A: Then there's some — some of these models — the state point of view, I believe, they did the community analysis. And then there was — used to be the fish and wildlife service, they come up with guilds. When I saw one time — I have not seen the — how these guilds were put together. But there was one guild called Guild H or F or something that supposedly puts a speckled chub and channel catfish together. And that is not a guild.

Q: What about the community analysis that the

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fish and wild — that the game and parks commission used here? Do you have criticisms of that?

A: The community analysis?

Q: Yes.

A: Well, basically, I mean, my critique of the whole IFIM process used as a cookbook method has very little validity from the start. When you start to put two species — if each species has a large amount of error in it, you put two species together, you say does two wrongs make a right? When you put 11 together, do 11 wrongs make a right? That's my analysis of the community analysis.

Q: Now, you've told me why you thought that the channel catfish data were wrong. And I can see where you're saying that that's an error. And if you had an error with each species, you're compounding that is what you're saying; is that correct?

A: Right. Except you might actually — you never know until you do a lot of testing. Maybe they cancel each other out so the community analysis comes out. But just by pure chance, maybe that's really good. But there's no data. The data presented would suggest to me that you really don't come up with the right answer by putting 11 wrong answers in, except by pure chance.

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Q: My question, though, is, Why do you say there are 11 wrong answers?
A: Because not one of those 11 fish species are really correctly predicted. What's being made here is a prediction.
Q: Right.
A: Relating flow to weighted usable area from there to a community.
Q: How did you determine that every one of those species was wrong?
A: Okay. Well, you can actually run a calculated test on this. Each of these — of the four or the three reaches of the river that the flow recommendation has been made for, in the back of each one of those is the weighted usable area computed for each of the species — okay —
Q: Right.
A: — For different flows. Now, let's take — the test we're going to make here is to say we're going to take two or three of the rarest species, like speckled chub or sturgeon chub. Compare that with two or three of the most abundant; red shiners, plain shiner, sand shiner. Now, if habitat as calculated by the — in the reports really relate to anything meaningful biologically in these species, then those

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W — weighted usable area scores, call it two flows, would reflect the relative abundance of those species in those river sections. And that's what the prediction is being made. And it's not too difficult to test. Go out there and look.
Now, there's one — I made some notes. I have to go back through. But I suggest you do this. You'll find, for example, in the upper — like the J-2 downstream, the speckled chub essentially doesn't exist. I think two specimens out of thousands and thousands of fish collected there. And yet it has a high weighted usable area in there. So obviously that would tell you right away, there's something more to the speckled — that limits speckled chub than depth and velocity. And again, after 12 or 15 years, somebody should have been looking at what that something else is.
Q: Well, does that tell you that the prediction by the model is invalid as to how much habitat there's going to be? Or does it simply tell you that maybe you don't know — maybe there's something else about the speckled chub other than the habitat?
A: That's what I'm getting at. There is something else, but it doesn't come out in these

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models. It's just depth and velocity. Essentially velocity is driving it.
Q: But if the model is only attempting to predict habitat for the species, are you saying that it can't predict habitat for the species?
A: I'm saying there's more to habitat than depth and velocity.
Q: What else is there that should have been considered that wasn't considered?
A: Habitat complexity.
Q: What does that refer to?
A: That refers to all kinds of configurations that you don't get out of a — you know, the most complexity I guess I've seen in these reports is the nine compartments, nine different combinations of depth and velocity compartments. Here is another — picking up another recent book. They're doing one species and one stable river system. You might take a look at some of the IFIM modeling that goes on here. I was hoping to find some kind of sophistication and level of understanding in these state and federal reports on the Platte, but they seem to be in a time warp from 20 years ago.
Q: I guess I don't see what you're referring to.

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A: Well, you see this article here is on using IFIM. And to kind of really relate flow to habitat complexity. Notice how much more complex you have to do in getting into nine depth and velocity compartments. There's the article.
Q: We're referring to Transactions of the American Fisheries Society for September 1995, Two-dimensional Hydrodynamic Modeling: A Neglected Tool in Instream Flow Methodology by Leclerc, Boudreault, Bechara and Corfa. Specifically figure No. 6, simulated flow regime for site 1, et cetera. And that would be the type of niche analysis that you think should have been performed?
A: Well, it's a habitat analysis. A niche is a part of a — a habitat is part of the niche, but only a small part.
Q: Okay. So the analysis that was conducted by the game and parks commission you think was insufficient in failing to look at the complexity of the habitat of these species that use the Platte River; is that correct?
A: Yes. And they shouldn't have been — refused to learn anything. Because Chadwick was doing the work, and maybe his was in the J-2 upper section. And he had — his habitat analysis was — did take some

complexity under the banks and snags and so forth. And also, his data is the only one that actually tries to test assumptions in relation to, you know, these biological significant periods. For example, I forget what the flows — there's one of the — your summer flow, that was a — period one is higher than the spring flow. One of these have that. This is not the way natural stream systems work.

You've got — see, your fish spawn. Spawning is — usually a reproductive period is the most critical. If you want to design a flow, you only had one choice to design, it would be probably that reproduction flow. And what's very critical there is that as the eggs are laid, and most of these small minnows will hatch out in two or three days, so the actual incubation is short. But when the larvae come out, they're helpless. Can't withstand any velocity. They're swept away in high flows. Here's one. September 16 to January: BSP-1, 1,000; BSP 2, 1,200; BSP 3, 1,200.

Well, there's two critical periods. The first is reproduction. You have to get your surplus young produced each year. Then you have to have them survive to the next year to reproduce themselves. So the over-winter period is critical. These are the two

most critical periods. But they don't correspond very well to this.

For example, after your flow, like in — the Platte will start to come up March, April, May, come down, and as the water warms, that's when reproduction take place. Most of the spawning is going to take place in these species in the downward swing of the cycle, the hydrodynamic curve. And the young are hatching out, and they have to get into like side channels, back waters. They have to get — find zero velocity water to survive. And you raise the flow, you sweep, that's not a good way to do it.

Chadwick's data does, indeed, show this. There was five years of data. Three summers, 1990, '91, and '94, I believe, had lower flows than requested. And two had flows just about that made the requested flows, even a little higher. Those are '92, '93, I believe. And he sampled every spring and every fall. And in the summer with the low flow years, there were more fish in the fall than there were in the spring; in the two high flow years, there is much reduced numbers in the fall. We have statistical regression there to show a negative relation with summer flows and fish abundance in the fall. I think that — doesn't prove it to me, but it makes good

sense, because young — the reproductive stage are very vulnerable to high flows. I think there's something to learn there.

Q: Do you think there is any value to fish in the Platte River of having variability high flows and low flows?

A: Yes. If you want — again, you've got the — one of the ecosystem management concepts, we want to promote biodiversity, promote the greatest diversity. I'm sure that there's more diversity of fish life than bird life in the Platte than there was historically because the channel has changed. So we have perennial flows and a well-vegetated flood plain which promotes diversity. For example, in my backyard now, I see white-tailed deer that have come all the way up the river corridor. That was never in Colorado historically. Eastern blue jays. We have more diversity due to the change in the Platte land form than was there historically. I'm sure the same is in Nebraska.

But let's say you want to maintain diversity and reuse the — there's actually an ecological theory called an intermediate disturbance hypothesis which addresses that subject, that your greatest diversity comes by having not stable

conditions, but highly variable — not highly. Let's say moderately variable conditions. And of course in aquatic systems, that relates to flows and temperatures particularly. But you know, flows — varying flows will help to maintain a greater variety of species, fish species.

Q: Do you think there's more likely to be a diversity or a variability of these conditions if an instream appropriation would be granted or not?

A: Well, again, the best I can determine here — I have to find out more about it, but it looks to me that the — if the state gets the instream flow request or not, it's really not going to make very great difference in that Platte flow as far as variability goes. You know, to my mind, why all the fuss about this? There's really not going to be that much change, because so much of that water is already spoken for. You could go through a scenario saying if we — the only way you could do it is put some kind of great reservoir like a McConaughy, and every time a rainstorm comes, every time the flow gets above it, you store it in that reservoir. And that reservoir is completely devoted to meeting these flow requirements. Then you say, What would you do there? You would get great stability then. You don't really want stability

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if you want diversity.
Q: What if the flows that have been requested were instead diverted? Wouldn't that decrease the variability in flows on the Platte River?
A: Well, you mean, if you go from — say you request 600 instead of 1,000, you mean that would allow 400 to be diverted, perhaps something like that.
Q: If the — if there were — if the appropriation was not granted to the game and parks commission, and instead that water was available for diversion.
A: I think that question would be how much would be granted here, you know, 500 versus 1,000. I think right now is there 500 minimum flow for cranes or birds.
Q: Right now there's 600 for fish and 1,200 for cranes at a certain time of the year.
A: But not all the year then?
Q: No.
A: I recognize that's going to be very — I think everybody recognizes it's going to be very limited opportunity to modify these flows in the river from whoever uses the water.
Q: Well, if someone came up with a project to — say Mr. Doyle's client wants to have a diversion

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for some purpose like recharging the groundwater aquifer, would that decrease the variability in the flows?
A: Well, it could actually increase the variability, because then your cycle from low to high would be greater. In other words, your low flow would be lower, right? Say if you had — your recommendation 500 versus 1,000, say if you went down to 500 and the top might be 10,000 CFS in some years.
Q: Well, but the effect — you know, they can only appropriate when a senior appropriator is not appropriating already, so all they would be able to do is appropriate during periods of high flow, wouldn't that be correct?
A: Yes. Essentially — of course, that has some opportunities for benefits because the really high flows are quite detrimental to fish and invertebrates, and probably your birds too. That's a catastrophic event. That's what I call — that's more than intermediate disturbance. That's a catastrophic disturbance. And ecosystems survive this, but they do it at a very stressed level for a while.
Q: Your opinion would be that decreased variability in the flows would be good in that instance; is that correct?

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A: That is to avoid — well, if they had the opportunity to avoid catastrophic flows — and of course you've got the flooding damage from those too — and store that water to be released for some other — a planned flow regime, that would be built into some intermediate disturbance and/or variation level. Could certainly benefit the whole system, the birds and the fishes.
Q: You say if you built in some type of intermediate disturbance?
A: Yeah.
Q: How would you do that?
A: There's no way you can keep it out because you've got summer rain storms and tributaries coming in.
Q: You stated that there was no testing — let's look at your interrogatory answer. Do you have that available there? I've got another copy if you don't. Okay. You mentioned that there was no testing for accuracy of the predictions of the modeling.
A: As I just went over. If you can go back in these and test — look at the weighted usable area predicted, this one's on — it's different parts of the river. This is for the whole community. You can get different fish species. And what they're doing

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that's predicting that at these flows you should have — if you have so much weighted usable area for a speckled chub, and it's 10 percent, 50 percent, or 75 percent that of the red shiner, let's go out and sample and see if, indeed, our speckled chub is at 75 or 50 percent of your relative abundance of red shiner as the model predicted they would be.
Q: If there's a linear relationship between habitat and populations, then you would be able to see that relationship?
A: Right, if the weighted usable area calculated really does reflect the habitat — and the habitat is what really drives these species — then that's what you would find. Obviously you don't find that.
Q: Do you think there is a linear relationship between the amount of habitat and the abundance of a species?
A: No, not as calculated here. There is two aspects here. Is the species' food limited or habitat limited? The IFIM model assumes that its habitat is the complete limiting factor, but they don't get all the aspects of habitat either. We have lots of examples where you can change the food supply in a river and have the fish population change by four or

five fold with no change in flows or habitat.

Q: Well, but you can't change the food supply by an instream flow appropriation; isn't that true?

A: Changing your food supply by appropriation, probably not. Most of this relates to a dam.

Q: All can you affect is the amount of habitat by an instream appropriation; isn't that correct?

A: Essentially, yes. Amount of — how much water is in the stream channel.

Q: And is there any claim in — did you find any claim in the — in the reports that you reviewed that there was a linear relationship between habitat and population?

A: Well, that's an assumption that's made there. And I said it's never been tested. If you did test it, you would find there is no such association.

Q: Why do you say that claim is made though?

A: That's the assumption that's made. What do you think these weighted usable area tables are there for related to flows? Percent optimum habitat, that's — their basic assumption is that there's a biologically meaningful relationship between these WUAs and the species and the flows. And you could go to the

river and test that, and you'd see it's not so.

Q: If there's an indirect relationship, though, would it necessarily follow that the populations would increase when weighted usable area increased?

A: Well, this might be useful. The way I would recommend that the — if this — if I had my druthers and I started advising people back 10, 12 years ago. One part of IFIM or this PHABSIM model is the water, the depth relationship. They talked about the WSP, or the IFG-4 they mentioned. This relates flow to some water level in the stream. If you looked for key characteristics, for example, a back — plain streams, first, notoriously they are unstable through time.

Another assumption that these habitat units — and this is what Mr. Payne was getting at, is that you can't make the weighted usable area criteria based on unstable shifting sand bottom, which was done. But let's say that because of these shifts, you have these oxbows — this is very common in wetlands — that are connected here and there. That could be very valuable for some species. And they could be maybe rejuvenated. Or if the — you might have to dig a ditch, reconnect to the channel occasionally to get

recharging and things like this. What level do you need to do that?

But could you — I say a good biologist going through this stream system and knowing the birds and the fishes and everything would say to pinpoint some critical habitats, and how do they relate to flow? And then you can make a direct connection without going through all of this pretty much wasted time, getting all these weighted usable areas for all these fish species, lumping them into nine compartments or into a community, which basically has no validity. Assumption that was based — that was based on a wrong — if that effort could have been put into more useful direction —

Q: Okay. But if you did what you've described and were to preserve these wetland areas, would that have any affect on the fish using the river?

A: Yes. Well, there's a — well, it's not a paper, in here that — it's the upper Mississippi River, and it shows how — it's an example of doing something positive, and not too much on studies. They connected a backwater — used to go anoxic. And they just did a — for large-mouth bass, of course a sport fish. But they identified a critical potential

habitat, that by doing some manipulation, reconnections to the main channel, then could create a very valuable sport fishery.

Q: And you're referring to an article in the North American Journal of Fisheries Management for November 1995 entitled "Large Mouth Bass Response to Habitat and Water Quality Rehabilitation in a Backwater of the Upper Mississippi River," by Gent, Pitlo, and Boland, correct?

A: I think that's it.

Q: Now, would that be an exclusive — would that approach be exclusive of an approach where you're also trying to provide flows for fish habitat?

A: Well, again, I would have stressed the area of reproduction. What flows were these different species — especially the ones that were feeding the birds. There's five different areas of rivers. Five different species that make up maybe 90 percent or so of the total fishes. And I think one of the most important feed terns. Probably other life. Is there anything critical about their habitat? I'm not too concerned personally there because most of these species that have long evolved in the great plains region are habitat generalists. They have a very broad niche. Very adaptive. They can spawn at a variety of

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flows and temperatures, and they can flow over a longer period of time. So they're well-adapted to disturbances and instability.

Q: So if you had that situation, would you let those species fend for themselves and model for species that might be more — less general a species?

A: Well, the one we have is — there are things like the special speckled chub or sturgeon chub. Maybe — the Platte River itself may be what's called a sink. This is a term from landscape ecology. There may be tributary species that during times of surplus they invade the Platte, but don't reproduce there, or very well. So there's a net loss to the species by living in the Platte. This is a habitat sink. This is something that should be looked into.

Q: Okay. You were critical of the failure to recognize the relative significance of species' abundance and life stages in the community approach. What would your recommendation be as far as —

A: You'll have to prioritize. You just can't say everything is equal. It's just not so in reality. You may come down to listing endangered species. At least terns, whooping cranes, piping plover, bald eagles. How did these — are some species more important to them than others? I can't find any

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information on that. But I assume since they're shallow water feeders — we have birds like mergansers and comorants that dive under the water and catch fish down deep. I think all the Platte birds are surface feeders. They have to be in shallow water. And especially the terns, small bird, they eat small fish. So assume — what's the most important fishes for them? I assume it's going to be the five most common small species that are pretty ubiquitous in the different parts of the river. And they are shallow water species. But again, if you're really interested in terns, that should have been looked at. What are the most important species for the terns? How do the terns get most of their food? Is their reproduction rate associated with different flow rates. Like Chadwick's report showed that high flows in the summer give you less fish late summer. Is there any relationship to turn nesting success and the flows? How do they relate to the recommendations?

Q: And what if you wanted to have a broader focus than simply preserving forage fish for the terns and plovers?

A: Essentially the ecosystem approach, again, which supposedly makes for healthy, balanced ecosystem — well, what? All life. And that would be

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nice, even down to bacteria, fungi, micro — unicellular organisms. That's all a very important part of these ecosystems. They're there. Are you going to manage for them? Really you don't have to. You couldn't do anything about them anyway. But they're there and they're important. You can recognize this.

Q: So —

A: But what's important in relation to flow?

Q: In your opinion, there's no — you cannot have a flow that is good for the ecosystem and do these — preserve these various elements as you've described?

A: Yes. But I'm saying I have no — from the data presented in all the reports I've been over, I can find no, I say, empirical evidence or any evidence based on testing that the flow recommendations, indeed, are the best flows for this ecosystem. And in fact, I would — if, indeed, they could get their wish, you might say, and maintain these year-round flows, it would be quite stable, it could be a disaster.

Q: What if they weren't stable? What if they were allowed to fluctuate up as high as these flows?

A: See, that's never clear in there. You say, here's the recommendations for three periods of

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the year. And would you like to have them stable like that? Well, for some purposes, like tail water below dams, and you want a trout fishery, the stable regime, your biodiversity goes down but your values go up because your abundance goes up enormously.

Q: Do you think that — do you know under Nebraska water law whether granting this appropriation would result in stable flows in any way?

A: Well, as I said, you go through an impossible scenario to do that. But in reality, granting these flows, I think, is going to have very little influence on the Platte River flow variation or stability, because there's just not enough water to play around with.

Q: Would it preserve the status quo to grant these flows, do you know?

MR. DOYLE: Objection. Calls for speculation. No foundation. Go ahead and answer, if you know.

A: Well, the status quo, you might say, has been built up over the last 50 years. I suspect — since I don't think there's going to be much change if these flows are granted or not, or what the final version is granted, I really don't expect to see any great change in the biodiversity of the Platte

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ecosystem.
Q: (BY MR. CONFER) Let me return to a question I asked before, and I don't know that I got an answer. If the water were diverted instead of appropriated for this instream appropriation, would that have an effect?
A: I doubt it. So long as there's water of some kind, like a 500 cfs or so. But it would be roughly brief period. It would be like a sudden rainstorm perhaps. In most years, there's very little water, I think, available to divert anymore. And if you leave it in or divert it probably is not going to see a great change in the annual hydrograph of what we've been seeing over the last several years.
Q: You used the figure of 500 cfs. Where did you come up with that?
A: That was the flow that had been granted to the cranes — or the fish — or cranes. Maybe fish or the terns. But isn't there some kind of a minimum flow imposed on that?
Q: Yes, there is.
A: Okay. And so that is the flow that's been there for how long? But there have been periods that there have been lower. I've seen the gauge even down below the Loup River. You had from 39 to 69 — 39 cfs

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to 69,000 cfs over a 50-year period. With that kind of a range of fluctuation, what we're talking about here is not going to do diddly about the influence of that long-term trend that's been there for the last 50 years.
Q: And so if every drop above the 500 cfs that's currently granted was diverted, in your mind, it wouldn't matter?
A: Well, as I said, if you look at — the only empirical evidence is Chadwick's five years of data, which shows that if somehow you could have diverted that flow when they got up over 1,000 and brought them back down towards 6 or 7 hundred, probably would have been better for the fish in 1992 and '93.
Q: What species was Chadwick looking at?
A: It's all the species. He had, what, 35 species. But you had the same — there's five, except you have two up there, the plains top minnow and the mosquito fish, which become more dominant up there than lower down the river. But you do have the red shiner, sand shiner, and could be — fathead minnow is very common up there. But a relatively few of the most common species. And of course, when they go down, the rare species can't make up for it even if they did improve.

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Q: So the abundance is dependent on pretty much those general species?
A: Really on five species.
Q: You mentioned that, "The flow regime established by the methodology is rarely available, sporadic, and unpredictable, and as a result, the desired results from the community of fish approach will not be biologically realized in the manner sought by the applicant." You're saying there — well, what are you saying?
A: Two things. One, the fish community approach is biologically not very real. And what — the limitation — even if you did put some reality into it, the reality of how much flows you're really going to have available to — I say to meet your recommendations — and it's — I don't think it's very much. Especially in the lower flow, moderate flow years. Only in the high flow years you've got unappropriated water coming down.
Q: And is there any value to having that occur?
A: Some level. I think — well, until I guess this 500 cfs was imposed, I guess you could dry the stream up on a low flow year. So at least this — that would be my basic recommendation, to keep a

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continuity, a permanence of flow in the — somewhere in that channel so you've got a connectedness through your system. And in the past that — in fact, historically that probably was the case. I know John Fremont in 1833 was in the South Platte, walked across, and it was dry. And you'll see Mr. Williams points this out. There are times in many years the late summer there was no flow in the lower or North Platte, South Platte, or main Platte River. It was a dry channel. But the fishes were there. There would be pockets below the water table that they could hold over and next year the floods come and they disburse. But I don't think they've had it as good as they have in recent years where you do have a perennial year-round flow. I think that should be maintained to some level.
Q: What about in areas of the river where there is no appropriation? Are you aware that below Columbus there are no appropriations in place at the present time?
A: Well, nobody would be diverting the water there. And there would be no diversions then. There's just no appropriation.
Q: If they apply for an appropriation to divert the water, then there will be.
A: I'm not familiar with the details of the

water use in Nebraska.
Q: Would that make a difference to you, if there's no instream appropriation in —
A: There should be. I definitely think there should be an instream — a minimum instream flow that would protect the connectivity, you might say. Of the whole Platte ecosystem. Now, what this should be is that — I did notice that even — I say the bias of the weighted usable areas towards the high velocity species, which is not correct. But even then, Dr. Hardy's analysis mostly came out peeking out around, oh, 600 cfs, would have been his recommendations. And to get them up higher, you had to either throw in a catfish and speckled chub guild, again, which is very unreal, or invoke a temperature condition or wetland or something like that.
And so we would agree their needs to be for the South Platte ecosystem — or the Platte River ecosystem some kind of minimum flow. I have no opinion on what that should be, except that the instream flow analysis itself predicts at the upper section, at least with the J-2 canal, about 600 cfs seems to maximize most of those fish species. But I would be particularly worried you don't get the flow up too high after about June. If you can manipulate — you really don't. But

if you did have this opportunity to manipulate, you wouldn't want to follow the recommendation and raise it to 1,200 after the fish spawned.
Q: When you say that according to Dr. Hardy's analysis, the habitat peaks at about 600, you're excluding catfish and speckled chubs?
A: Catfish never should be in there in the first place, and they certainly shouldn't be with speckled chub. The speckled chub is questionable, because as I said, you can just check how much weighted usable area it has in the different sections of the Platte, and go see how many speckled chubs are there. And there's almost none.
Q: Let me ask you, when you say — what species are you referring to when you say that most of them peak around 600? The minnow species?
A: Yeah, the five most common species. In fact, most of them. Because I would worry that maybe that's too low because that's based on most fish species don't — they really don't prefer velocity. They will seek the lowest velocity necessary to meet their needs, like feeding or whatever. So when you pick up this data and you make your model, you're really favoring your low flows and low velocities. And I would worry that maybe you're missing something. But

you do see that — at least a quantitative analysis of most of those species. And if you don't, say, try to bias it by putting in a catfish and chub guild, around 600 cfs seems to be the best flow. And I think Chadwick's work supported that assumption too.
Q: So if I — maybe I don't understand what you're saying, but it sounds like you're saying if you were doing this type of analysis, you would model for the most abundant species.
A: They're the most important. But if I was doing it, I wouldn't be using the IFIM in the cookbook fashion it was used here. I don't have any faith whatsoever that Hardy's 600 cfs recommendation is any better, any worse than the 1,200 cfs recommended by the game and fish. The only empirical evidence is back to Chadwick's reports from five years from 1990 to '94.
Q: Wouldn't the empirical evidence suggest that the species that are presently in the river are dependent on the flow regime that presently exists in the river?
A: Within wide range. I think the main thing is that there has been perennial flow in the Platte most of the time for about 50 years. Once the river was regulated and there was enormous water that goes into irrigated agriculture which raises your — and

water table return flows, you now have a perennial flow in river channels that historically did not have perennial flow. This has probably been the main benefit to biodiversity in both plants and animals.
Q: Isn't it true that empirically you say the flow that we've had over the last 50 years is what's resulted in the populations that are out there today?
A: That's been highly variable. Enormous variation. And within the context of that variation that's just documented within a 50-year period, the idea of playing around with a few hundred cfs here and there is not going to make a big difference.
Q: I don't understand why you say if you maintain the minimum flow of 5 or 6 hundred cfs then that would be sufficient, when we've had this immense variability over this long period of time which has resulted in the —
A: But you've had times in the past where you've had less than 500 CFS.
Q: And the instream appropriation isn't going to change that because there won't be additional water coming down, will there?
A: Well, we do know that the fish — the present species association, ecosystem, has experienced times in the past of great catastrophic floods and

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probably catastrophic droughts that have brought the minimum flow way down to zero in some sections of the river. So 500 cfs would be a big improvement over zero as far as maintaining a continuity.

Q: Are you aware that under Nebraska water law, any instream appropriation isn't going to make water come down the river because it can't be reduced from storage to meet that flow? So if it's going to go to zero, instream appropriation isn't going to change that. Do you understand that?

A: Unless there was an agreement with the Bureau of Reclamation operating McConaughy or one of the reservoirs in Colorado to achieve this.

Q: But the instream appropriation isn't going to stop the zero flow or make the flow equal to the instream appropriation; are you aware of that?

A: What is on Nebraska water law is on — what's already appropriated, that's — by priority, that's legally spoken for.

Q: Correct. But if you want to preserve the status quo, then you'd appropriate all the water that's unappropriated now for the instream appropriation; isn't that true?

MR. DOYLE: I object. Calls for speculation. No foundation. Go ahead and answer, if

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you know.

A: To maintain the status quo. What I'm pointing out is that the status quo has been so variable over this 50-year period that a small amount we could add to that, what I call status quo, you have never even quantified the borders, you might say, at a confidence limit. It would be insignificant.

Q: (BY MR. CONFER) I guess where we're not — I don't know if we're communicating here. How is an instream appropriation going to increase the status quo? It just preserves the status quo.

A: Maybe it's in Hardy's report. It shows a 50 year by 10-month periods. There. This might be a status quo at Grand Island gauge. It starts in 1950. I guess that's a 10-month period. You might show me how by institutionalizing, you might say, the status quo you get any improvement over that. The range that you could change this would be so slight.

Q: We're agreed that there wouldn't be any improvement whatsoever.

MR. DOYLE: The reference we have is to —

THE DEPONENT: This is the Grand Island gauge.

MR. DOYLE: — figure 15 in Hardy's report?

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THE DEPONENT: Yeah.

A: In other words, this is the status quo.

Q: (BY MR. CONFER) Correct.

A: Highly dynamic fluctuation. All you can do by appropriating little bits of this peaks in here — or not appropriate. I mean to claim a right to leave in the river. And without that, the amount that that could be reduced would be unnoticeable on this long-term graph.

Q: So you're saying because of the fact that it's not practicable to appropriate those flows that aren't appropriated already?

A: After some — you know, I'll say that the claim for some appropriation, do you need — is 500 enough or 1,000? No matter what you claim, you're rarely going to get it. And you get it at such a low point, that you project this out in the future, say we're going to do that, and you really wouldn't show much change in this status quo.

Q: Now, let me ask you about modeling for the most abundant species. Do you think it's ever appropriate to model for a rare species?

A: Certainly if you have an endangered species, this is what you'd — I mean that would be — that's what I said in the — in this case, there's

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no — well, you've got pallid sturgeon that comes up in the Mississippi occasionally — or the Missouri. But there's no modeling on that because nobody knows how much it uses the Platte River. But it's mainly — I guess you're tern that depends on the five most abundant species. So your rare species here is your least tern, which depends for its food on the five most abundant fish species.

Q: But if a species is not abundant, you would say don't model for it until it gets to be endangered; is that correct?

A: If the model was going to do any good, I'd say go for it. If you use modeling to provide insights and it's a learning experience, I'm all for it. Recommend this highly. But if it's used as a cookbook method, you'll never get to be a top notch chef.

Q: I think I know what you mean by cookbook method, but what's your definition?

A: Just following the rules of — well, Tom Payne was pointing out some of the errors that, you know, IFIM has moved along in recent years. And so a lot of the old errors are incorporated in, because the old cookbook method was followed. This is the way it was done 15 years ago. Put a transect across, and you measure it, depth and velocity, and you ignore habitat

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complexity really, you don't really get your key information on biological aspects, like the reproductive season, the over-winter season. What's called over winter here is — the last sampling took place in the first week of November, but it's well known that the biggest change in habitat use curves when the temperatures drops near the freezing at 32 or zero Celsius. This is when fish goes into more — well, they don't hibernate, but become more quiet, have a dramatically different change in their habitat use. There's no indication of that in their BSPs here. It completely ignores that.

Q: How would you model — or how would you analyze that?

A: Well, I would see what habitat they're actually using. See, for example, trout and salmon, of course, have been the most widely modeled species. In fact, this little booklet we have, an IFIM Primer here, tries to — you know, IFIM has been — thinks it's only a trout model. No, you can use it for other things. But it's been used mainly — it's been most widely developed and testing and found quite lacking for trout. The over-winter habitat is an important part because the — like a cohost salmon, many of the Chinook salmon, endangered species part, have to spend

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one winter in fresh water before they go to the ocean. You have to find what kind of habitat they're using. It's often off-channel type. Could be beaver ponds. Once you find this, then you can associate that habitat with flows.

Q: So you would do — so you're critical because the modeling wasn't done at that time that period?

A: You have to understand the biology of the species. How can you have much faith in modeling 11 species for a community, compared with a salmon species that have been modeled so much and still don't get very good results, and expect this to come out an accurate predictor of the associating flows with fish in the Platte River.

Q: Let me ask you about the — I think we're actually getting through your opinions here. I believe that you had some opinions concerning the niche analysis. Were you critical of the niche analysis?

A: Yes, that was one of my early critiques of IFIM, is that it does critique in habitat, but — and the problem was that it's the niche as a whole that governs a species' well-being or abundance. And I might put this in a Nebraska context. Every species has a niche. A niche is often described as the

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occupation of the individuals; in other words, what they do, how they make their living. The habitat is where it lives. So there's a lot more to making a living than where you live.

And let's say a Nebraska farmer was told, "We're going to predict your" — in agriculture, corn production is based on two habitat — two abiotic components, elevation and latitude. Okay. That's very much like depth and velocity. And, well, you would laugh. But yet it does convey quite a bit of information to it. You wouldn't raise corn at the north pole or south pole. There are some limitations that relate to climate. Too high elevation. But the niche of the corn also — you might say the goal of the agriculture is then to maximize the fundamental niche of the corn species. You do this by the type of soil, the nutrients, the water, insect pests, bird pests, diseases, bacteria. All of these are part of that niche.

So the farmer is trying to maximize corn production by maximizing the fundamental niche by reducing the other by using herbicides to get rid of the competing species, so forth. And you might say as a ecologist he's practicing niche ecology by maximizing the niche of the corn. And to him, now, to tell him

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that we can predict all about corn by two abiotic components of its habitat, latitude and elevation — you realize there's a lot more to growing corn that that. And it's the same with fishes.

Q: How would you have done the niche analysis? Or are you saying it's too complex to do?

A: It's really too — what you look for — again, what you call science is really nothing more than looking for patterns and regularities in nature and interpreting those. You look for some kind of pattern. You just can't go out and say everything is equal. Some things are more important than others. What was George Orwell's — "Everyone's equal but some are more equal than others." So then you look for — could be relationship between the tern and the birds or the birds and the fishes, or various fish species. Whatever. But come up with some kind of a biological type thing. That you start to ask some questions, develop hypothesis to test in relation to flows.

If you wanted more catfish, I said, Well, it shouldn't be too difficult for somebody to spot some kind of a — like in this article, an old oxbow off-channel habitat that might be rejuvenated for catfish or bass fish. Or maybe for bird production or something like that. And it's more of a qualitative

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aspect. The quantitivity of the data in the reports is quite misleading.

Q: So do you feel that there's any value to the niche analysis?

A: Well, I would call this a habitat volume analysis. To my mind, this is not a niche. It's a very minor, minor aspect of a niche. And I would avoid the term. They would call it a spacial niche or hydraulic niche. Call it habitat, spacial habitat volume, or something like that. It's misleading to use the term niche there.

Q: Other than your objection to the use of the word niche in this context, would there be value to determining what flows maximize the different spacial habitat in the river?

A: Well, that was done. That's part of — you know, I think Mr. Payne went over that. You had Hardy's work. You had the little different shaded areas and different flows and how much of this. Nine different compartments.

Q: Um-hum.

A: If you really want to put biological meaning into that, you have to put the fishes into those compartments. Let's go out there and check. You can make the predictions what should be there and the

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relative numbers from the weighted usable area criteria published in the back of all these reports. Let's go test it. And you'll find there's probably very little relationship there.

Q: How would you test it?

A: Well, we got the compartments in the — really it's the weighted usable areas. Again, my suggestion is take two or three of the rarest species and two or three of the most abundant species that we know from actual data collection that are rare or common. And then look at the predictions, how common or rare they should be based on their weighted usable area criteria that's calculated. And then go test those niche compartments, as they called it, and see how those fishes fit the accuracy of the prediction, the fishes that should be there in the relative abundance versus what they actually are.

Q: But how do you — if you say your niche or your habitat space analysis predicts maximum diversity of habitat at any number you want to say, 700 cfs, but the flows vary between 25 and 1,500, how do you test to see if —

A: What you do? Mr. Payne was trying to explain. It would have to be — it was called a time series analysis. The model is all set up. And you can

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see, here is how much the weighted usable area of the different species are, and goes up and down, up and down through the years. And supposedly this is to look for — you see a — they used the term ecological crunch. Like a bottle neck occurs at some very high or low flow. And you do it for things like that. But you can calculate at the end up to the present time — you might go back in the last just one or two years, might say two years — and calculate for all these species their total — how it varied. And then here is where they are today. Now make a judgment how abundant they were. And what you would see is that the rare species have considerable weighted usable area, and the habitat that they calculated in here is quite considerable, sometimes even more than the common species at different flows, but they don't occur anywhere near these predicted abundance or the habitat that's predicted for them. So what I'm saying is that there's actually much more to their habitat than depth and velocity.

Q: So if I understand correctly, you're saying that you — if you did this time series analysis, you would be able to tell how much of these different spacial habitats were available during a period?

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A: Like during a year — like might say — take a 12-month or a 24-month period.

Q: And then you could somehow predict the population of the speckled chub based on that?

A: Well, that's what this is doing here. That's really what — what it doesn't say is you're predicting that this flow speckled chub has 100,000, let's say, weighted usable areas per thousand feet, linear stream feet. And let's say 2,000 cfs. Then we look at the red shiner has so much. But now you go back over a 12-month period and you compare red shiner with speckled chub, and you'd end up with what do you think it should be at the final term? That's where professional judgments will come in here. But in any event, there's not much difference between the — in the calculated weighted usable area, there's very little difference between the most common species and the rarest species.

Q: But that's the way that you would test the —

A: Test the accuracy of the prediction being made with — that weighted usable area actually reflects the habitat of those species.

Q: That's also the way you would test the validity of this habitat space analysis?

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A: Right. And then the next step — assumption that the habitat alone is what determines abundance.
Q: And that is the unspoken assumption that is in this, according to your opinion?
A: Right.
Q: Okay. Let me go on to, Did you do an analysis of the temperature modeling?
A: No, I had no personal experience with the modeling, except that both Kenny Dinan and Bill Miller were students of mine.
Q: Okay.
A: Kenny's — Kenny's was his master's thesis. It was a professional paper, wasn't a research — was this model. Miller has done an oxygen model but he was doing work for the fish and wildlife. He did develop a temperature model for the Fish and Wildlife Service quite a few years ago.
Q: But you haven't reviewed either of those papers?
A: No.
Q: You don't want to take sides here, I assume.
A: No. Kenny's a good administrator. Be a good person. He's not a brilliant researcher, but he's

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a fine fellow. Hard worker.
Q: Let's take a short break here. I think I've probably covered everything that I want to cover with you. Do you think — let me ask you, Have we discussed all of the opinions that you've developed in this matter? Are there some additional ones that we haven't touched on?
A: I don't think there's anything. Some of the opinions I would — just looking at recent literature, I might say here is — we were talking about deterministic models. You might take — this is written for, well, Popular American Scientist, Sigma Xi. They're Talking about predicting human behavior, a common thing that was chaos theory. But you can see what kind of — when you got natural systems, you just cannot really use deterministic models and expect accurate predictions. It gives a little explanation of between physics and chemistry and biology. And that should be understood. That should have been right up front in any of these reports. We recognize this. Here is what we're doing about it.
Q: You're referring to the PHABSIM analysis as being deterministic?
A: Yes.
Q: And you're saying that it — there are

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matters which you can't model for because they're chaotic?
A: Stochastic, so much uncertainty.
Q: Stochastic?
A: Again, it's one I've used in class, my seminars. Carl Walters was another CSU student years ago. Carl is an internationally known authority on modeling and also on natural resource issues. And Carl recognized that modeling, you cannot really use deterministic modeling for these purposes and expect any kind of accurate results. So what he says — he wrote a book. He has a whole book called Adaptive Management. You have to make — you test these predictions. You go in and try it out, come back, refine, improve, go back. And you learn by doing.
And I said I've never seen any reference — after 15 years in the Platte River do I see any reference to adaptive management. Has anything been learned by doing, by testing, trying to make it better? And this is all quite apparent in the literature that's been for many years. I said it's almost like the — you know, there's another one. You might say nonequilibrium determinance, biodiversity is promoted by some disturbance, like fires, flood.
I noted this one maybe you could use

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called "Teaching Critical Thinking in Science." A video. I was going to send that to the lawyers. These are some of things that I use in teaching and developing my opinions. I think that's about it.
MR. CONFER: Let's take a break.
MR. DOYLE: No objection.
(A break was taken.)
MR. CONFER: I'm done. And I don't know if those guys have anything or not.

EXAMINATION
BY MR. LAUGHLIN:

Q: I have a couple questions. Do you have any opinions with regard to the flows other than the fish flows that are requested in the applications?
A: No. The only thing that I mentioned, I think the fish in relation to the terns probably would be a critical matter that should be looked into more than I've seen in these reports. I don't see any analysis really of what is the best flows to provide food for the terns.
Q: Do you have any opinion with regard to the flows that are necessary for scouring the river to maintain the riverbed?
A: No. That's a problem beyond my area of expertise of fluvial hydrology.

Q: You've indicated that it's your opinion that there should be a minimum instream flow to maintain the connectivity of the river.
A: Yes. I think what's happened in the past — I said, you know, you could get a drought and unconnective dry areas that may take a year, I suppose, so a person will have to come back again. They'll reinvade. You'll have little fossae, you may say, of survivors' areas that they would reinvade from. So they were never completely absent. But I said, to maintain sort of a moderately stable level of diversity and abundance, some minimum connected flow would be of benefit.
Q: You haven't developed an opinion as to what that flow should be?
A: No. I said I can't find the — no real evidence to support one flow or another in what I reviewed.
Q: And you don't expect to be doing any studies that would determine what that is?
A: No personal studies.
Q: You talked about the abundance of the speckled chub in the Central Platte River or Central Platte Reach on the river?
A: I think most of the collection have come

from the lower part. As you move upstream, they get more and more rare. Even though their — well, their habitat as calculated in the weighted usable area should be quite good up there.
Q: Isn't the optimal habitat for the speckled chub a greater discharge rate than is commonly found in the central Platte?
A: They're a stream fish. And I said probably the — good corollary there is — probably more clear-cut in my mind would be the darters. There's two native darters, the Johnny darter and the Iowa darter. And they need clean water. They live in rivers, but they live in the substrate. So you have to have rocky boulder substrate. I say occasionally darters have turned up in the study. But I'm sure the Platte serves as a habitat sink for darters. They're not going to maintain viable, reproducing populations in silted areas and high turbidity. And the speckled chub is probably not the extreme of the darter, but somewhat analogous to it. It needs — streams with rocky, boulder, gravel substrate is more preferred than shifting sand bottoms.
Q: But isn't its optimal flow a higher discharge rate than commonly found in the central Platte, it's optimal habitat?

A: The discharge rate — of course, it's according to how much stream channel you put it into.
Q: Um-hum.
A: A little brook that they might live in would have 1 cubic foot per second that would maintain greater depth and velocity than 500 cfs on a 1,000 foot channel would. So I think what you're getting at is do they need —
Q: Do they need a higher discharge rate for their optimal living conditions than is commonly found in the central Platte, is what I'm asking you. You're familiar with the stream bed and how it looks in the central Platte.
A: Yeah. I'm saying that there's more to what limits speckled chub in the central Platte than just depth and velocity. And I expect it's mainly the substrate, which is very limited, rocky, gravel boulder-type substrate.
Q: Um-hum.
A: That's really their preferred. That's why you usually find them in streams.
MR. LAUGHLIN: That's all I have.
MR. CONFER: I don't have anything further.
MR. DOYLE: You have a right to read and

sign the deposition, or you have the right to waive your reading and signature of the deposition. I'd recommend you reserve your right and that you read and sign the deposition.
THE DEPONENT: Okay.

WHEREUPON, the within proceedings were concluded at the approximate hour of 5:11 p.m. on the 19th day of December, 1995.

I, ROBERT JOHN BEHNKE, Ph.D., do hereby certify that I have read the foregoing deposition and that the same is a true and accurate transcript of my testimony, except for attached amendments, if any.

ROBERT JOHN BEHNKE, Ph.D.

( ) No changes ( ) Amendments attached

SUBSCRIBED AND SWORN TO before me this ____ day of ______________, 1996.

NOTARY PUBLIC
Address ____________
My commission expires ______

CERTIFICATION

I, Sharon R. Dobson, Registered Professional Reporter, appointed to take the deposition of

ROBERT JOHN BEHNKE, Ph.D.,

certify that before the deposition he was duly sworn by me to testify to the truth; that the deposition was taken by me at Denver International Airport, Concourse A, 8700 Pena Boulevard, Denver, Colorado on December 19, 1995; then reduced to typewritten form, by means of computer-aided transcription, consisting of 74 pages herein; that the foregoing is a true transcript of the questions asked, testimony given, and proceedings had.

I further certify that I am not related to any party herein or their counsel and have no interest in the result of this litigation.

IN WITNESS WHEREOF, I have hereunto set my hand this 2nd day of January, 1996.

Sharon R. Dobson
Registered Professional Reporter

Proofread by: A. Warren

HYATT COURT REPORTING & VIDEO
Registered Professional Reporters
1719 Emerson Street
Denver, CO 80218
(303) 830-0208

January 2, 1996

Robert John Behnke, Ph.D.
3429 East Prospect Road
Fort Collins, CO 80525

Re: Water Appropriations for Instream Flow
Deposition of: ROBERT JOHN BEHNKE, Ph.D.
Date of Deposition: December 19, 1995

Dear Dr. Behnke:

Enclosed is a complimentary copy of your deposition. It was agreed at the time of the deposition that you may use the copy transcript as a convenience in reading and signing your deposition.

Also enclosed is the original signature page and form of amendment for changes, if necessary. All changes are to be made on the amendment form only. Please sign the original (white) signature page and amendment form, have them notarized, and return to this office within 30 days from the date of this letter.

You may retain the copy transcript. The only pages necessary to return to this office are the original signature page and change form.

Please call if you have any question regarding this procedure.

Sincerely,
HYATT COURT REPORTING & VIDEO

Enclosures
cc: Rodney M. Confer, Esq.; James E. Doyle, IV, Esq.; Steven G. Seglin, Esq.; Mark L. Laughlin, Esq.

HYATT COURT REPORTING & VIDEO
Registered Professional Reporters
1719 Emerson Street
Denver, CO 80218
(303) 830-0208

Rodney M. Confer, Esq.
Knudsen, Berkheimer,
Richardson & Endacott
1000 NBC Center
Lincoln, NE 68508

Re: Water Appropriations for Instream Flow
Deposition of: ROBERT JOHN BEHNKE, Ph.D.
Date of Deposition: December 19, 1995

Enclosed is the above original transcript...
____ signed, no changes
____ signed, with changes, copy enclosed
not signed, notice duly given January 2, 1996, pursuant to the Rules of Civil Procedure

not signed, notice duly given January 2, 1996, since hearing is set for February 20, 1996
____ signature waived
to be signed in court or signature pages to be returned to court on date of trial

signature pages/amendments to be returned to

above counsel
____ signature not required
____ mailed by certified mail ____
____ hand-delivered ____
Sincerely,
HYATT COURT REPORTING & VIDEO

cc: James E. Doyle, IV, Esq.; Steven G. Seglin, Esq.;
Mark L. Laughlin, Esq.

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Notes of Counsel

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Hyatt Court Reporting & Video

Notes of Counsel

Page	Line	

Petrock, Fendel & Dingess, P.C.
Attorneys & Counselors at Law
1630 Welton Street • Suite 200
Denver, Colorado 80202

J.J. Petrock
Frederick A. Fendel, III
John M. Dingess

(303)534-0702
Fax (303)892-5628

February 21, 1990

Dr. Robert Behnke
ERO Consultant
Department of Fishery and
Wildlife Biology
Colorado State University
Ft. Collins, Colorado 80523

Re: Water Division 4, Case No. 86-CW-37
Application of Aurora

Dear Dr. Behnke:

Please find enclosed a photocopy of your deposition relating to the above-captioned case. Please review the deposition and contact John Dingess regarding any comments or questions.

Thank you for your time and attention hereto.

Sincerely,

PETROCK, FENDEL & DINGESS, P.C.

Charley Goins

Charley Goins
Legal Assistant to
John M. Dingess

/cag

Enclosures

AGREN, BLANDO & BILLINGS
1100 - 10th Street, Suite 403
Greeley, Colorado 80631
(303) 356-3306

February 15, 1990

John M. Dingess, Esq.
1630 Welton Street, Suite 200
Denver, Colorado 80202

Re: Applications of City of Aurora, Upper Gunnison River and County of Arapahoe
Case Nos. 86-CW-37, 86-CW-202, 86-CW-203, 86-CW-226 and 88-CW-178
Deposition of ROBERT JOHN BEHNKE

The deposition in the above-entitled matter is ready for reading and signing. Please attend to this matter by following BOTH blanks checked below.

____ Arranging with us at the number listed above to read and sign the deposition in our office

_XX_ Having deponent read your copy and signing original signature page and amendment sheets, if any (original signature page enclosed)

____ Reading enclosed copy of deposition, signing attached signature page and amendments, if any

_XX_ Within 30 days of this letter

Please be sure that signature page and accompanying amendment sheets, if any, are signed before a notary public and returned to us at the above address. The original deposition will remain in our office until the time of filing.

If this matter has not been taken care of within said period of time, the deposition will be filed unsigned pursuant to the Rules of Civil Procedure.

Thank you.

AGREN, BLANDO & BILLINGS

cc: Anthony W. Williams, Esq.
Charles B. White, Esq.

I, ROBERT JOHN BEHNKE, do hereby certify that I have read the foregoing transcript and that the same and accompanying correction sheets, if any, constitute a true and complete record of my testimony.

____
Deponent

Subscribed and sworn to before me this ______ day of ________________, 1990.

My commission expires:__________________

____
Notary Public

Address:____________________________

____

MJH-G

STATE OF COLORADO)
) ss. REPORTER'S CERTIFICATE
COUNTY OF WELD)

I, Mary J. Harms, do hereby certify that I am a Certified Shorthand Reporter and Notary Public within and for the State of Colorado; that previous to the commencement of the examination, the deponent was duly sworn to testify to the truth.

I further certify that this deposition was taken in shorthand by me at the time and place herein set forth and was thereafter reduced to typewritten form, and that the foregoing constitutes a true and correct transcript.

I further certify that I am not related to, employed by, nor of counsel for any of the parties or attorneys herein, nor otherwise interested in the result of the within action.

In witness whereof, I have affixed my signature and seal this 15th day of February, 1990.

My commission expires September 26, 1990.

NOTARY PUBLIC
MARY J. HARMS
STATE OF COLORADO

Mary J. Harms

Mary J. Harms, CSR, RPR, CM
1100 - 10th Street, Suite 403
Greeley, Colorado 80631

AGREN, BLANDO & BILLINGS
1100 - 10th Street, Suite 403
Greeley, Colorado 80631
(303) 356-3306

February 15, 1990

John M. Dingess, Esq.
1630 Welton Street, Suite 200
Denver, Colorado 80202

Re: Applications of City of Aurora, Upper Gunnison River and County of Arapahoe
Case Nos. 86-CW-37, 86-CW-202, 86-CW-203, 86-CW-226 and 88-CW-178
Deposition of ROBERT JOHN BEHNKE

The deposition in the above-entitled matter is ready for reading and signing. Please attend to this matter by following BOTH blanks checked below.

____ Arranging with us at the number listed above to read and sign the deposition in our office

_XX_ Having deponent read your copy and signing original signature page and amendment sheets, if any (original signature page enclosed)

____ Reading enclosed copy of deposition, signing attached signature page and amendments, if any

_XX_ Within 30 days of this letter

Please be sure that signature page and accompanying amendment sheets, if any, are signed before a notary public and returned to us at the above address. The original deposition will remain in our office until the time of filing.

If this matter has not been taken care of within said period of time, the deposition will be filed unsigned pursuant to the Rules of Civil Procedure.

Thank you.

AGREN, BLANDO & BILLINGS

cc: Anthony W. Williams, Esq.
Charles B. White, Esq.

LAWYER'S NOTES

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LAWYER'S NOTES

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DISTRICT COURT, WATER DIVISION 4, COLORADO

Case Nos. 86-CW-37, 86-CW-202, 86-CW-203, 86-CW-226 and 88-CW-178

DEPOSITION OF ROBERT JOHN BEHNKE   February 6, 1990

Case No. 86-CW-37:

CONCERNING THE APPLICATION FOR WATER RIGHTS OF THE CITY OF AURORA, COLORADO;

Case Nos. 86-CW-202 and 86-CW-203:

CONCERNING THE APPLICATION FOR WATER RIGHTS OF THE UPPER GUNNISON RIVER WATER CONSERVANCY DISTRICT;

Case No. 86-CW-226:

CONCERNING THE APPLICATION FOR WATER RIGHTS OF THE COUNTY OF ARAPAHOE, COLORADO (as substituted for NECO 9/1/88); and

Case No. 88-CW-178:

CONCERNING THE APPLICATION FOR WATER RIGHTS OF THE COUNTY OF ARAPAHOE, COLORADO.

APPEARANCES:

PETROCK, FENDEL & DINGESS, P.C.
By John M. Dingess, Esq.
1630 Welton Street, Suite 200
Denver, Colorado 80202
Appearing on behalf of Applicant City of Aurora.

WILLIAMS, TURNER & HOLMES, P.C.
By Anthony W. Williams, Esq.
200 North Sixth Street
Grand Junction, Colorado 81502
Appearing on behalf of Applicant Upper Gunnison.

APPEARANCES (Continued)

BROWNSTEIN HYATT FARBER & MADDEN, P.C.
By Charles B. White, Esq.
410 - 17th Street, 22nd Floor
Denver, Colorado 80202
Appearing on behalf of Crystal Creek Homeowners Association.

Pursuant to Notice and the Colorado Rules of Civil Procedure, the deposition of ROBERT JOHN BEHNKE, called by Crystal Creek Homeowners Association, was taken on Tuesday, February 6, 1990, commencing at 10:15 a.m., at 410 - 17th Street, 22nd Floor, Denver, Colorado, before Mary J. Harms, Certified Shorthand Reporter and Notary Public within and for the State of Colorado.

I N D E X

I N D E X (Continued)

P R O C E E D I N G S

ROBERT JOHN BEHNKE,

being first duly sworn in the above cause, was examined and testified as follows:

EXAMINATION

BY MR. WHITE:

Q State your name, please.

A Robert John Behnke, B-e-h-n-k-e.

Q Do you prefer to be addressed as Dr. Behnke?

A No, you just call me Bob.

Q Bob, my name is Barney White. I represent some landowners on the Taylor River who are opposing water rights applications by the City of Aurora and Arapahoe County in Water Division No. 4. Those cases, as you probably know, relate to the proposed Collegiate Range and Union Park Projects.

Have you had your deposition taken before?

A Not for this case, but --

Q For other cases?

A Yes, for other cases.

Q Are you familiar with the procedure?

A Yes. I -- let's see, the last one was

probably about three or four years ago -- three years ago, I think.

Q I'm going to ask you a number of questions about the work that you've done on this project, and Mr. Williams may also ask you some questions.

If you don't understand my question, if you want it clarified, or if you need to confer with Mr. Dingess, please feel free to say so. I want you to feel comfortable with the questions before you give any answers.

Could you describe your educational background.

A Well, my formal higher education, I got a bachelor's degree from the University of Connecticut and then a master's degree and a PhD degree in zoology from the University of California-Berkeley.

(Brief interruption.)

Q (By Mr. White) When were those degrees obtained?

A 1957 for the bachelor's and 1960 for the master's, 1965 for the PhD.

Q Where are you employed now?

A Half-time I'm employed by Colorado State

University as a professor of fishery biology. I am not a regular tenured faculty. I guess this is an arrangement that's been going on for many years. But they hire me each year, I get an annual contract to teach graduate courses and to supervise graduate students in the department of fishery and wildlife biology.

Q What do you do with the other half of your time?

A The other time is doing consulting work, advising. I also have a translation business, translating Russian literature into English in fishery science.

And my own, I'd say personal research, for -- that I present, that's symposiums, publish in the national and international literature.

Q You mentioned that you're, on a contract basis, a professor of fisheries biology; is that right?

A Right.

Q Is that your specialty, if I could use that word?

A Yes, you could say fishery biology, ichthyology. I would say the world of fishes and their environment.

Q I would appreciate it, just for my own edification if nothing else, if you could tell me something about the field of fisheries biology.

What does it involve?

A Oh, it's enormously diverse. Students -- one way to look at it, the students, the job employment opportunities after they graduate with a bachelor's or master's or a PhD, the range is quite enormous: working for a state agency, doing -- specializing in habitat, physiology, biochemistry, statistics, data analysis.

The field is very broad.

Q Within that broad field, do you have a particular niche yourself?

A Well, I -- probably my own specializations, or reputation, is based on the understanding of the evolution of fish. Evolution and co-evolution, which I often tell the students, no matter what field they eventually go into, the evolutionary paradigm is probably the most useful common denominator that you can apply to all of these different fields.

Q I'll just apologize now for my ignorance in this field, and I'm sure I'll thrash around a lot during the deposition.

Without getting into too much detail, what do you mean by the evolution of fish and the evolutionary paradigm?

A If we're going to talk about the reproductive success, they have a trout population in the Taylor River and the Gunnison River with the interaction of any other species that lives with it.

That influences, you may say, the niche of one species. How that niche changes with different environments and in the presence of other species' niche, this type of interpretation, it has, you know, broad applicability in a wide range of areas that we could relate to fisheries.

Q So for you, this isn't simply an academic exercise understanding fisheries' evolution, but you seek to apply it?

A Yes. Originally it was, you know, developed -- it was an academic part of my graduate work. In my early research publication, many applied to when you're understanding the classification of fishes: how do we classify -- how do we classify anything, and the classification of group, what evidence we use for grouping.

That led to an understanding, I'd say, once I felt comfortable with -- had an understanding of, say, evolution, that developed as a paradigm, a broad application. That besides the evidence we used for classification, we realized that the whole ecological aspect of fish evolution is also part of this evolutionary process; the niche, as I said.

All of the components of the environment that influence the well-being of a fish is all part of the evolutionary process; as I said, the broad application you can draw from this.

Q I'd like to focus on your own particular application of this concept. And maybe the best way to do that is to talk about particular projects or types of projects that you've worked on where you've actually used this concept.

A Okay. Let me see --

(Deponent examined document.)

I -- I guess I was granted, last year -- for a couple of years I did advise the Nebraska Public Power District on an FERC license for oxygen standards for regulating the reservoir below Lake McConaughy. And the point was the standard of
milligrams
6 million grams per liter was a problem with the regulation of a power plant that was installed.

And my advice at the regulatory hearings was to demonstrate -- and also we collected, over two years, sampling data, that the trout stock had -- in relation to water temperature, had no problems handling an instantaneous oxygen standard of 4, if the water temperature remained at 18 degrees centigrade or less.

But also, the -- just the whole -- as I say, the evolution of the aquatic community there, did things that wouldn't be understood from strictly, you know, a mechanistic point of view looking at oxygen standards.

The primary production -- it was a rich lake -- the primary production from plant life produced abundant oxygen.

Going from the primary production to the invertebrate form to the fish, we put this in evolutionary perspective, and presented it to the Environmental Defense -- or the Environmental Control Board of Nebraska, their Fish and Game Department, and finally the EPA, to convince these people there was -- there would not be an environmental problem by giving an instantaneous oxygen standard of 4, but to tie that to a water temperature standard.

So a relatively complex type of standard was evolved and -- but it was accepted, and I think the fisheries proved to be better than ever was historically.

Q Can you give us some more examples?

A That's -- the -- in the last year, I did publish a paper with a chemist -- out by Glacier Park -- I did a study for Glacier Park on the -- when I started this, it wasn't known if the native ~~need of~~ trout of Glacier Park still existed. And we'd made many collections and found that in one series of lakes, in the Flathead River Drainage, the -- all the lakes that had native cutthroat trout, they still persisted, despite an introduction of another subspecies of cutthroat trout from Yellowstone Park over about a 50-year period.

And this was almost unbelievable to many people at the time. And by working with a geneticist using biochemical analysis of the fish, we can demonstrate that when hybridization did take place, there was strong selection against hybrids that the native fish co-evolved into a native environment with the biotic and abiotic factors of those native lakes of Glacier Park, were greatly superiorally adapted to those lakes than the non-native, even though they are members of the same species, though a different subspecies.

And when we got above waterfalls where there were no native trout, you could find the Yellowstone non-native fish existing in great abundance in thriving, excellent populations.

So this was nothing to do with the water quality, it was just the evolutionary history of the two groups, one specializing or co-evolving into a native environment. And we used the morphological evidence or the biochemical evidence and then I did the interpreted synthesis for the paper to explain this in terms of evolutionary biology.

Q In terms of work that you've done on the impact of water development projects on fisheries, could you give us some other examples? The Nebraska case I would -- I would put in that category.

A Remember, we brought up the Juniper Crossmountain Project on the Yampa River. There, I -- for the design of the Juniper and Crossmountain Project, the water would have been released into the squawfish spawning areas from the Crossmountain Dam, the lower dam on the Yampa.

We viewed all of the evidence on the -- when the squawfish -- we could find, at that time, about when and where they were spawning and we assumed that this was a -- an evolutionary fix, you might say. They would spawn in a certain temperature range, that would be -- they wouldn't spawn either above or below, that they were hereditarily determined -- it was deterministic at this temperature range.

I think you could see in different years it occurred at different flows and different times of the year. So my attempt there was to try to incorporate this evidence into the operation of a -- the flows from Crossmountain Reservoir that would optimize the squawfish spawning or reproductive success in the lower Yampa.

Q Could you give us some other examples?

A Well, I've used the same -- when I say thought process, or the evolutionary paradigm for all other endangered species work in the basin there for the Northern Colorado Water District concerning the -- the Windy Gap Project, that was the complete flows.

Q I'm sorry, what was the issue?

A I think the Windy Gap Diversion that the Northern Colorado Water District -- I've done the assessments for them. I did the --

Q I'm sorry, what was the issue in that Windy Gap --

A Well, it was depletion, I think. That was up to 60,000 acre-feet a year would be depleted from the Upper Colorado River and transferred into the Colorado Big Thompson Project viaducts over to the East Slope. That raised the issue of endangered species downstream.

Q What did your work involve?

A Oh, again, to try to analyze the potential impacts to the endangered species, mainly the squawfish and the humpback, that occurred in the Colorado River, mainly below the junction with the Gunnison.

Q Did you make recommendations as to project operation?

A Yes. This was some time ago, but I -- I think they were incorporated; then that would be a minimum flow, I believe, of 125 cfs to be maintained below their diversion structure.

Q Was your work in that case limited to assessing the impact of the project on a particular species or were you trying to optimize conditions for those fish?

A We tried to look for a win-win situation, which is often quite possible below regulated -- in regulated rivers.

In fact, our most -- almost all of the most famous trout fisheries in the west are below large impoundments. So there is a lot of opportunity to greatly improve a natural flow regime, at least when it comes to the well-being of fish.

Q Is that what you tried to do in the Windy Gap case?

A Yes. First, we always try to come up with a win-win situation.

Q Was the 125 cfs a win-win flow?

A I think so. The -- that was mainly -- Windy Gap did not exert that much influence on the flow that the state -- at the state line, which we were zeroing in on the endangered species.

125 was mainly to meet -- there was a pretty good trout fishery in the Upper Colorado River, and that has been maintained at optimum level since the Windy Gap Project.

Q Was 125 cfs your recommendation?

A No, I think that was a general synthesis. My -- as I recall, my input on the Windy Gap Project mainly concerned endangered species.

It was a negotiated settlement that -- I think the Division of Wildlife requested 125, I think the Northern Colorado Water disagreed with it. And I certainly didn't have any objections.

Q You say that you were mostly involved with the endangered species questions. Did you also, in that case, study the impact of a particular flow on the trout population in the Upper Colorado?

A As I recall, not in great detail. In looking over the flow data and the -- since this was a -- we know that the trout had, indeed, persisted at flows less than that. There seemed to be offered, actually, some opportunity for improvement.

Q Did you prepare a report in that case?

A I think the report was prepared -- that time I was assisting -- was it Bob Erickson? -- who actually was the consultant for the water district.

Q So he prepared a report?

A I believe so.

Q Did you prepare a separate report?

A No. Anything I wrote would have been in his report.

Q What other water projects have you worked on?

A Well, I had been involved in the Gunnison River over there. Most recently, the Upper Gunnison -- the recreational analysis that was done by HDR, I provided the fishery input for that.

Q What work did you do in order to provide that fishery input?

A It was not a great deal of my time or effort involved. It was mainly reviewing possible ways that maybe we could improve and attract more fishermen to the Gunnison area.

And again, one example of using, you know, evolutionary biology as a paradigm, I would suggest you might read it in the HDR Report. I think you will see something about the importation of special strains of rainbow trout that attain a very old age at maturity, a long life span, with the potential of reaching a very large size, especially if they would prey on the -- develop a predator-prey relationship with kokanee salmon in the reservoir.

My contention was that this could great -- that people catching a 25 or 30-pound rainbow trout in Blue Mesa Reservoir would move Blue Mesa from state-wide attention to national attention. And I expect later that we could do that if we had the right strain of rainbow trout.

I also recommended that the Gunnison -- or the -- the Gunnison River and maybe the East and the Taylor, that more vigorous efforts be used to try to establish wild strains of rainbow trout that have been proven to, you know, thrive in similar conditions.

Those rivers -- essentially, the wild trout there is almost strictly brown trout. The rainbows have been maintained over there from hatchery -- domestic hatchery stock, which is not good at surviving.

So my emphasis there was how to make the fishery in the Gunnison area better, to attract more attention.

Q Did you make any recommendations about streamflows in the Gunnison River as part of that project?

A No. The only -- my stream flow recommendations, that was several years earlier -- what was that hydro project that was going to use Gunnison Tunnel to operate a turbine?

Q The AB Lateral?

A Yes, I think that's it. I did write two reports. I imagine they went into Environmental Impact Statement on that project -- on the operation of that project and the Gold Meadow Trout Fishery in the Black Canyon of the Gunnison below, and the -- my recommendation was that a minimum flow of, I think it was agreed on 300 cfs, should be maintained at all times as a minimum flow. And that the removal of flows, say, when you get to about 1,000 cfs level, keeping it at that level or below, actually would be beneficial for the trout.

So the -- so that AB Lateral did have a potential. I also recommended that at spawning time, which could be figured from water temperature, the flow should not be depleted more than about -- by about 30 percent during the egg incubation stage.

Q Was that brown spawning?

A Yes. Again, the -- well, there are rainbow -- a pretty good rainbow population in the lower Black Canyon now, and so it would apply to both of them. But it would be much more difficult to manage with the rainbows because they are a spring spawner, where the -- you have more control over the operation of Curecanti in the fall and winter months. A big spring runoff will top the dam, as it has, and so you -- your degree of control or regulation of the river is better for the brown trout, more predictable with brown trout, than it is with rainbow.

Q Who was your client on the AB Lateral Project?

A Oh, I'm trying to -- I never did meet them, I did it all over the phone. And then it was -- there was an engineer from Minneapolis, I believe, and then he left or some other company took over and they had -- a few more questions were raised on winter flow conditions.

So I did another paper on the winter flow conditions and there was a different person I worked with then. I never personally met these people. I really can't remember who it was.

It was simple -- it was a relatively minor job, like a phone call, Could I handle -- or do this? Yeah, send me the information, I'll look it over and write you a report. And I did.

And then the next year they wanted another one on winter flows. And it was a different person. I think a different company or something was involved.

Q Did you do any fieldwork in connection with that project?

A No. The only fieldwork -- one time in 1966 I hiked through the whole bottom of the Black Canyon, so I was personally familiar with the area. But the fieldwork was all done -- the data we used for that was all done by the Division of Wildlife.

Q What was the purpose of your 1966 hike?
A That was a national parks -- the Monument wanted a documentation of the fish species in the Black Canyon before and after the Curecanti Project went on line. So we documented the -- what the fish species were down there in 1966, and then how they changed through time.
Q Did you prepare a report on that?
A I didn't. It was -- we had a graduate student named Brian Kinnear who wrote it. It was part of his master's thesis work and that was prepared as a special report for the Park Service, The Fishes of the Black Canyon National Monument.
Q Did you do any post-Curecanti fieldwork yourself?
A No, not -- just except for fishing. But that's one of the better study streams in the state division. The Division has an annual monitoring stamping program there.
Q I'd like to go back to the AB Lateral Project. You indicated you used field data from the Division of Wildlife. What data did you use?
A They had developed those instream curves called habitat suitability index curves. Some of the early ones were done down there. And they did

show -- as I said, I'm not a great defender or believer in such simple methods for complex systems, but they can be in the ballpark because they were based on empirical evidence of the fish sampling.

And it showed that -- well, actually, about 250 to 300 cfs would be very good for the fish. And when you got up above 5, 600, it starts to be too high of velocities.

Q This is work that you relied on in forming your own recommendations about the AB Lateral; is that right?

A Yes. I'm just, actually, just taking the Division of Wildlife's recommendations and applying them as how that would apply if you changed the flow. And the main benefits would come as when, say, reducing a flow from maybe a 2500 cfs flow back to 1500 definitely would be beneficial for the fish.

Q Who at the Division had done the work you relied on?

A It was Barry Nehring. They are issued an annual report that goes back, well, maybe 10 or 12 years, at least. They are called a -- it's a Federal aid project in relation to fish flows in Colorado. And every year a report comes out that will include data from the Gunnison River. The early ones had data from the Taylor River.

Q What use did you make of those reports in particular?

A I looked at the recommended flow regime, or the flow regime trying to correlate flows to fish habitat, and then superimposed over the change of the Gunnison flows with the year-round diversions to the AB Lateral.

In other words, there was a -- here's your -- I think we had a virgin river hydrograph before Curecanti, and before even Taylor River was on line, and then with Taylor, with Curecanti, here's by month -- average flow per month.

And then we had a zone of that Division of Wildlife, which would be an optimum trout habitat zone. Then we draw the line with the AB Lateral in there and show that for most parts of the year -- a larger percentage of the year -- your optimum habitat flows could be met with this increased diversion through the AB Lateral.

Q Do I understand you to say that you used the habitat suitability index curves which the Division had prepared?

A I just used the Division's curve.

Q You didn't prepare your own?

A No, no.

Q You didn't do any streamflow modeling of the river yourself, did you?

A It was already done.

Q Did you find the Division's work acceptable enough so that you could rely on it in that case?

A You can rely on it if it's based on -- it's essentially like predicting the outcome of the Super Bowl after the game, if you could fine-tune and backtrack your model. After Barry Nehring has the evidence of reproduction in the fall and, like I say, the Gunnison River, then he can relate that to the flows and fine-tune the model to look good.

But the problem you have of transferring that into the future or to another river has to take a large measure of experience, expertise and professional judgment.

So my complaint about the limitation of using any kind of method or model to predict what's going to happen in natural, complex biological systems concerns the -- I'll say the naive application, using it as a cookbook or user manual.

Q But in this case, again talking specifically about the AB Lateral, did you feel that

Mr. Nehring had enough field data and actual correlation of results so that you could rely on his habitat suitability index curves?

A We had nothing better to go on. This is typically environmental assessment work. You go with the best evidence you have, come up with -- essentially, it's professional judgment much more so than mechanistic modeling data.

Q In this case, it was his professional judgment?

A No, he has -- he built his professional judgment into those models.

Q And it was the result of those models, with his professional judgment, which you relied on?

A Yes. In fact, they -- I know the Division still goes with those flow curves for the Gunnison. They still want, you know, their 300 cfs minimum.

I think, also -- I was the one who built in, though, the idea that they should not change -- for reproductive success, to not diminish -- after the spawning, to not diminish more than about, say, 30 percent to avoid exposing reds.

Q Did you apply your own expertise, experience or professional judgment to the Nehring curves in making your own recommendations?

A Yes. I'd have to look at the -- my original reports that I submitted on this to see just how I did that, but obviously there's my individual interpretation in there.

Q Can you recall what individual interpretation you made of the D.O.W. curves?

A Well, one was, as I said, to try to improve reproductive success, to organize a flow regime. And this would be up to the Bureau of Reclamation.

I did go through the -- you know, the U.S.G.S. flow data from the Gunnison, and go through Nehring's year-class survival and success rate. And you could definitely see -- you didn't have to be a great biologist to recognize what was going on in that Gunnison River with the operation of Curecanti, that determined some -- at least the ruination of year-classes --

Q I'm sorry, the what?

A The -- what I'm talking about here is called negative correlation, which is predictably very accurate: no fish, no water.

And you could find those years that has virtually no fish survival of the young; you could find periods where the Bureau of Reclamation had turned that river just about off.

On the other extreme, with too much water, no fish. You could see very high flow, if it came at the time the young fish were hatching, for about a six-week period. About -- during the -- when they are coming out of the gravel, too high a flow sweeps them away and you could lose them.

So just going over this data was -- this is what I do for my interpretation. You can -- it's not difficult to do.

Q And in the case of the Gunnison, you were able to do that because there was a lot of actual information about fish survival or success rates?

A Yes. The Division has these annual samplings there and they determine the success of the year-classes, the young fish that reach year. It's not absolutely hard data, there's a lot of room for, let me say, error.

But as I said, you go by it and then you can check it the following year; recalling the age-zero fish, that were born this year, next year they will be age one, so you do have a check on this.

Q You've described at least three projects on the Gunnison in which you've been involved. There was the work for the National Park Service before and after Curecanti, the AB Lateral Project and the HDR study and, of course, there's your work for Aurora.

Have you been involved in any other projects in the Gunnison River Drainage?

A I don't believe so. Let me see.

(Deponent examined document.)

About the only one was -- I have one of my -- my special hobbies is, as I say, the preservation of native cutthroat trout. And over the years, every once in a while someone will find a new population, say, in the Gunnison River Drainage and they will send me the specimens to look at, to identify.

Are these really the native cutthroat trout or are they hybrids or whatnot, for identification. And then the native cutthroat trout are essentially gone from the Gunnison River Basin.

Q So you have actually gotten some samples, specimens, from the Gunnison? What's your answer?

A Yes. Yes, uh-huh. I don't believe we

ever -- we ever verified a pure population left in the Gunnison Basin.

Q Other than that work, have you been involved in any other projects?

A Also, when I say just standard -- my interest in fish evolution and distribution, I have looked at the Gunnison fishes, I think that was, say, some of the oddities. It's the only place we seem to have a -- a good establishment of the longnose dace, which is native to the East Slope but not the West Slope.

And the only place the longnose dace seems to have been established in the Colorado Basin, to any extent, is the Gunnison. The other oddity is the Black Canyon, the Gunnison has the main sucker species there, which is the longnose sucker. Which, again, is an East Slope species that is not common in the Colorado Basin.

But they do very well in the Gunnison River below the Curecanti Project. I've also investigated the native sculpin of the Gunnison Basin. We -- there's kind of a mystery there. Colorado has two native sculpin species, cottus bairdi and cottus beldingi. And for some reason, the habitat looks just fine for cottus beldingi in the basin, but we've never found it and I've examined many collections from all these ideal habitats, and all of the sculpins we find are bairdi.

MR. DINGESS: Barney, I wonder if we might take a restroom break.

MR. WHITE: Sure.

(Recess taken.)

Q (By Mr. White) Dr. Behnke, before our break we were talking about your work on the Gunnison. I just want to make sure I understand your prior experience.

Have you worked on any water projects beside the Curecanti work which you have discussed, the AB Lateral, the HDR study and Aurora's project?

A I don't believe so. There is a possibility -- could you think of any -- if you could give me a name of a few projects, I will see if I've got anything -- any involvement with them.

Q None come to mind right now.

What other water projects have you worked on, in any location, in which you've been asked to study the effects of a certain water flow regime on fisheries?

A Let me see. Well, I have been involved with the endangered species aspect of maintaining the squawfish, humpback, saw -- the -- most of my flow analysis work were -- or consulting jobs -- has been with Colorado River Basin endangered species in the Upper Basin: squawfish, boneytail, humpback and razorback sucker.

In the Lower Colorado Basin, I have been an adviser to the Salt River Project for many years. And there is a different species complex, different type of river systems, different flow regimes and also some trout fisheries and Indian reservations there.

So I have done quite a bit of work over the years for the Salt River Project on potential impacts from flow regime changes.

Q Let's talk about the Upper Colorado Basin projects first. You mentioned the Windy Gap Project and your work in the Gunnison. Have there been any other water projects you've worked on?

A As I remember, it was some years ago there was an oil shale group -- it was in this neighborhood, as I remember, downtown Denver here, the GCC Corporation, it was Getty, Chevron and CitiService, I believe, had formed the coalition to develop oil shale in the basin.

And one of the first steps was to construct a large reservoir over near Parachute. I think it was called Grand Valley at the time. And I was their adviser on the project to -- they were going to pump water out of the Colorado River and store it in this reservoir up in one of the canyons.

And they were going ahead. We had written several reports and -- until the -- that fizzled. But I'm trying to think, it was the NUS Corporation, I think, was the lead consulting agency that was writing the reports. It was comparable to this where I gave some input to ERO.

At that time, I was giving input on endangered species flows to the NUS Corporation for their -- and they would put them together in reports for GCC.

Q That was many years ago, wasn't it?

A I think it was like 1981 or '82.

Q What work did you do in order to make your recommendations in that case?

A What I did was work -- get an original hydrograph, or a virgin hydrograph, to reconstruct, put in the present hydrograph in the Colorado River. We used certain -- like the state line was one critical point, where U.S.G.S. gaging stations were available. And also plot, you know, say, one in a 10-year high, one in 10-year lows, things like that.

And then we would incorporate the new flows from the -- this diversion. How would they impact at this point and that point? And would this be a serious problem with endangered species? What could be done to mitigate?

And it's interesting that -- what I would do is essentially express the flow or desired flow regime; what those endangered species, as far as we know, what do they -- would be beneficial for them? What would be negative? But it was expressed as percent of, you know, average daily flow or the call called the Q Flow exceeds. You got a flow curve a certain percent of the time and more and more, more or less than this.

And the Fish and Wildlife Service most recently has gone back to that type of recommendation. They have abandoned IFIM as a decision-making tool, they have done it both in the Upper Basin and Lower Basin.

Q How did you come to conclusions in that case about what the impact of a particular flow regime would be on the fish --

A With an example, using the evolutionary principle that a squawfish lives to be quite old. So one of the advantages of being old is that in a highly fluctuating environment, you assume that the -- its ancestors have been there for thousands and thousands of generations, exposed to this highly fluctuating Colorado River-type environment. And that you cannot expect to get successful reproduction every year, maybe only 1 year in 5. But if they are going to live 30 or 40 years, you are going to get -- they are going to make -- they are going to make it, because they have for thousands of years.

So by looking at the natural range of variation that the river is exposed to during, say, the spawning season of the squawfish and also when the young hatch out, this is a very vulnerable period. You can see the -- what the range was exposed to that they had successfully been able to, you know, survive in.

I'm trying to come up with what's the optimum range and that, again, is difficult. But the same evidence was used as, say, with the Division of Wildlife's sampling of young trout in the Gunnison. The sampling of young squawfish would give us some idea of their relative success in different flow years.

But one thing that turned up, of course, is that the type of habitat that the young need, they don't -- once they hatch out in a main channel, they quickly -- if they are going to survive, they get into a backwater or side channel and these -- so my recommendation was to identify these type of areas that were so important as a nursery ground to establish the -- what's called the year-class strength of the productive success of squawfish.

Q Did you conduct your own fieldwork in that case?

A I did some fieldwork, made raft trips down the river, both the Yampa, Green, Colorado River, oh, several times, over several years; not all for the same project.

I participated in the Division of Wildlife samples and the -- I think I was the first one in 1978 when the squawfish -- I was suspicious that the squawfish really were more abundant than sampling had shown, and I had organized a night sampling in the Yampa River in the middle of October.

I know we almost froze to death. We did fall out of the boat and everything, but we did come up with more squawfish in one night in Juniper Canyon, Crossmountain Canyon, than had been found in the last year over there.

Q What kind of field data did you need in that case to form your recommendations?

A We needed some kind of data to show the -- first, the distribution of adult fish, the areas they spawned in, and then some kind of data associating flows and temperatures with the number of young collected and where they were collected.

Q When you say flows, are you talking about a variety of different flows?

A Right. The -- if you realize -- like the Yampa River had the July -- typically July is the month they spawn. The July flow over a 30-year period was 2,000 cubic foot per second, just about there, below the Little Snake.

But there wasn't -- I think only 1 year out of 30 that it ever really actually came within plus or minus 10 percent of 2,000. In other words, there was a high variable range that they had successfully reproduced and over a wide variety.

And trying to pick the optimum, really, all you could do is come up with an intelligent speculation. And then you take future monitoring to see how it's -- you could recommend a flow regime, but then how it's really going to work will take future monitoring.

But we could make an assumption that the squawfish had been able to reproduce over a very wide variety of flows, and over a wide variety of time during -- it could spawn anywhere from late May, early June, into late July, early August.

Q Am I correct in understanding you to say that you needed data relating fish population to particular flows historically and that you needed to monitor that information into the future?

A Historically, the historic flows gives you some indication of what the, say, selective factors that their life history, strategy, their adaptation to survive, were tuned in to.

Some species, you recall, have a very narrow niche. They cannot tolerate much perturbation or fluctuation. It was obvious the native fishes of the Colorado River over there were supremely adapted to very highly fluctuating conditions.

Q Were you trying to optimize flows for those endangered species or simply gage the impact of a particular flow regime on those species?

A Well, for the Yampa River -- and all the others were done essentially the same way, was to come up with an -- a proposed operational regime. How does that operational regime change the present operational regime as far as, you know, cubic foot per second flows per time, through the year?

And then we look for, does it look like we're going to have a problem? And the first one you would see that might turn up, like Crossmountain Dam, is if the water -- if the water was released from the cold area of the reservoir, that would, I would predict, have a negative impact because it would delay spawning. It would cool the water down below what it would be normally.

So obviously, then, I would tell the engineering firm who's designing the reservoirs that you would have to design a variable release or a surface release so you could optimize temperatures in relation to squawfish spawning about 30 miles downstream.

Q Let's back up just a minute and talk about the relationship between flows, per se, and fish populations.

My question was: In assessing the impact of a particular flow regime on a fish species, did you, in those Upper Colorado River Basin cases, need data correlating fish populations with flows, historically? Or were you able to make some assumptions to resolve a lack of data?

A I'm not sure exactly what -- let me see if I could rephrase that. Do I need data to associate fish with flows?

Q Yes.

A And the whole life cycles of adults or --

Q You tell me. Would you want data about the whole life cycle of the fish? My question is generally: What data do you need in order to make your recommendations about a particular flow regime?

A Well, at the first -- the first point would be to develop a -- some kind of historical distribution and abundance of the species; in this case, a squawfish.

Q Let's stop there and talk about that. How do you develop that information?

A And that's often difficult. In fact, there was a 1950 report that the Colorado Division of Wildlife had on the fishes of the Yampa River based on a -- this was the only real sampling that had been done, you know, in the early years and this was before the concern for endangered species was expressed.

In the Division report, however, we see this -- I saw the squawfish were appearing way up above Steamboat Springs and squawfish were very abundant all over. And it became obvious that they had misidentified -- what they were calling squawfish really was the roundtailed chub.

So the first thing I had to do was throw out the Division report as a reliable basis for squawfish distribution in abundance.

Q So if I could interrupt you, you needed information about squawfish distribution in --

A Right. We wanted to see -- in other words, where did the squawfish regularly occur and in what number, say, in the upstream limits? Did they occur above Juniper Canyon or Craig or where? How big were they? How abundant were they?

And the first problem you have of getting any reliable knowledge on this was the -- the uncertainty of identification of the old reports.

Q Go on. What other data do you need?

A I went through old records and looked through -- in the 1880s and '90s from journals such as the American Angler, Forest and Stream, which would have correspondence in Colorado reporting on the fish. And it became evident, really, only a few people who really know what squawfish were.

But those people did get good, accurate accounts. And it became clear the squawfish was never a common fish, but it did evidently reach a much larger size than it does today.

Q Would you have preferred to have actual creel census data or stocking data?

A That would have been better but, of course, that wasn't done until -- like I said, the first electrostocking data the Division of Wildlife did, they misidentified the fish. So I couldn't use that very well.

Q Did you then make some attempt at correlating historical fish populations to historical flow regimes?

A We assume you don't know what these flow regimes were. Some of the earliest records, of course, are before U.S.G.S. took any gaging data.

There are sources of a -- you know, a re-creation of a virgin flow is putting back in all of the diversions and depletions and arriving at a historical or virgin flow regime.

So this is what the fish had for several thousands of years, but it was obviously very variable. I might add, I even looked at Indian archeological sites of the fish bones that Indians got from about 1500 years ago in the area around Craig.

Q Have you worked on projects in the Platte River Drainage?

A Platte River.

(Deponent examined document.)

Let's see. I recently was doing some work for the City of Colorado Springs, but they are in the Arkansas Drainage. I don't recall.

And again, except just the, you know, my ichthyological explorations, fish surveying, but I don't believe any, you know, consulting work. I don't recall offhand a -- you know, being paid to do a consulting job in the Platte River.

Q You didn't work on the Two Forks Project?

A No.

Q What project in the Arkansas did you work on for Colorado Springs?

A Dealing with the water quality of the standards, the sewage plant effort.

Q What I'm trying to get a sense for,

Dr. Behnke, is the particular experience you've had in assessing the impact of different flow regimes on non-endangered trout populations, such as rainbow or brown.

Have you worked on projects like that before?

A Yes. I regularly -- as I say, I've been -- oh, for the last seven years I've been writing a column in Trout Magazine, and also serving as scientific adviser to Trout, Unlimited. And I'm often asked to comment on the environmental actions, typically a flow regime change that's being proposed for this river or that river, and should the -- you know, should Trout, Unlimited, as an organization, oppose this? Do I see a problem with it?

But lots of environmental -- in fact, the Environmental Defense Fund has come to me for advice on flows.

Q Is your work for Trout, Unlimited gratis?

A Yes, this is stewardship work.

Q Have you served as a paid consultant at any time in evaluating the effects of different flow regimes on trout populations?

A Well, the AB Lateral, I was paid for

that. And that was, you know, the effect of the Gunnison River flows on trout population.

The -- as I said, I remember I did look at the northern -- Windy Gap Project Diversion on the flows in relation to the trout population in the Upper Colorado River. I -- let's see.

Some of my Salt River Project work did relate to flows on the -- to maintain the trout fishery on Indian reservations.

(Deponent examined document.)

Probably my own personal expertise is with trout. In fact, in 1984 I was awarded the first Starker Leopold Award for a professional trout researcher.

Q Can you recall any other particular projects you've worked on in relation to trout fisheries?

A No. I do remember looking over the, you know, Taylor and East and Upper Gunnison flows for the HDR Project. That was -- I -- you go over each year of the Division of Wildlife's flow reports to familiarize yourself with what's going on in the state, and . . .

Q Well, let's talk about the HDR Project. What work did you do for HDR?

A As I said, mainly the concern of looking for opportunities to increase the recreational fishery there to bring more people in from longer distances, who will spend more money. The main Blue Mesa Fishery was not a high-value recreation fishery.

Q Did the work you did for HDR include any analysis of the impact of different flow regimes in the Gunnison River or its tributaries on the fishery?

A I don't believe so, because at that stage we weren't -- I remember they did look at some options for, you know, possible -- or storage projects that could improve flows.

But I don't recall if I was ever really asked to analyze any because I think the possibility for influencing a changing of flow regime work that we were doing there was so slight that I think the only question that came up that maybe we could improve Ohio Creek was one I recall that if we put a reservoir at the headwaters, we could actually have better fishing by regulating.

But I guess the cost benefits didn't figure out on that.

Q Did you actually come to that conclusion yourself about the reservoir on Ohio Creek?

A No, I didn't participate much in that. I -- because I didn't -- it was not deemed feasible. It wasn't -- I think it might be mentioned in the HDR report, but I was never really -- it was never really seriously considered, as I recall.

Q When Trout, Unlimited comes to you and asks for your opinion about the effects of a particular water project, what work will you do to respond to them?

A I just draw on my experience or the -- that I have been doing for years, that most of what we call is a preliminary survey, or I think we call, in this report, a reconnaissance-grade survey, is really: Do you have cause for concern? Should you do further work? Do you need further data?

I try to highlight that, obviously, you don't have enough data to answer this question, or you would have to get it. But if I look at a -- their flow and temperature regimes, this looks quite ideal.

You may not be able to get reproduction for some miles below a dam because of this or that, but you could stock the fish. You could -- mainly I would have a fairly -- I think a fairly accurate prediction of it. Given some basic data on a proposed water development project, I could predict what would happen with the trout fishery below.

Q Let's just take an example. Let's say Trout, Unlimited asks you for your opinion about the effect on trout fisheries of a hypothetical project on the Michigan River, which is a tributary of the North Platte. What would you need to do in order to give them an opinion?

A I would like some data on the fish population in the Michigan River, the species, the growth rate, the longevity, reproductive success, biomass and fluctuations through time.

Example: The South Platte, the Two Forks Project, which I was asked to comment on, has a -- what's called a gold medal area, but you do have an average of over 500 pounds per acre of stream of, essentially, adult-size, you know, catchable size trout, which is fantastic, very excellent. And you simply cannot reproduce that in another stream.

No matter how you quantify it, there are so many subtle complexities, but the South Platte is a gold medal, but how do you define or quantify gold medal except: Is that 500 pounds per acre or more?

Q Let's go back to my hypothetical about the Michigan River. Let's say that you have the data you described about the fish population itself. What else would you do in order to render an opinion?

A Well, what was to be the question, though? What was to be asked? What would happen to the Michigan River?

Q A particular water project will go into operation --

A Say a dam would be built.

Q Let's assume it's a dam and they give you a flow regime that will result from the operation of the project.

A First, we would have to know the reservoir that would be constructed, where this water's coming from. How deep in the reservoir does this water come out, what the temperature is going to be. It could either be too cold or too warm.

We want to get a -- for most of the year, we would want a temperature regime in the area of, oh, say, 48 to 58, maybe up to 65 degrees for optimum growth. We would predict -- with a fairly constant temperature like that, though, you would predict that the invertebrate food-fly for the trout in the river below would increase in abundance, but increase in diversity.

If you maintained a flow regime within a certain -- we could express it as a percent of the average daily flow or, you know, percent of a Q-excedence flow within a certain range. We would say that this would be maintained optimum habitat.

Q How would you come to that conclusion about what the desired flow range would be?

A Again, looking at the -- I would assume there had been some cross-sectional work done on this stream and we see -- but simply a quick observation could be done at different flow stages.

We would look at: We want to maintain a flow through a stream that maintains the water almost bankfull, not really -- but enough to -- for the prime fish habitat in most small, medium-sized streams is the undercut bank.

Often there is a willow whoop mass up here, and the water goes on the fish like a great condominium in there. And simply observing the flows, as I said, this is ideal. Then you go up late in the year and say, oh, oh, that's all being posted and dry and the water's all out, like in the channel, and you have seen what you've lost.

Q So you would need to go up there and observe the river --

A I would prefer if it was a -- if it was a critical matter, I would prefer to observe.

Q We've had this problem a few times where you start to answer before I finish my question. It works better if we each let the other one complete his sentence before jumping in.

You would actually want to go and observe the river at different flow rates; is that right?

A If it was a critical matter, you know. As I say, typically, I do not. If there's a -- there may be an abundance of sampling data on that river that there's no need for any more.

Q You mentioned some cross-sectional work being done. What did you mean by that?

A That's the -- I think the Colorado has used this method for flow requests, or minimum flow, is you put a transect across the stream at a critical riffle area, and you can express flows in relation to how much of the -- what's called the wetted perimeter of the stream channel is covered.

The problem is that it calls for an -- a Manning equation, that when you project, you know, above or below that, that -- and there's a lot of room for error, so if it was a critical case, really you would have to go back -- if you really wanted to be accurate, you would have to go back and actually make these measurements at the different flows to see how well they agree with your prediction, and you find there's often quite a room for error.

Q What measurements would you make?

A Well, it's a hydrologist term called a stage flow. You have a gage and you know the -- did you have a cfs, say, gage measuring the flow, and then a certain -- you might say your critical riffle area that you might want to use as your monitoring point, that the flow's 10 cubic foot per second and you see it -- see the gage register 6 inches.

At 20 cubic foot per second it may go to 7-1/2 inches; at 50 cubic feet up to 9, something like that, until you got a range. And you can relate that, quantify that, to your habitat parameters that you identify key undercut bank areas, key reproductive areas.

And that type of quantification is quite a valid application.

Q Oh, on a particular stream you'd look for key habitat areas and try to pick a flow rate which gave you the right amount of water in those areas?

A Yes. And with trout, we can identify four critical stages called reproduction, a spawning which would include the laying of the eggs and the incubation of the eggs in the gravel; and then called the nursery or young stage when they come out of the gravel for the first year of life, is -- especially the first six or eight weeks, is very critical.

And then we've got an over-winter type of habitat -- that is a critical period of survival. And then what we call adult habitat.

So those -- you could look at different sections of the stream, different flow regimes, in relation to assessing those four components.

Q And you'd want to consider each of those four life stages; wouldn't you?

A Yes, certainly.

Q How do you pick the key habitat areas that you examine?

A Well, it would depend on the -- what you think is limiting. In other words, a lot of Colorado streams are high gradient, relatively shallow, high velocity water that often provide, you know, adequate, good spawning.

You find a lot of young fish but not very good habitat to over-winter or to grow to be an adult -- you know, large adult. So here you might say we could mitigate or change that by increasing adult habitat. Placement of large boulders or logs, called a stream improvement-type project, is usually designed to improve adult habitat.

Q Let's start with that first question, if I understand it to be the first question. How do you decide what is a limiting factor on fish populations?

A Well, as I said, first if you went to a stream that was a relatively shallow, high velocity stream but it does have trout in it, and -- but there's very little deep-pool habitat, little undercut bank, you would make a judgment that there's probably very limiting adult habitat and very unlimiting over-winter habitat here.

Q Does this depend on the actual physical characteristics of each stream?

A Yes, each stream is individual. It's -- the gradient, the flow regime that comes off most Colorado streams have a very skewed flow regime. And it's more pronounced in the -- at least the ratio between high and low flow. It's the higher up you go, the lower you go, fifth, fourth, first order streams, you typically get the ratio between high and lows more pronounced.

Q Before you, Dr. Behnke, give an opinion as to what the limiting factors are, you would have to go to this stream yourself and look at it, wouldn't you?

A It would help, unless, as I said, somebody like Barry Nehring for the Division of Wildlife, who does these annual reports, they have an annual monitoring program, if I could read -- if the data's expressed in that report, I would -- I could give you another example.

It did occur to me that I did testify in court as an expert witness in Michigan, on the factors that control the trout population, by visiting the stream the day before the trial. But there was 30 years of accumulated data on that stream that I was thoroughly familiar with it before I ever saw it.

Q Let's go back to our hypothetical Michigan River Project. Let's assume you go up and look at this river and pick some key habitat areas and you have the cross-sectional work done that gives you a relationship between wetted perimeter and discharge. How do you then use that information to form an opinion about the effect of a particular flow regime on the fish?

A Well, aesthetics is merely more a matter of common sense than any special expertise. If you know the fish are spawning, like I say, brown trouts spawn in the fall, a brook trout is fall spawns, rainbow trout and cutthroat trout are spring spawns, and they will spawn when the water temperature is in a certain range. So -- and they will spawn almost exclusively in air with a substrate range between, oh, 4 and 5 millimeters up to 60 or 70 millimeter diameter. That's the predominant type of substrate.

So you can identify these areas, you can identify the time of the year that the spawning is going to occur and then, of course, as I said, what's the best flow -- at least adequate flow, for spawning? Once you achieve that, the -- that's enough to cover that area you've identified as spawning ground.

Q How do you do that? How do you decide how much is enough water for spawning?

A You have to cover the spawning gravel to adapt the -- we might say 6 inches. We want to have a minimum depth of 6 inches, at least, over this main area we have identified that has the ideal spawning substrate.

Q So you need to know where the spawning grounds are on a particular river?

A Yes.

Q All right. What do you do next? Let's say you've got the spawning element covered pretty well. What do you do then?

A Well, let's say we were going to put this information into a mitigation plan for this development project upstream. We then request the -- a flow regime that would, say, maintain a 6-inch depth over these, is spawning zoning, and that had already been figured. Translate that into cubic feet per second, we could give the time of the year that would occur at.

And then the next recommendation would be that then you should not drop it to less than 4 inches during the incubation stage, that could be translated into a cfs flow. And then ideally at the time of hatching, we'd like to keep the -- really keep the flow low to get the young fish out and started in life.

You might reduce that to a 2-inch flood

-- or level at a certain cfs.

Q At the spawning ground itself or somewhere else?

A Right downstream from the spawning ground. Or to mitigate by, perhaps, constructing side channels or reactivating old side channels. But the young fish have to get essentially in areas of zero -- very low velocity to get started in life or they are just simply swept down the channel.

Q In order to come up with recommendations as to particular flow rates, would you then need to transect at those locations below the spawning ground?

A That would be on the -- how much data has been collected on the stream; how important has the stream been historically. But this would usually be done as part of the EIS for this water project development upstream. So all of this data would be available to me.

If I was called into the case, I may point out to them early on, you should have some kind of quantified data on the rearing habitat downstream. How does that relate to the success of the reproduction?

Q So in order to give an opinion as to the nursery stage, you would prefer to have transect that showed you the configuration of the stream --

A I would really prefer --

Q I'm sorry, you've got to let me finish.

You prefer to have these transections that showed the configuration of the stream channel below the spawning grounds; is that right?

A No, I would much prefer to have the actual empirical data of the fish population itself, like the Division of Wildlife sampling of the young fish, which is the manifestation of the success of spawning, incubation and hatching out up to that point, say, in the late summer.

So -- and then look for the periods that, as of certain years, have been failures. And then correlate why have they been failures, or certain years have been great success? Why have they been great successes? That is much more informative in arriving at, you know, a judgment than all that transect data.

Q So if a particular flow regime historically produced successful reproduction, would you come to the conclusion that it was a desirable flow regime?

A If you looked at the historical flow

regime, you saw that successful reproduction occurred within this range of flows, say, in -- for these months, these different -- you plot the different ranges of hydrographs that had produced successful flows, there certainly --

Q You mean produce successful --

A Successful year-classes. And you would recommend that your development would keep your future flows within this range.

Q Now, you talk in terms of ranges. What's the level of precision that you can make these recommendations? Do you always talk in terms of broad ranges or can you be more precise?

A No, dealing with natural systems with the enormous complexities and uncertainties built in, anybody who talks about precision outside of the two extremes, no water, no fish or too much water, no fish, in between that is an enormous range of uncertainty that precision is not possible.

Q What kind of ranges are we talking about?

A It would depend on individual streams. I would look at the data, I would say, on the Gunnison or the Taylor River, the -- say, the Gunnison was very clear with the Bureau of

Reclamation, the year-class fails were associated with the spill over the dam grade at flood stage or when the water was essentially shut off. And they are very -- you could definitely see what happened to those fish in those years.

But in between there's a wide range in there that had produced quite successful year-classes, and trying to say which is the best, so -- but the main goal is to maintain a viable, valuable trout fishery there. So you know they have been successful in this very wide range, so at least we have something to go on.

And we do know that there's going to be a failure if we go below here or above there (indicating).

Q Let's go back to the hypothetical on the Michigan River and think about the adult life stage. What would you do in order to make recommendations about a particular flow regime for the adult life stage?

A Well, often small rivers like the Michigan, unless, you know, beavers come in and build a pond, there is limited adult habitat. These streams are very good for producing spawning and rearing the young, but there's just not much toward, you know, large volume habitat for adults to thrive in. So, often a beaver pond does wonders for some of these streams.

Another option is to try to throw like a -- take a whole tree, the roots and all, and lock it into the bank. And this will create -- over time, this will create a -- if you just look, going along the stream, you will find the best natural habitat where a tree naturally falls in and over the years it works its way in.

And we try to duplicate situations like that.

Q What is the optimum adult habitat? How could you characterize it?

A It's probably more easily qualified -- in a qualitative way, for example, I would be finding it with an expert fisherman who fishes the stream, knows it very well, and watch where he spends most of his time casting his line.

He knows, by experience, where the largest trout are and where the highest concentration is. And that would -- and you could quantify that by his casting efforts, and probably very accurately identify optimum adult habitat.

We're trying to put that into a

quantification, which would be very difficult.

Q So if there was an expert fly fisherman who knew this stretch of the Michigan River very well and he took you fishing with him and you learned by observation where the adult fish were found, would those, then, be key habitat areas for the adult population?

A Yes. Those would be -- usually yes, they would be associated with some kind of a complex cover. But I -- we would also like, well, what kind of flows would you need to maintain that habitat as optimum adult habitat?

Q How would you do that?

A Again, this would be qualitative. You could express it in a quantitative basis, but habitat by individual habitat. In other words, we said -- there's a certain level that the water -- the surface of the stream, when it attains this level, creates this sort of underwater condominium under a root mass. And as it drops below that level, we lose, and this is exposed. So simply recording that level is one of the simplest ways to do it.

But you may go down to the next downstream, and it's not -- it wouldn't be the same flow.

Q Let's assume that our fisherman on the Michigan River takes you out to this stretch of stream and shows you the best adult habitat that he knows and you have this one site that's been identified. How would you determine the flows you would need to optimize that habitat?

A You would simply phrase the question: How does the flow relate to the habitat characteristics? What are the characteristics? And they would have to be identified.

Q They would have to be --

A You would never get them all because there's interacting.

Q They would have to be identified in relation to that particular habitat done on that particular stream, right?

A Why is this excellent habitat?

Q And you would have to answer that question in relation to that particular stretch of stream, wouldn't you?

A That particular site.

Q Is that a yes?

A Yes, to that site.

Q Would you then need to observe that site at different flows in order to come to your conclusions?

A Again, if this was a major project and I was hired to, you know -- it was a very important decision, yes, I would -- I, or have somebody -- recommend somebody to gather how would that habitat -- the factors that we have identified as key elements that make it excellent habitat, how would they change at different flows?

Q Dr. Behnke, we've talked about a process for determining the effect of various flows on fish habitat. Is there any published literature which you regard as authoritative in this particular area?

A On the correlating flows to habitat?

Q Yes.

A There's an enormous volume of literature, mainly from proceedings of symposiums. The U.S. Fish and Wildlife Service, through the American Fish Society, published the first two volumes of flow habitat work in 1976, and almost every year another -- some kind of a preceding (sic) volume comes out.

There's an enormous amount of, you know, published information. It ranges from various stages of good to bad.

Q But let's talk about the good. And I know you have some opinions about what is bad. Is there any literature in this particular area that you think is particularly authoritative?

A Well, I would recommend the Division of Wildlife's -- as I mentioned these -- their annual reports on their flow -- fish flow investigations. Because they have been using the same streams for, as I say, many years and have an annual sampling data. You have adult fish and you have young fish, and there you have a clear pattern in Colorado, the Rocky Mountain streams in general, that the natural flow regime -- really, the average to high flows are very detrimental to year-class streams.

It is the lower-than-normal flows that produce the best year-classes, mainly because of the gradients and velocity.

Q I am just talking about the literature that describes the methodology or the consentual approach to the problem.

A Well, most of these reports always include the methodology, and sometimes you have to go back to an original -- that was originally described at, I think, for example, the U.S. Fish and Wildlife Service, the IFIM, you will find that originally described in the 1976 report as the California method that was developed by -- oh, PG&E biologists.

Q Do you think that's authoritative?

A It can be authoritative without being correct.

Q Do you think it's correct?

A No, the only correction you can get on any kind of a method or methodology of trying to make predictions from natural, highly uncertain systems -- the only place you can feel confident is when you are into those extremes of negative correlations of no fish, no water.

I feel very confident about that, unless we're dealing with lung fish.

Q Let's talk about the range in between.

A And that's the uncertainty.

Q Is there any literature that you think is correct that describes the approach you should follow in order to make flow recommendations between the extremes?

A Well, I've done some of this for the Salt River Project. Some of my recommendations I was critical of trying to resolve the -- there was an endangered species or native fish assemblage in the Upper Verde River, which I had predicted could not be resolved by any methods or models.

Q Does your work describe your recommended approach?

A Yes. I recommended -- or simply what I had mentioned before, is to identify critical life history, which is usually reproduction. And we knew enough about -- we identify a critical indicator species, which, in this case was called a spikedace. You know the time of the year they spawn, the type of habitat they spawn in. And simply identify those areas that are critical for the spikedace reproduction in the Verde River, and to maintain -- what kind of flows do you need to maintain this habitat during either not too high or too low flows?

To give a precise recommendation, I said it was quite impossible unless you have many, many years of monitoring.

Q So it's really your own writings that would express your preferred methodology?

A As far as any methodology, one of my own writings was referred to -- I wrote a paper called The Illusion of Technique, where people are deluded by methods or models into thinking they are correct when they are not.

Q What other papers have you written that describe the preferred methodology, not criticizing others, but your own approach?

A I said there's no such thing as -- there should be no such thing as a preferred methodology. It's a -- it's almost like scientific programs in general.

You should -- anything goes. You put it all out there to contend with. What works the best? Something might work very well in this situation but not there. Something else works here. You have to be open-minded and be amenable to changing your mind.

Something's working here. Why? But why doesn't it work there? Often the exceptions to the rule are your best learning examples.

Q It sounds as though it's a very case-by-case, site-by-site approach to each problem; is that right?

A Let me --

MR. WHITE: Well, I'm sorry. What was his answer?

A Certainly. I said I'll give you -- let me see if I could give you a quick example of what we're getting at. Either where you had precise regularity in a natural system, and we're talking about -- let's get an example of tides. Tides come in and out and they are very predictable, because of the gravity. You don't have to know what causes them. But if somebody recorded these patterns of regularity, you could accurately predict into the future a tide table. I'm sure primitive people did this even when they thought the earth was not round, but your tide people are in the Bay of Fundy.

You go to San Francisco Bay, using the same laws of gravity, the same paradigm, the tide table's not going to work.

Q (By Mr. White) Would you say the same thing about habitat preference curves?

A They are site-specific.

Q Do you think they have to be site-specific in order to be applicable?

A Unless they are very generalized.

Q Are there generalized habitat preference curves for rainbow trout and brown trout which --

A Oh, my, yes, yes.

Q And are you comfortable in applying them to any river in the state of Colorado?

A It was -- some of my students at CSU put those curves together for the Fish and Wildlife

Service and I assisted with it. I advised or commented or critiqued. And one of my recommendations was not to just have a trout curve.

That -- I was looking for the most generalized way to handle the problem and I recommended going just for a trout -- not have a brook trout, a brown trout, a rainbow trout, a cutthroat trout, they are still here. And simply they said, Well, the way the Fish Service operated, they were being credited for those bulletins that they produce. So it was much -- they had to produce all these different species, even though they realized it didn't mean anything.

Q Would you be comfortable applying a generalized trout habitat preference curve to the Black Canyon of the Gunnison in order to predict the effect of streamflows on fisheries?

A According to the accuracy and the precision of your prediction, I would never try -- attempt a precise prediction, plus or minus 10 percent, that the biomass will change to 350 pounds per acre if you do this. I would never do that.

Q Well, how would you use a generalized trout habitat preference curve on the Gunnison

River?

A There was the -- really, the only thing we were concerned with in the Gunnison, mainly, was the reproductive success. Once the fish -- the trout spawn and the young got started by late in the first year or early the second year of life, they could withstand enormous flows, because in the canyon areas they could always find air no matter what the flow was. There were always pockets of, essentially, zero velocity. You shut the water off in the Gunnison River and you got a series of ponds, you might say.

So once the -- once you know how canyon areas react to flows, the critical point is getting enough young established into that first year, into the second year of life.

Q Do habitat preference curves have anything to do with that analysis?

A Well, yes. The critical ones were the preference of the -- what is called habitat suitability curve of the spawning and the young of the year. Those are the -- and I said you could correlate them or fine-tune them into the actual data of -- U.S.G.S. data on the Gunnison. You will see a good correlation with the future year-class success of the trout populations then.

Q And that curve would tell you that at that life stage the fish like as close to zero velocity as you can find?

A Well, as I have pointed out is that there is no need for a curve or a model. I arrive at the same conclusions that Barry Nehring -- by looking at U.S.G.S. -- did. The advantage of having a curve or a model is as a communication to nonbiologists, as I said, using the illusion of technique.

Q You're talking to one. Would habitat suitability curves be useful in predicting fish habitat in, say, the Taylor River?

A I would say they wouldn't tell me anything I didn't know, if I looked at the original data that it was based on.

Q Well, I'm talking about a generalized curve.

A Well, there are curves constructed for the Taylor.

Q Who conduct -- who constructed them?

A The Division of Wildlife. I think you will find them in the 1984 -- I think the 1984 of the -- the annual report, as I told you, this instream report. I don't think the -- let's see -- I forget if the curves are actually given or just the flow recommendation.

In other words, a table -- where you would find some of those reports, you would find the Taylor River curve.

Q Do you agree with those curves?

A I have nothing to disagree with. I do know that the -- they have a curve that was cut -- taken in the Gunnison River below the junction of the Taylor and the East that had optimum flows less than that of the Taylor, which obviously is wrong.

So you realize the limitations you have of using what are called the illusion of quantitative data or confusing quantitative necessity or sophistication with reality.

Q Would you be comfortable using the Division of Wildlife habitat suitability curves on the Taylor River?

A Let's say I may be just as uncomfortable using that as anything else, knowing the uncertainty involved in trying to make these kind of predictions. As I say, it's a start.

If it's used as a learning tool to improve on in the future, fine; but if an agency or personnel go out there and accept that as proven scientific truth, that is simply nonsense.

Q Well, let's talk about the Taylor River. We had a start, we have the Division of Wildlife's work. Have you done anything else to improve on that?

A No. This Collegiate Range Project, my -- my total involvement here was simply to come up with cost estimates. And it was mostly secondary of, do I see any really significant problems, environmental problems of -- you know, that relate to fisheries or endangered species or anything?

And that -- you will see all these comments are in there -- and that's been -- in fact, I think my total involvement all of last year came out to about four days.

I spent most of this past weekend trying to refresh my memory for the deposition, so at least I would remember what was going on. But I had very limited -- I assured I would keep my expenses to a minimum.

I would -- for a reconnaissance-grade survey, I would look at, you know, some potential costs where the issues are going to be raised, and just provide that information to ERO.

Q Did you do any fieldwork on the Taylor River?
A No. I spent four days of my time. I think one day was devoted to a meeting, maybe in Aurora, and then the rest of the time was an hour or two in Fort Collins, you know, over -- whenever they would give me a call or send a letter up, What about this question, that question?
Q So it was either in meetings or in your office?
A Mostly in my office, over the phone.
Q Or in meetings?
A I had -- we had one meeting, I think, that I attended last summer.
Q So in terms of the specific information that's available about fisheries on the Taylor River, from the Division of Wildlife, you haven't done anything to go beyond that, have you?
A No. I advised ERO, and I think, Mr. Dingess here, that I kept my involvement in this case at a very -- just as, call a reconnaisance-grade contribution, based on just the knowledge and experience on a similar situation.
And if I continue on the project, if it goes to that stage, and then the specific questions

are -- or the specific issues are raised by your group, or Division of Wildlife, then let me see what they are.

And then I would put more time in to respond to them or advise you to get somebody to respond to them.

MR. WHITE: Why don't we break for lunch.

(The deposition recessed at 12:05 p.m., February 6, 1990, to be reconvened at 1:15 p.m. of the same day.)

AFTERNOON SESSION 1:15 p.m.

EXAMINATION (Continued)

BY MR. WHITE:

Q Dr. Behnke, you used the word optimize fishery conditions, or optimum flows. Can you tell me what you mean by that?

A We've got a problem with words and meaning precision. To give you an example, now like we're talking about, you know, Division of Wildlife's Taylor River flow investigation. One of the -- as I recall, one of the best optimum type of flow regimes in the Taylor appeared to be that during the winter months, like October to March, the minimum and maximum flows didn't vary too much, but maybe between 200 to 500 percent mean minimum versus mean maximum.

Those conditions seemed to produce the best success of year-class. Now, okay, that's -- as best we can say, that's a -- that type of flow regime would optimize conditions based on taking Division of Wildlife's word for it that their sampling data, long-term observations, are correct, we would optimize there. But you wouldn't say, wait, well, how about if one -- there was only 1.5 times difference? Would that be better than two? More optimum?

So the point, I think, from our -- you got from our discussion this morning, is that my sense of the use of the word optimize is a wide range of optimum flows.

Q I was just trying to get a sense for what you meant by the word. And I gather it means --

A Yeah, I would look for just what I -- the example I gave would be an example of how I would try to optimize.

Q And optimizing is a way to produce the best success for each year-class; is that a fair statement?

A If natural reproduction seemed to be a major limiting factor on the population, we would optimize reproductive success.

Q Is there such a thing as an optimum flow regime for a particular trout species in a particular river?

A I'm sure there is, but we would never know with any precision what it is.

Q Is there a difference, in your mind, between an optimum flow and a minimum flow?

A A minimum flow implies the -- like I say, the least amount necessary to get by. And the assumption based on that is that a minimum flow would result in reduced abundance, say, you know, the spawning period or -- of adult habitat or whatever, that it's less than optimum but it would be adequate to maintain the population.

(Pause.)

Q (By Mr. White) I would like to ask you about some particular methodologies. Are you familiar with the R-2 cross methodology?

A Yes. Essentially that was the example I gave this morning about the wetted perimeter.

Q Are you familiar with the way in which that's applied by the Colorado Water Conservation Board?

A I don't believe I stated an example. That was directly applied for their filing of water rights, but I recall years ago how it was originally proposed and there might be some modifications in it.

Q As you understand it, how is the R-2 cross method used by the board?

A A cross-section across a stream channel is made and usually -- supposedly that -- the site that's selected where the cross-section is made is often called a critical riffle. It's a controlling point for the -- that accurately -- or relatively represents what's going to happen downstream over a large section of the river is controlled by the water going through this riffle.

And various ways are used to come up with a minimum or optimum or adequate flow based on how -- essentially two main criteria I have used. One was the depth across the critical riffle, and the other was the percent of the wetted perimeter that a certain flow would cover of the stream channel.

Q Were there particular quantitative factors applied to depth and wetted perimeter?

A Yes, it would vary. I don't know what the water board used but, you know, I can recall in different situations, 70 percent of the wetted perimeter was called for; 6-inch minimum depth was called for; maybe 1-foot per second velocity was called. But various things could be built into the data you would collect from a cross.

Q Could you use the same data to design minimum flows as well as optimum flows?

A Yes. Probably most of the original methods were used for minimum flow that would -- like that would -- for example, I remember one of the -- one case I can recall is, say, I'm going to have steel trout and would have to traverse a riffle upstream to spawn. These are relatively large fish. Let's say a minimum flow had to be at least 6 inches deep to let these big fish traverse the river.

That was one way of arriving at a minimum flow. But it's been used in a variety of ways with different conditions, different fish.

Q How does one define minimum flows based on the percentage of wetted perimeter?

A Really a judgment is made, someone thinks that when less than half of the stream channel is covered by this critical riffle, that would be a critical low flow, that below that you would lose too much habitat to remain viable. But really, it's a judgment call.

Or it could be quantified as an expression of the -- the old Montana or Tennent method as a percent of the average daily flow, and that could be expressed as a percent wetted perimeter.

Q Do you have an opinion as to the adequacy of the Tennent method as a means of determining minimum streamflows?

A As good as any.

Q What about the percent of wetted perimeter method?

A Good as any. But I said they could be combined. You could express a Tennent method as a percent of a wetted perimeter.

Q Now, you've written quite a bit about the IFIM methodology, haven't you?

A Yes. That was one of the examples I used in my Illusion of Technique paper.

Q Do you think that the IFIM technique is properly used at all instream flow studies?

A If it's used as a learning tool, you can -- shouldn't help but learn from it and how to do it better. You can fine-tune it, but I say usually when you're at the -- talking about accurate predictions, it's like, as I said, predicting the Super Bowl after it's over.

After you've seen the year-class results, then you build in your -- the flow that put it there.

Q You mentioned work that the Division of Wildlife had done in the Gunnison River Drainage. Was that based on IFIM modeling?

A The earlier Taylor River flow investigation was using the cross -- R-2 cross-section, I think, by Walter Burkhardt. And IFIM superseded that, I think, later in the -- I don't know, in the 1970s.

Q So it's your understanding that the Division has used IFIM on the Taylor River?

A Oh, yes. The Taylor River is one of the -- are the longest monitoring, you know, flow -- fishflow relation in the state. I believe it's one of the very first, I believe, that was done.

Q Do you have any objections to the way that the Division has used IFIM on the Taylor River?

A In what way? I don't know what the -- how do they really use it? They have come up with recommended flow regimes.

Q Do you have any objections to the way that they've used IFIM in coming up with their recommended flow regime?

A I would have to go back -- I don't believe so. I don't recall any specific objections. I would -- this would be at a later stage, if the -- if I continued in this case and Division of Wildlife or your clients made a claim based on division IFIM that I wasn't familiar with at this time, I could take -- in the future take it and I would object to it. I would say, wait a minute, this is not correct.

Q But you haven't done that yet?

A No.

Q Did you review any documents in preparing for your deposition today?

A Just the -- all of the documents that were sent to me by ERO, which they -- like they got flow data from Enartech and whatever was -- you probably have it in front of you there.

Q I'm not sure that I do. What did ERO send you?

A You took an ERO deposition last week. I assume -- I think everything that must have been mentioned there was -- if it related to fish or values of fish or anything like that, it would have been routed to me or I would have been questioned on or asked about. You can -- essentially, you could tell what I got from that paper there (indicating).

Q Just to dispel the illusion of technique in the way I'm taking this deposition, Dr. Behnke. I have an ERO report which I will hand you. It's been marked as Exhibit 172.

I'm not aware of any other documents relating to fish that ERO might have prepared or sent to you.

A (Deponent examined exhibit.)

No -- the questions that were raised in there (indicating): Does that identify where I got these?

These were brought up to: What about this or that? And I responded to it.

Do I identify the source of this information?

(Deponent examined exhibit.)

But a lot of what I said is incorporated in here (indicating).

Q Let's try to keep our record clear and mark, as an exhibit, the materials that you brought in this morning.

A Okay.

(Exhibit 196 marked.)

Q (By Mr. White) I have handed you Exhibit 196. Could you identify that, please?

A This is a -- notes I sent down -- well, if this is dated November 8th and this is October 6th, it wasn't for this report.

On November 8th I sent down to ERO people a summary of -- what?

(Deponent examined exhibit.)

Okay, this -- economic analysis -- the

things I thought pertinent to the Collegiate Range Project. This here concerns a CSU technologic analysis (indicating) and these are habitat suitability curves used in that analysis.

Q If I could interrupt you, Dr. Behnke, you're going through Exhibit 196. Is it fair to say that Exhibit 196 is a collection of the materials which you sent to ERO?

A Yes, this is a copy of materials sent to ERO.

Q I would like to go back to my previous question and ask you: What information did you receive from ERO or Enartech or Mr. Dingess or any other source in doing your work on the Collegiate Range Project?

A Well, let me try to refresh my memory by looking here.

(Deponent examined exhibit.)

Okay. I received a -- I got something on a fax machine and was asked -- well, I didn't see anything urgent, I claim. But operation of Blue Mesa -- oh, I see, these are questions I phrased.

Obviously, I received data on the operation of Blue Mesa Reservoir and flows in the Gunnison River. This page that has an October 9th date on this -- Exhibit 196 must contain two parts, obviously, November 8th and October 9th.

But this -- the October 9th concerns flow -- projected flow scenarios, cost -- fishery costs associated with stocking the reservoir; another comment on the -- they are trying to estimate the cost of replacing Roaring Judy Hatchery.

(Deponent examined exhibit.)

That's about it. Mostly it's based, I guess, on the flow regimes that were prepared for ERO -- that ERO supplied to me.

(Deponent examined exhibit.)

That's about -- like I said, I did not put much time in this project. And I tried to go through everything this past weekend to refresh my memory, but it seemed to me it was quite routine material.

Q What were you asked to do?

A I was asked to do what?

Q Who hired you?

A The ERO people. They have also -- they have been associated with me on the Salt River Project in Arizona for several years and -- how I got involved in this, I -- I'm trying to recall.

But I -- they've used my name for, you know, for doing -- as an advisory capacity. And evidently they asked me last year that they were -- they were doing something on the Collegiate Range, which I was familiar with, and I just said yes. You know, they have used my name.

And so then last summer, they asked me to look at the -- this project, on what they call the reconnaisance evaluation.

Q What did they ask you to do?

A Estimate costs of -- if the project was constructed, what kind of costs would be associated with fishery mitigation measures. And that's about it.

Q What information did they give you?

A Oh, there would be two reservoirs constructed and one -- a major cost would be the eliminate -- or the flooding of a major state fish hatchery, the Roaring Judy Hatchery.

What would it -- what might it cost to replace that hatchery. What I -- I developed a potential cost of managing these reservoirs, you know, stocking trout in the reservoir. But the Division of Wildlife might come up to request fish management costs.

Q Let me ask my question again. What information did they give you?
A Essentially something like this (indicating). It was an earlier -- maybe some kind of earlier explanation of what the Collegiate Range Project was all about.
Q You're looking at Exhibit 172?
A Yes, there's something before this that I got last summer.
Q From ERO?
A Yes.
Q What was that?
A It was a -- just a, you know, project description of the Collegiate Range Project. And I don't recall who -- whose name was on it.
Q Were there reservoir locations contained in that?
A Yes. And even, as I think you can see from here, there was some kind of -- not enough, I needed more information -- but there was some -- that on the reservoir locations, operation, or at least the drawdown regime and volume and . . .
Q What about hydrology? Did they give you any hydrology information?
A I got that later, I think. There was an

engineering form, Enartech put out a -- you know, the hydrology chart that had their different scenarios of operation.

Q So you got some information from Enartech?

A And through ERO.

Q What other information did you get?

A I don't recall anything of significance that I can recall that -- essentially what I responded to was in -- are in these two memos here.

Q Let me show you Exhibit 129.

A (Deponent examined exhibit.)

Okay. This is October 2nd, the date. Now, this -- what would -- the ERO people send just the -- I don't recall this document, but if it had relevant flow information in it, they would send me the flow data. But I don't recall -- if they sent me this, I don't recall it.

Q Look at the tables in the back of that exhibit.

A (Deponent examined exhibit.)

Q Did you have those tables --

A Texas Creek Pipeline Diversion. Let's see, Table 6 concerns the Taylor-Platte Aqueduct.

(Deponent examined exhibit.)

If I had this document, I would probably -- I wasn't asked any specific -- to comment on any specific parts of it, or I didn't see anything of great significance at this time that I should devote time to.

Q In doing your work for ERO, Dr. Behnke, did you have any information about flows in the Gunnison or Taylor River which would occur during project operation?

A Yes, I had the pre- and post-project flows.

Q And in what form were you given those?

A I think it was average monthly. The recorded flows covered like a 30-year period or more and that same period was projected ahead for the next 30 years, you know, what the flows would be with the project but different: Taylor Reservoir maintaining full capacity, as one scenario, versus another.

Q Was this information in tabular form?

A It was in tables, you know, just columns of data. I would just look at the bottom line, you might say, for the means.

Q So you looked at the mean values for the period of record?

A Yeah. I would then do it month by month to see what kind of change you might expect for the Taylor and the Gunnison.

Q If I can summarize, then, you had a project description that told you where the proposed reservoirs would be located and what their capacity and operational regime would be, and you had pre- and post-project hydrology on the Taylor and Gunnison Rivers. Is that right?

A I think essentially right.

Q Did you have any other information?

A I had information on the Roaring Judy Fish Hatchery, as I recall.

Q Where did you get that?

A ERO sent me something about the Roaring Judy Fish Hatchery. It didn't -- I don't know, we didn't get an accurate cost estimate, but it did have something about, you know, the production, mainly, on the number of fish, the different species, the total pounds produced.

Q What other information did you have in doing your work for ERO?

A I can't think of anything. Can you suggest anything?

Q Well, what about the Division of

Wildlife reports on the Taylor and Gunnison Rivers?

A Oh, I discussed those this morning. Yes, they had, as I said, a long series of instream reports that I used for the Taylor and Gunnison. Now, they are mentioned in the -- my comments here.

Q Is there anything else you can think of?

A No. Again, if you can stimulate my memory, maybe I could. I'm not trying to hide anything, but I can't think of anything.

Q With this information, you were asked to estimate costs for replacing the Roaring Judy Fish Hatchery; is that right?

A That was one of the cost -- that would be a major cost that I focused on.

Q What other work did you do besides that?

A Well, the -- I think I addressed several issues. One was the transport of the Mysis shrimp in the Taylor Reservoir over to the South Platte.

I also pointed out that there hadn't -- I didn't -- at least in the preliminary data sent to me, I didn't see anything about a minimum pool or conservation pool built into these reservoir operations.

Q I just would like to get a list of the particular aspects of the project which you focused on.

We have Roaring Judy, the issue of transportation of Mysis shrimp over to the East Slope, minimum pools or conservation pools built into reservoirs. What else? What other aspects of the project did you focus on?

A Fish-stocking of the reservoir.

Q Which reservoir?

A Both -- any reservoir that would be built. I would assume the Division of Wildlife would come up with a mitigation cost of stocking that reservoir.

Q And were you asked to come up with particular numbers, dollars --

A I just made them -- I just made a scenario, you know, something that the Division of Wildlife might propose.

Q What other issues did you look at?

A The recreational use in the Black Canyon of the Gunnison, the gold medal trout water. What we might perceive as an impact down there from the change in flows.

Q If I can paraphrase, then, you looked at the effect, which is what a proposed flow regime would have on that gold medal trout water; is that right?

A Yes. Its not in great depth because I had already done that, you know, some years ago, for the AB Lateral.

Q What else did you do?

A I think that's about it, unless you can refresh my memory. I might think of something else -- I think everything is in this -- if you can go through these documents, if there's anything I missed, but that is essentially the sum of my contribution to the -- to ERO to the Collegiate Range Project.

Q Do you consider yourself an expert in the economics of building a fish hatchery?

A No. I think I have the recommendation in there that if you get to that stage, then you call in an authority.

There used to be called Chin, Mayo & Kramer, they were an engineering corporation that specialized in designing construction of fish hatcheries. You would not use Bob Behnke for that.

Q Did you form an opinion related to the Mysis shrimp problem?

A The opinion is there won't be a problem because they will just be transported to an area that's already been subjected to Mysis shrimp via Twin Lakes.

Q That being Antero Reservoir?

A Yes. That the -- that all of the reservoirs in the South Platte are -- have been too shallow to establish Mysis shrimp. They have been --

Q You mean all of the existing reservoirs?

A The existing reservoirs.

Q What about Two Forks?

A Well, they are going to get Mysis from Twin Lakes.

Q So your conclusion was Mysis are already in the South Platte and this won't make it any worse?

A Right. They are established in a reservoir in the headwaters and they are constantly being pumped over there out of Twin Lakes.

Q Did you form any opinion relating to the minimum pool or conservation pool in Aurora's proposed reservoirs?

A No. That would take, you know, much more time trying to come up with a -- my estimate. That would -- that's part of the -- I believe, the Fish and Wildlife Service Coordination Act, using Forest Service land. The Forest Service, in consultation with the U.S. Fish and Wildlife Service of the Colorado Division of Wildlife, would request a minimum pool.

Q I would like you to look at Exhibit 196, the 11th page of that exhibit, in the middle of your handwritten comments on sensitive issues.

A Okay. The hatchery placement costs.

Q I'm looking at a place that has Reservoir Operation in the middle of it.

A Okay. Yeah, Pieplant.

Q Do you know -- at the bottom there's a sentence beginning, "I would doubt that permits for reservoir construction would be granted without minimum or conservation pools."

A Right. I wanted to let them -- whoever the engineers are, who would put this together, I think, were aware of the Fish and Wildlife Service Coordination Act. It's a Federal law that licensing agencies for fishery products have to consult on, you know, fish and wildlife values and mitigation plans built in.

So the Forest Service, even if they wanted to give a permit to Pieplant or Almont Reservoirs without any reference to a conservation pool, they couldn't do it.

Q What do you mean by a minimum or conservation pool?

A It's usually an amount of water left in the reservoir; it's like a minimum flow. It's a minimum volume that supposedly is enough water to get your fish population at least through the winter, or through some critical part of the year, into the next year.

Q Did you see any proposed minimum or conservation pools for the Pieplant or Almont Reservoir?

A Well, not the -- at least the first -- see, that was part of my job was to find these kind of problems. And I said -- at least in the early operational regime, I assumed, from the engineering firm, didn't have -- point out there wasn't a conservation pool in there.

Q Did you see any later operational regime that did have such a pool?

A No. I did converse with -- who was it, Mark Dehaven or the other ERO fellow, after this on the phone and he said that, you know, this was a very preliminary and -- and once they have talked to the engineering people involved in that and they say, you know, there's no trouble in manipulating these waters.

Now, I haven't seen what these manipulations are going to be but they said they didn't see a great problem in building a conservation pool or an operational regime into these reservoirs.

Q Do you have an opinion as to what conservation pools would likely be required for Pieplant Reservoir?

A No, I wouldn't hazard a guess on that.

Q Can you give us a range?

A They could range anywhere from, you know, 10 to 25 percent of the volume.

Q Would you say the same thing about the Almont Reservoir?

A Probably. That's just a range of -- that's usually used in minimum pool estimates. But it varies from site to site.

Q Did you form any opinions about the cost of fish stocking in the reservoirs?

A Yes. I used an assumption that catchable trout would be stocked. That's the most expensive type of management. And I said typical -- I just give an example of how the Division of Wildlife might be expected to come out with a scenario of cost.

They want -- they have a goal of maintaining so many angler days of use. To maintain that many days you stock so many fish, and it's usually expressed on a per-surface basis. So I just gave an example, following that type of -- you know, it's a very simple procedure. And not what the cost of the fish may be.

I just pointed out that would be a cost -- obviously a cost to be figured in. If you do build these reservoirs, they will be managed and stocked with fish.

Q Did you form an opinion as to the effect of the Collegiate Range Project on the gold medal trout waters in the Black Canyon?

A The Black Canyon, I came out with a slightly positive benefit, mainly because it would probably increase recreational use. In June, the flow would decrease a bit, say, from 1500 to 1200 or something like that, as I recall.

And most of the recreational use is rafting through there and that usually decreases after -- above about 1,000 cubic foot per second because of the high velocities.

Q Who told you that?

A That's in these Division of Wildlife -- you know, the annual flow reports. They had to compare two years with high flow versus average flow and the use -- recreational use that greatly declined, exceeded 1200 cfs.

Q Based on the hydrology which you were given and anything else you knew about the project, have you formed an opinion about the effect of the Collegiate Range Project on the fishery in the Black Canyon?

A It would probably be negligible. It could be slightly beneficial in that the early flow reduction would come at the time when the young -- the very vulnerable young trout are coming out of the gravel. Then any reduction downwards, optimally there should be about 200 to 300 cubic foot per second, I think, would be ideal for their survival.

The amount of change is going to be negligible, but I wouldn't argue for a benefit or a -- either positive or negative change.

Q Do you have an opinion as to what the optimum flows for all life stages of trout in the Black Canyon are?

A No, unless it was given in the -- one of those Division -- I think they do have different life stages. But as I said, the critical -- the only one that really is important that has some kind of validity, as prediction goes, is the young of the year, the hatching of the new -- the baby trout.

Once they are established by the next year, they are well-established and enormous fluctuation flows do not seem to bother them after that stage.

Q So what is your opinion about the optimum flows in the Black Canyon?

A The optimum flows probably relate more to recreational use, the flows that are in the range of -- that the fishermen use --

Q What --

A -- attract them.

Q What are those?

A Those are about -- the optimum seems to be about 500 to 1,000 cfs.

Q During what time of the year?

A Well, any time that's warm enough for the fisherman to go out and fish. This could be as early as May or as late as October.

Q So it's your opinion that from May to October, flows in the range of 500 to 1,000 cfs would be optimum?

A Optimal for rafting, and probably in the range of anywhere from 250 to 500 or more optimal for the trout, at least getting the young trout established.

Q What about for the fishermen?

A I said the fisherman, they use -- they prefer that range of -- well, it depends if you're a shore fisherman or boat. The shore fisherman likes it lower on the shore, the boat fisherman likes -- likes about 4 or 500 cfs where they can get the rafts over the rapid areas, not hitting rocks.

Q What do the shore fishermen like?

A I haven't seen any good data but I'd say probably more in the range of 2 or 300, really, because that would allow them to fish more of the whole river channel. The higher the flow, essentially, then they are restricted right to the bank, because they can't get out that far.

Q So the optimum flows for fishermen are a little bit less than the optimum flows for fish, which I think you said were 200 to 500?

A I would say the optimum flow for the rafters is a littler higher than the optimum for the fish, but the bank -- the fishermen who wade, probably their optimum would be less than the rafter fishermen.

Q What are the optimum flows, in your expert opinion, for the fish in the Black Canyon?

A I don't know. I would have to go back to my 1981 or '2 type of studies that I -- analysis I made for the AB Lateral.

Q You haven't done any work since then as to optimum fish flows, have you?

A No. I don't recall anything in the Division of Wildlife Annual Gunnison River Flow sampling that changed my opinion from that time.

Q How long has it been since you read the Division of Wildlife reports on the Gunnison River and its tributaries?

A I was reviewing some just this weekend because -- obviously, that was part of my expertise of the business -- or my comment on Taylor and the Gunnison, because that's your major source of information on the Taylor and Gunnison fish habitat flow relations.

Q So can you recall what the Division of Wildlife recommendation is for fish flows in the Black Canyon?

A They did come up with a 300 minimum, but as I said, I recall probably no more than 300, at least for the young-of-the-year flow, the early life history flows.

Q Is that a minimum flow or a --

A That would be optimum.

Q During what months of the year?

A At the time the young hatch, which would be -- well, for brown trout it could be from April -- March, April, May; rainbow trout, April, May, June.

Q Do you recall what the Division's recommendations for optimum flows are during other times of the year?

A No. There they are mainly concerned, probably, with the raft -- the recreational use more than the fish, as long as a 300 minimum was maintained.

Q But that's a minimum flow and not an optimum flow? I'm sorry?

A The 300 cfs is a minimum flow that I believe the Bureau of Reclamation has agreed on.

Q In your opinion, other than the times needed for the young-of-the-year fish, is that also an optimum flow for fish?

A Again, my term optimum is somewhere between -- maybe 250 and 500 might be an optimum range.

Q In the Black Canyon?

A Yeah.

Q Do you have an opinion as to the optimum flows for rainbow and brown fish in the Taylor River below Taylor Park Dam?

A No, I -- I do recall the Division had come up with a table of flow recommendations there, a minimum and an optimum range by time of year and also by life history stage.

And, of course, you do have some built-in contradictions between these different stages.

For example, the optimum flow for the early life history, the newly hatched fish, is 50 cubic feet per second; the optimum for the adult was 250.

So, obviously, you couldn't -- if the -- if these indeed had a relationship to reality, this is indeed what they need, we would see a difference between the best flow for the young and the best flow for the adult.

Q At what point on the river are these flows being measured?

A I'm not sure if the -- if the cross-section analysis that they used to develop these were below -- just below the Taylor Reservoir or downstream near Almont, because both sections are mentioned.

And I believe both areas have been modeled, and the Almont Section, really, normally gets 50 or 75 cfs more than the upstream section.

But as I recall in the Division reports, it's not clear the -- the specific site is not clear. It just says Taylor River.

Q Do you have an independent expert opinion as to what the optimum fish flows on the Taylor River are?

A No, I didn't put the time in on trying to look -- do a great in-depth analysis. But I do recall that a very useful ratio seemed to be the one that was -- said, well, the -- really, the way to use -- well, Barry didn't correlate very well with the year-classes or biomasses. But as I said, really a useful indication seems to be expressing the ratio between maximum and minimum flow during the spawning incubation, early-hatching period.

And I would -- I would probably put more time into looking into that if I really got into this in a more in-depth manner.

Q If you could look at Exhibit 196, the

page just before the one we were on. The first sentence beginning, "I would point out that most 'superstar' type of trout fisheries . . ."

Do you see that?

A Yes.

Q About 10 lines down in that paragraph, there's a reference to reduction in flows during the spawning season.

A Right.

Q And increase at the time the young emerge. Do you see those figures?

A Yes.

Q What are those figures based on?

A That's essentially what I just explained about the Division's observations on the Taylor, and also the same type of observation on input that I made for the AB Lateral, was that you try to maintain stable conditions. The more stable -- especially during the spawning, incubation and early life history.

And, you know, given the range that you could really expect to do that, I -- it's fairly liberal there, but that is really quite stable, though, as far as natural flow systems go.

Q Is this a generalized figure that you

would apply to any river?

A If you don't know anything else. But the Division did have long-term data on the Taylor that supported these figures.

Q If the Division's figures were different than these general percentages, would you defer to their numbers?

A It's according to how -- how intricately I was involved in the case. Did it really matter to me or not?

Q Today, Dr. Behnke --

A Today, I didn't see anything I really disagreed with with the Division, or any real problems, you know, with the Collegiate Range Project with the Divisions's Taylor River flow recommendations.

If such a problem does develop in the future, then I would take the time to do an in-depth analysis and critique.

Q The second figure given here is a 300 to 500 percent increase at the time the young emerge and for several weeks thereafter.

Is that figure based on any study in particular?

A I was a little more liberal. The

Division said the best results came when the -- the increase was no more than -- well, I guess 200 to 500 percent of the low flow. And that's found in those annual flow study investigation reports.

Q What led you to be more liberal?

A Well, because -- I just thought it would be a little safer than -- I think I said 200 to 500, I -- it was 3 to 5, there's no big difference. 5 -- you try to keep it below 5, the factor between low and high.

Q What time of the year is referred to here for this percentage limit?

A The -- well, the total -- I also included the spawning and incubation period but not reduced it.

In other words, the minimum flow should not be reduced more than 30, 40 percent below what the spawning flow was. And then at the time of hatching, then that low -- the lowest flow should not be increased more than -- no more than five times -- less than a five-time increase.

Q What specific times of the year are referred to here?

A Okay. The times are given in the Division reports, because the Taylor River is almost strictly -- is strictly -- it's a brown trout natural fishery, the rainbow trout are only stock.

So the hatching time is given, I believe, from the middle of May to the first of July, something like that. May 15th to July 1st, as I recall, was the critical period, probably, for the -- to keep the flows down to protect the young.

Q That would be the 300 to 500 percent of low flow figure?

A Yeah. I think that was the -- the optimum flow that the Division came up with, that would be 50 cfs during that period.

Q And the spawning period on the Taylor is when?

A Probably mainly in October. It could start as early as September and run into November, but probably most of it all takes place in October.

Q What about flows from July through October?

A There are -- I guess now we're dealing with fishing flows, the flow the fishermen like to fish. And I believe the Division's optimum flow during this time would have been about 250 cubic feet per second.

Q Measured where?

A Again, I'm not sure if this is -- I believe the Almont area.

Q Now, you're reciting from memory figures from the Division reports. You don't have any independent opinion on this today, do you?

A No.

Q I'd like to ask you a few more questions about Exhibit 196. If you could turn to the first page.

A (Deponent complied.)

Q Your letter of November 8 to Mark, that's to Mark Dehaven?

A Mark Dehaven.

Q That was after the October 6th, 1989 ERO Report, which is Exhibit 172.

Were you doing some continuing investigations after October 6th?

A No. This just -- I just wanted to -- this, you know, has relevance to the Collegiate Range Project. And I just simply xeroxed these pages down and sent them down to let everyone know that there was a CSU economics survey project that they would -- if they didn't already know about it, they likely would.

But I said it was really -- it's an

academic type of exercise that wasn't really designed to help people make decisions on water use.

Q Are the people at CSU doing independent IFIM modeling?

A Fish and Wildlife, as -- as I understand, the Fish and Wildlife Service has done -- the Division of Wildlife has done all of the modeling and just provided the data to the economist.

Q Is this, then, Barry Nehring's modeling?

A I'm not sure. The upper figure here, which is Gunnison simu- -- simulated Gunnison River and the lower figure, Taylor River. The lower figure had been the Taylor River data, I did see in Barry -- you know, the annual instream report. The Gunnison figure, I did not see -- I wasn't aware that they had modeled the Gunnison River -- you know, below the junction of the Taylor and the East.

So I'm not sure where they -- who did this.

Q You are looking at the tables on the fourth page of Exhibit 196. Is that right?

A Right. The -- these two figures (indicating).

Q Are these -- are these your handwritten notes on this --

A Those are my notes. The point -- to point out the obvious inconsistencies between the two recommendations, you might say, the optimum flow regime, comparing the Gunnison River and the Taylor River.

Q Your note on the right-hand lower margin says, "Taylor River optimum habitat at 200 to 300 cfs"?

A Yes. I just -- you see little lines they drew up where you -- the peak, the sum total of all the life history stages pretty much comes between this 200 to 300 cfs level.

Q What's the peak for the spawning stage?

A Let's see. Which one is -- the spawning peak's a littler higher. But as I said, the difference between 35 and 40, especially with the precision of IFIM to make accurate predictions, is negligible.

Q I gather that you interpret these curves to be IFIM model output per se, without any adjustment based on experience or other factors?

A Well, this was the data that was given to the economist to put this study together.

Q Do you have an opinion as to whether

habitat, for any one of these life stages, is the limiting factor on fish biomass in the Taylor River?

A I don't know if the Taylor comes out like the Gunnison, the downstream. But in the Black Canyon there's definitely a good correlation between the reproductive success, the year-class strength, you may say, with future generation abundance. And this is a fairly common phenomenon in high evaluation rivers.

Q So spawning habitat, then, is the limiting factor?

A Not so much spawning habitat as the habitat right after the young hatch out.

Q Is that what's shown as "fry" on this table?

A Fry, yes. It would be fry habitat, with a little X.

Q So it's your opinion that the fry habitat's the limiting factor on the Gunnison?

A In some years. Other years, I've seen -- I told you when I looked at the old hydrograph, the U.S.G.S. records, where the water was turned off, the eggs would have died in the gravel. And in other years, the yearly -- yearly the fry habitat -- the negative correlation were too-high flows, the high velocity.

Q Do you have an opinion as to whether fry habitat's the limiting factor on fish biomass in the Taylor River?

A No.

Q What would you do to form such an opinion?

A I would go back and analyze the -- you know, just do a little more in-depth analysis of what is available. Probably talk with Barry Nehring about it, see if he's got some personal observation-type, personal communication-type information that's not in his reports.

Q Would you do some fieldwork yourself?

A I wouldn't do any -- if Nehring or the Division people, someone thought the type of work should be done, I would do it.

But usually, you know, it's for -- for most firms, you know, that would hire me, it's much more economical to let, you know, field biologists go out and do your sampling for you.

My job has always been mainly the interpretation, the presentation, the analysis of the information.

Q Well, if a client asked you to develop an independent professional opinion about optimum fish flows in the Taylor River, what would you need?

A I would have to give it some thought to what -- you know, what the species involved are.

I would see if -- mainly, I would go back -- since it has been well-studied, there's a good database on it -- to critically evaluate year by year, going back to Burkhardt's old sampling, to see if I do see some kind of pattern that we could talk about.

As I mentioned, that ratio of low to high flow from the October to March period, that seems to give you an interesting clue as a point to work on, to look into a little deeper.

Q You will forgive me, I hope, for being too comprehensive. But what else would you need?

A Well, that would be a starting point.

Q What else would you need?

A Well, as I go along, I would see what else developed.

Q Would you want to do some fieldwork?

A I may. I may suggest that there are some questions that are unknown. But you have to realize that the fieldwork often just -- the vagaries of sampling is such that it's often -- to get the type of data you really want to have may take years and years and enormous effort.

(Pause.)

Q (By Mr. White) I would like you to look at the note you wrote in the right-hand margin of these tables on Exhibit 196, beginning "Gunnison, below Taylor. . . ."

A Right here I have an arrow going up and it says Gunnison.

Q Yeah. What does that say?

A Oh, this -- the upper figure is the Gunnison River below the junction of the Taylor and the East River, which normally would have about twice the historic flow of the Taylor River. Right? Okay.

Now, if you look at the IFIM curves that developed, they say the optimum brown trout habitat related to flows there, really -- that area requires less flow than the Taylor above, which only has half the flow. So when I see something like that, I realize it's not reflecting biological reality and I call it to people's attention.

I did advise the justice department many years ago on early use of IFIM, how to defend it for a wild and scenic river designation.

Q These tables talk about brown trout habitat. There are rainbow trout in the Taylor River, aren't there?

A The rainbow trout are all stocked. There's essentially -- there is no natural reproduction of rainbow trout in the Taylor River, as I recall.

Q Does that suggest to you that it's not worth studying flow requirements for rainbow trout?

A Now, I think the -- my recommendation for the HDR-Gunnison Basin was to try to establish rainbow trout in the East and the Taylor River by the introduction of wild strains of -- of wild rainbow trout that have proved successful in Colorado rivers of similar type.

Q Do you have an opinion as to the flow regime which would optimize conditions for those particular species?

A As I mentioned before, there's really no consistent difference between flows -- between rainbow trout or brown trout, between the trout species that you could really have confidence in.

That was one of my recommendations at the Fish and Wildlife Service was to make a generic broad-based trout flow.

Q There is a difference in the time of year that they spawn and hatch?

A Yes, but the -- you see, the flows would be the same for the -- in other words, if we say the optimum flow for this spawning is this, and for that spawning is that, you could still have the same -- you want to maintain the same velocity through the gravel, it didn't matter what time of year it is.

Now there's the -- the optimum conditions for spawning in the spring would be the same in the fall except there is a different temperature regime, and you're really on a flow regime that was about -- the same optimum conditions that they will spawn in the same areas at different times.

The same conditions that governs survival of the eggs and the hatching of the fry are the same.

Q Is it possible that the brown trout, which have already hatched, would prefer a different flow from the rainbow which are spawning?

A Yes. This is one way you -- that does explain which species is dominant: rainbow or brown. When the spring flow is higher, it gets the rainbows more -- the browns have to come out earlier and may be well-established by the time the high peak comes along in June, or even July, and they could wipe the rainbows out.

In another year, this high peak may come earlier, wipe the browns out and the rainbows then spawn after, and they have a successful year-class.

So a lot of the differences in -- between maintaining brown trout and rainbow trout in the same river is a reflection of the flow regime of that river.

Q The preference -- or at least the disproportionate attention that's been paid to brown trout, then, is simply a reflection of their existing dominance?

A Yes, I believe so, because that's -- those were the only naturally reproduced trout in the Taylor.

Now, there are rainbows in the Gunnison and quite a good population in the Black Canyon. But that was one of my -- the HDR recommendation was because rainbow trout are really more attractive for anglers, they are easier to catch. You can support more angling use with rainbow trout, especially with special regulations, than you can with brown trout.

So I thought it would be a real plus if

we could get more rainbow trout established in the Taylor, East and Upper Gunnison above the reservoir.

Q I'm continuing to page through Exhibit 196, and am on the second page of your handwritten notes that begin, Collegiate Range Project Fisheries.

A Oh, the -- is this the October 9th memorandum? Okay.

Q Turn to the second page of that memo. The next page.

It has a number 2 in the upper left-hand corner.

A Okay.

Q The first word on the page is interest.

A All right.

Q Down at the bottom, you say, "The large drawdown proposed for Almont Reservoir may make it infeasible to use as a water supply."

What did you mean by that?

A That was for the operation of a hatchery. The logical place, I would think, to put a replacement hatchery there would be below the reservoir and operate it from the reservoir water.

But you need a -- to maintain optimum temperatures, you have to have the temperatures in the reservoir to draw from.

Q Do you have an opinion as to how Almont Reservoir could be managed to achieve such a temperature regime?

A No. I didn't give it much thought. I would like -- first, you want to see the -- you know, proposed limits of the reservoir, its volume and temperatures, are -- that would be the prerequisite.

Q And you haven't seen that yet?

A No, I'm sure that hasn't been done.

Q If you could turn to the next page. There's a paragraph towards the bottom of the page beginning, Stream Flows.

A Uh-huh.

Q You say you have not yet received any detailed, projected streamflow data, only figures on discharge from Taylor Reservoir. Did you ever receive any detailed projected streamflow data?

A Yes, I believe some were sent to me after that. But I believe, on the Taylor, I was operating on the assumption of flows not so much for fish but, for a legal basis, the -- an agreed upon legal flow. I think it was 50 cubic feet per second, supposedly, I was told, or the project would maintain all -- or meet all minimum flow requirements.

Q So when you say in that sentence that "figures on discharge from Taylor Reservoir would meet present minimum flow requirements," is that what you were talking about?

A (Deponent examined exhibit.)

It's not very clear. I would have to go over it again. Okay.

At this time I did not have the detailed flow done. Only figures from the discharge of Taylor.

Okay. Yeah, I guess what I had was to demonstrate that all minimum flow requirements would be met, but I didn't have the downstream flows at Almont or -- and these were sent later.

Q Well, what conclusions did you reach, if any, about the effect of the project on fish flows in the Taylor River?

A I didn't really, as I say, put the time in on it. Before I would do that, I would like to see, you know, the claims made protesting the project saying why these new flow regimes would be detrimental. And then I would respond to that if I was still involved in the project.

Q Would you look at Exhibit 172, please?

It's the ERO report.

A This one (indicating)?

Q Turn to Page 10.

A (Deponent examined exhibit.)

Q Do you see the paragraph which has the heading Taylor Reservoir, Potential Impacts?

A Yeah.

Q Is that your opinion that's stated in that paragraph?

A (Deponent examined exhibit.)

Probably. Most likely. I guess anything that relates to fisheries here is probably at least, in part, from me.

I think the idea was that Taylor Reservoir, as operated, has -- or historically has been operated on a fluctuating basis, and to maintain it at stable, full levels would certainly, I think, be judged beneficial from a recreational use point of view.

Q Do you have an opinion as to how full Taylor Reservoir should be to optimize fishery conditions?

A Well, I think the scenario that this refers to is -- it's full year-round, as I recall this. There is no fluctuation.

Q You like that scenario better than the one in which it's empty?

A Oh, yes. I'm sure -- you know, the boulders, the picnickers, the user group -- but that includes not only fishermen -- much prefer full reservoirs, stable reservoirs.

Q But you don't have an opinion as to the effect on the fishery of the reservoir level which is less than full but more than empty?

A No, you could -- it could be either way. It could actually be beneficial, it could be detrimental according to what fish species are involved.

Q But you haven't formulated an opinion on that yet?

A No.

Q Look at the next paragraph on Page 10 discussing Taylor River.

A (Deponent examined exhibit.)

Q The second sentence -- excuse me, the third sentence of that paragraph says, "Remaining flows will still be about 50 percent to 90 percent of average daily flows during fishing season and are about ideal for habitat maintenance and for angling."

A Yes.
Q Is that your opinion?
A Yes, that's the -- well, the 50 to 90 percent is ideal, is reflected both in the -- the Tennent and Montana method but also the game and fish habitat flow methods called the Habitat Quality Index, HQI.
Q That's the Binns methodology?
A Binns method.
Q And 55 to 100 percent is your most optimum fishery range?
A That was your highest correlation of correlating fish habitat to flows, those streams that maintain a base flow of 55 to 100 percent is the most ideal flow regime.
Q That's 55 to 100 percent of the average --
A Average daily flow.
Q -- daily flows?
And in your opinion, can those figures be generalized to all streams in any state?
A No.
Q Can they be generalized to the Taylor River?
A Well, it can be generalized, certainly, but the degree of accuracy is doubtful that that

would override everything else.

Q So your opinion in this report that remaining flows at 50 to 90 percent of average daily flows are ideal, is based on the Binns method and the Tennent method?

A Right.

Q Anything else?

A No. Everything else being equal, we're not changing food supply or water quality. The flow regime changes so that during the height of the fishing season, the flow would be 50 to 90 percent of the average daily flow.

That's the result of just about ideal habitat conditions and ideal fishing conditions.

Q What's that opinion based on?

A I said both the Binns method and the Tennent method are based on thousand -- you know, hundreds of streams in the Rocky Mountain region observation.

Q And are you comfortable, to a reasonable degree of scientific certainty, applying those methodologies to the Taylor River?

A There's no such thing as scientific certainty with what we are dealing with here.

Q That's why I said reasonable degree.

A Reasonable degree.

Q Can you state an opinion with a reasonable degree of scientific certainty?

A Reasonable degree of professional judgment, I would believe this would be a very good fishery flow.

Q Based on the Binns and the Tennent methods?

A Yes. That it's a -- it covers a wide range of situations and this -- everything else being equal, this should be an excellent flow for fishing.

Q What other things might not be equal?

A All kinds of things can happen. You can change the food supply for some reason.

Q Is the particular stream channel that you encounter a relevant factor?

A The stream channel is not going to be changed here. It was just a diversion, only the flow's changing.

Q So you think you can reduce flows by 50 percent and still have an ideal fishery irrespective of what the stream channel looked like?

A Well, if the flow volume through a stream channel was running at 150 percent of average daily flow and you reduced it by 50 percent, I would confidently predict you would have a vast improvement in both the fish habitat and fishing use.

Q And you would say that about any stream?

A Knowing nothing else, yes.

Q Now, if your client wanted your best professional judgment, would you rely on the Binns and Tennent methods or would you do something else?

A I'd ask for a question: Is there any reason to believe that it doesn't work in this case? Is there any -- why should this be an exception to the rule? Is there any evidence that it would be an exception to the rule?

Q Would you want to go look at the stream yourself and see?

A Yes. At that point if it became a key issue, then we would have a personal field inspection.

Q Have you been on the Taylor River, Dr. Behnke?

A Oh, yes. I've been over there, you know, many years ago, but not related to the Collegiate Range Project. One time, you know, I was collecting trout and fish specimens in the headwaters of the Gunnison Basin, all through that area.

Q How many years ago was that?

A Oh, the first time was, I guess, at least 20 years ago and then I have been over there maybe 5 and 10 years ago.

Q Where did you go?

A Over Cottonwood Pass, down the -- to the reservoir, up Taylor Creek, and Tincup and around in that way.

Q Did you actually look at the channel of the Taylor River below Taylor Park Dam?

A No.

Q At the bottom of Page 10, second to the last sentence says -- referring to the Taylor River below Taylor Reservoir -- "Flows for this reach will also be reduced, but with about the same impacts as the reach above Taylor Reservoir."

Is that your opinion?

A I don't remember writing that. If it's not -- most of what I put here is here. My stuff would also be in here.

Q When you say here, you're referring to --

A These notes here. My handwritten notes.

Q Exhibit 196?

A I would imagine that's a -- I read this and commented on it, so I -- I didn't disagree.

Q Is that your opinion today?

A I would have to give it some thought and critical examination, but I remember there was -- the percent change was not great.

Q What was the percent change?

A I don't recall. I had a little analysis, the major change was during the winter months, that to meet a minimum flow would be 50 cubic foot per second release from the dam.

That seems to be adequate to maintain the spawning and the incubation through the next year. The Division of Wildlife, I believe, was 75 cubic foot per second, is more optimum as a minimum flow.

As I say, I didn't -- I could not detect any evidence to support one position or the other.

Q Dr. Behnke, if Barry Nehring's recommendations as to optimum flows in the Taylor River, based on his knowledge of the river and experience and data collection, differed from the results of the Tennent method and the Binns method, would you give more weight to Nehring's recommendations or more weight to Tennent and Binns?

A I would see just how they differ. Usually the critical part of the Binns and Tennent is that percent-flow of the base, the low flow base period. And they don't really have much of a consideration for the spawning or the hatching flows that Nehring has stressed.

So I would take a critical look at Barry Nehring's flow and see just how they disagreed. And if they didn't -- if Nehring requested a lower flow during the early life history stage, he's probably got good data to base that on, and hold it down to maybe 20, 25 percent of the average daily flow to reduce the velocity, to increase year-class survival of the first few weeks of life.

If he has evidence to suggest this would be definitely a benefit, it would contradict the Binns or Tennent flow, but it's based on site-specific evidence -- if it is, I would agree with Nehring.

Q So if Nehring's flow recommendations are based on site-specific evidence, you would give that more weight than the generalized Binns and Tennent method?

A Depending on how the evidence is put together, the con- -- how convincing it is.

MR. WHITE: Do you want to take a break?

MR. DINGESS: Sure.

(Recess taken.)

Q (By Mr. White) Dr. Behnke, in considering the average daily flows in applying the Tennent method, do you look at a particular period of record?

A Yeah, you have to have, you know, U.S.G.S. records available or you can -- there are some, you know, hydrology form and precipitation watershed slope, all that, you can guess.

Q If your substream is below a reservoir, would you limit yourself to the period of records since the reservoir was put in?

A No, you would -- you really should use the -- the stream channel was originally a product of historical virgin flows. And now after -- how many years -- the reservoir -- it may readjust to the reservoir conditions. If that's the case, then you use the reservoir flows.

Q Do you have an opinion as to what period of record should be used to define average daily flows in the Taylor River below Taylor Park Reservoir?

A I believe the Taylor Reservoir did not change -- except for what was lost of evaporation -- didn't change the flow volume, and the annual amount of water going down the Taylor River stayed the same except what was lost with evaporation.

So the average daily flow really didn't -- you know, might have changed very slightly from the Taylor -- from putting the reservoir on the river.

Q So which period of record would you use?

A Well, it wouldn't matter. Any record that you were -- to get an average daily flow, just -- you know, the total acre-feet that go down -- flow past a point during a 365-day period, divide by 365 and you got an average daily flow.

The hydrograph itself -- the shape of the hydrograph undoubtedly would change with the reservoir, but the average daily flow really didn't change but very slightly.

(Pause.)

Q (By Mr. White) Do you still believe that the cash payment to the Fish and Wildlife Service for mitigation of water projects will be adequate to get a favorable biological opinion from the service?

A Well, this is the -- one of those

warning signals I put in. It's been assumed that an agreement had been reached between water developers in the Colorado Council and the Fish and Wildlife Service and endangered species. And the base -- the problem with that assumption is, under the Endangered Species Act, anyone can bring legal action that, say, the Fish and Wildlife Service is not enforcing the Endangered Species Act and, of course, this was done recently with the spotted owl case in the Pacific northwest. It's also done with the razorback sucker.

So if that's the case, then what I'm pointing out in here is that you cannot expect a guarantee that there is no endangered species problem.

Q Look at your memorandum of September 7th, 1989, which is towards the end of Exhibit 196.

A Is that under endangered species or -- which -- is there a date on that?

Q September 7th.

A Okay.

Q In the middle of the page there's a reference to endangered species. Do you see that?

A Oh, yes, okay.

Q Why don't you take a minute and read

that paragraph.

A Regarding endangered species?

Q Yes.

A (Deponent examined exhibit.)

Okay. That was the Southwest Water Conservation. I had a discussion with these people in Durango, Animas-La Plata Project -- we're reading from this page. Let me start again.

This is from the September 7th, 1989 letter I wrote to, I guess, Steve Dougherty, and it's regarding endangered species.

I had a recent discussion with people from the Southwest Water Conservation District, Durango, concerning Animas-La Plata Project. They were told by U.S. Fish and Wildlife Service spokesperson John Hamil that the Animas-La Plata Project is not automatically exempted by payment of water depletion tax into the conservation fund; that certain flows to the San Juan River would be required to avoid jeopardy to squawfish.

I said there are probably two reasons for this: San Juan River subbasin may not be covered by the Fish and Wildlife Service, Colorado Water Users Agreement; and two, such public proclamation would be deemed advisable to avoid a

legal action challenging any automatic exemption.
And that was a controversial project that would likely draw a wide range of challenge.
Q Do you have an opinion as to whether the Collegiate Range Project could receive an exemption -- if I can use your term -- based on a one-time water depletion tax payment?
A Well, supposedly they -- the assumption was they would do this. This would be a -- an agreement within the U.S. Fish and Wildlife Service and the Colorado Water Users that the endangered species conflict with water developers was taken care of with this agreement.
Q Do you have an opinion as to whether the project will be exempted?
A I don't have any opinion.
(Pause.)
Q (By Mr. White) Do you have an opinion as to whether the inundation of the Roaring Judy Fish Hatchery by Almont Reservoir can be mitigated?
A I don't believe I came up with a mitigation scenario, I just suggested it probably likely would be expensive, because the Division of Wildlife has a policy not to accept reservoir fishery as a replacement for stream fishery.

And the typical mitigation there would be to purchase access rights or private property on the Upper East River, I'd say, that is not open to the public now, and make it public access. I think this would be very expensive.

Q You're talking now about the loss of stream fishery --

A Right.

Q -- on the East?

Do you have an opinion as to whether that mitigation proposal would be accepted?

A I don't think any mitigation proposal has been made.

Q Well, the ERO Report discusses potential mitigation for the loss of that stream fishery as well as the stream fishery on the Taylor River. Do you have an opinion as to whether that potential mitigation, which is discussed in the ERO Report, would be accepted?

A No, I don't know.

Q Do you have an opinion as to whether the loss of the Roaring Judy Fish Hatchery, itself, is an impact which could be mitigated?

A We can always build another fish hatchery.

Q Do you have an opinion as to whether another fish hatchery would adequately replace the functions of Roaring Judy?

A Certainly a new fish hatchery could be designed to exceed the production of Roaring Judy Hatchery.

Q And would it, in fact, replace the present function of Roaring Judy as it's used by the Division?

A That would have to be because the Roaring Judy is a -- was a mitigation hatchery mainly for stocking Blue Mesa, and any mitigation would have to do the same thing, meet all of the demands of the Roaring Judy Hatchery.

Q My question wasn't whether it would, but whether it can be. Can the loss of Roaring Judy be mitigated?

A I don't see any reason why not, but I have no personal knowledge on that.

Q So you haven't formed a professional opinion on that?

A No.

(Pause.)

Q (By Mr. White) I gather from your remarks, Dr. Behnke, that you reviewed a draft of the ERO Report, Exhibit 172, before it was finalized; is that right?

A 172? This (indicating)?

Q Yes.

A It has an October 6th date.

(Deponent examined exhibit.)

Yeah, I think, you know, some of the information I supplied is in this report.

(Deponent examined exhibit.)

Q Did you review a draft of that report before it was finalized --

A When was the draft out?

Q -- Dr. Behnke?

I can't tell you.

A My memory is vague.

Q They didn't send it to me.

A Okay. My -- obviously, I -- you know, I can recognize some of my comments here, but how they were drawn from me, I don't recall. Sometimes they would just call on the phone and ask a question.

(Pause.)

Q (By Mr. White) You mentioned that you had visited the Taylor River years ago on several occasions. Do you know what the streamflow below the dam was at the time you visited it?

A No.

Q Have you considered the instream requirements on Texas Creek?

A I believe Texas Creek also fit into that 50 to 90 percent of average daily flow. The post-project flow looked quite good for a fishery. I didn't see any problem with the Texas Creek projected flow.

(Pause.)

Q (By Mr. White) In making your instream recommendations for the Gunnison River in the Black Canyon, did you use the Tennent or Binns methodologies?

A I never even made recommendations. I simply used the -- I think Barry Nehring's habitat flow curves.

Also, I think that probably the Tennent -- some of that might have been expressed as average daily flows. But I didn't try to make, you know, optimum recommendations, and I just merely was looking at the minimum of what would happen with increased year-round diversions through the Gunnison Tunnel.

Q Did Mr. Nehring use the Tennent method, do you know?

A No, he was using his curves, the IFIM

curve, habitat suitability curves. He had one early, about 1975 or '76 -- he does have a Division of Wildlife publication where they compared making, you know, flow recommendations based on the Tennent method, the R-2 cross method and the instream IFIM method.

Q Was that report prepared under the same Federal grant-in-aid project?

A I'm not sure. It's sort of that same series. It may have been funded by the U.S. Fish and Wildlife Service maybe directly. But it is a Division of Wildlife Report and -- I can't recall the exact title.

Q Have you worked on other projects using the IFIM modeling technique?

A I have off -- you know, I mentioned some of the stories I write for Trout Magazine on special regulations. I did -- I have used: What makes good habitats? And one example that I have cited is the Frying Pan River below Ruidi Reservoir, that has a long history of sampling of good data. Nehring has good IFIM data on that.

And for many years, the trout population there maintained about 200 pounds per acre, it would vary from 100 to 300, and then Mysis shrimp started coming out of Ruidi Reservoir. And last year that trout population, with no change in habitat, no change in flow regime, exceeded 1,000 pounds per acre for a new world record, I believe.

Now, the point is that IFIM didn't evaluate the habitat use, the weight, usable areas didn't change, except the new food supply. That is completely overlooked in most of these models and methods, the Tennent method or anything else.

Now, in retrospect, you can make a model and put that in. But the uncertainty involved in these -- this is the point I try to get across to students, to attorneys, to the general public.

Q I think the question I asked was whether you had worked on any projects with IFIM.

A Yes. I said the -- I was an early adviser, about 1980, with the justice department on a filing for minimum flows into Red River, New Mexico.

Q Have there been any more recent instances?

A I have to go back and look. I'm sure there is.

Q You can't recall any right now?

A I work on several different projects

each year.

(Deponent examined document.)

Well, the most recent one we had with the Colorado Springs project on the Fountain Creek, we used the -- EPA has a -- called rapid bioassessment protocol, a little -- slightly different type of assessing flows to habitat, but it was a method used there.

The -- the Salt River Project, the Verde River, was with an analysis of the IFIM data that was finally rejected.

Q Have you done any IFIM modeling yourself?

A I have never stepped in a stream and pulled a line across and made the velocity measurements, the depth measurements or the substrate measurements. I --

Q Have you --

A I have not done any hands-on work. My -- my IFIM familiarity is theoretical.

Q Do you work on projects with other consultants who use the IFIM technique?

A Oh, yes, they are so widely used.

Q Can you give us an example of that relationship?

A Well, some of your people you're familiar with, Steve Canton and Jim Chadwick, used IFIM, I believe, on the San Miguel River.

On the project -- well, I'd have to sit down and think and make a list. But there's -- I have quite a long familiarity with IFIM.

Q The point being that you do work on projects that use IFIM?

A I'm supervising three graduate students that are doing an IFIM thesis for the Fish and Wildlife Service currently, and I have had some in the past.

Q Is the IFIM technology still considered state-of-the-art?

A There's nothing, really, logically, to replace it. It does offer the -- as I said, it's like the -- you can always do it in retrospect. After you have the data, you can change your input to make it conform.

Q Does the Tennent method replace the IFIM technique?

A No, the -- it's sort of like a -- you could use like a sensitivity analysis. You might try various methods to see how they agree or disagree and why do they disagree.

Q Do you think there is a correlation between the output of the IFIM technique, weighted usable area and fish biomass?
A No. Only in retrospect, wherever -- there's no good, valid data to show this. In fact, it would be just the opposite.
Q So you think there's no correlation?
A No dependable correlation that you will base -- have confidence in making any predictions on that. The IFIM -- the proponents of IFIM now disavow this. They say it's not to produce biomass estimates, it's a negotiating tool now.
Q It's a comparative technique, in other words?
A I compare it to the game of Monopoly, that the way to use it is like play money.
(Pause.)
Q (By Mr. White) Have you seen any information about macro-invertebrate populations in the Taylor River?
A No, I don't recall any.
Q Do you have an opinion as to whether the availability of food is a limiting factor on fish biomass in the Taylor River?
A I have heard of Mysis shrimp coming out

of Taylor Reservoir and I could expect that you will get a very large increase in trout because of a new food supply, at least the upper mile of the Taylor River.

But I believe the Taylor River -- most of the sampling I've seen is in the neighborhood of maybe 100 to 200 or 150 pounds per acre of trout, which is good. But I have never seen any studies talking about food-limited versus habitat-limited.

Q So you don't have an opinion as to whether the fish populations in the Taylor River are food-limited or habitat-limited?

A No.

Q Do you have any opinion as to what factors may be limiting fish biomass on the Taylor River?

A Well, since, I believe, the -- it's been several years, now, since the Taylor Reservoir has been releasing a -- trying to achieve a minimum 50 cubic foot per second winter flow, the biomass has, I think, stabilized at a fairly good level, over 100 pounds per acre. That's a very good trout stream in the Rocky Mountain west.

How much better it could get if you, you know, had more food or more habitat, I wouldn't hazard a guess, but there's not too many streams that regularly produce over 100 pounds of trout per acre.

Q So you don't have an opinion as to what, if any, limiting factors there are on trout biomass in the Taylor River?

A No.

MR. WHITE: I have no more questions.

MR. DINGESS: I don't have any questions.

MR. WILLIAMS: I don't have any questions.

(The deposition concluded at 3:15 p.m., February 6, 1990.)