USING SYSTEMS ANALYSIS FOR FISHERY MANAGEMENT IN RIVER BASINS

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Several themes have emerged from this conference: (1) underlying all of the discussion is an awareness of a manageable physical system in the Rio Grande Basin; (2) the system's water is valued in diverse ways; (3) opinions differ about how the system's water would best be distributed for the greatest social benefit; (4) improved planning for future water management and use is imperative; (5) desire to communicate and resolve differences in perceived values is earnest; (6) resolution of differences sometimes appears overwhelmingly difficult and; (7) better management tools are needed to define values in commonly understood terms, to logically sort out alternatives, and to analyze for optimal solutions to water-use problems.

I will briefly describe recent development of one management tool, which is specifically designed for managing sport fisheries in the New Mexico Rio Grande. Fishery managers have long recognized a need for improved fishery management of river basins managed primarily for irrigation and flood control. Fish habitats in the Rio Grande and elsewhere in New Mexico fluctuate greatly in response to watershed supply and downstream user demand. Different reservoir and connecting-water habitats form a system of physically and economically linked parts. Management applied to any one of those parts usually has ramifications elsewhere in the system, many of which are difficult, if not impossible to predict without the organizational capability of computers. One current example is the impact of site-specific instream flow alterations on other parts of the river system. In large, complex river basins, like the Rio Grande, an array of tradeoffs can be expected with any proposed alteration of flows.

The need for a fishery management tool has grown more acute with growing awareness of the trends in fishery-resource supply and demand. Per capita angler expenditures (1980 dollars) have increased about 60 percent over the past three decades, reflecting growth in leisure time and disposable income (figure 1). The percentage of people who fish and the mean time each spent fishing has steadily increased. Also, the population of New Mexico nearly doubled between 1955 and 1985. Extrapolations of

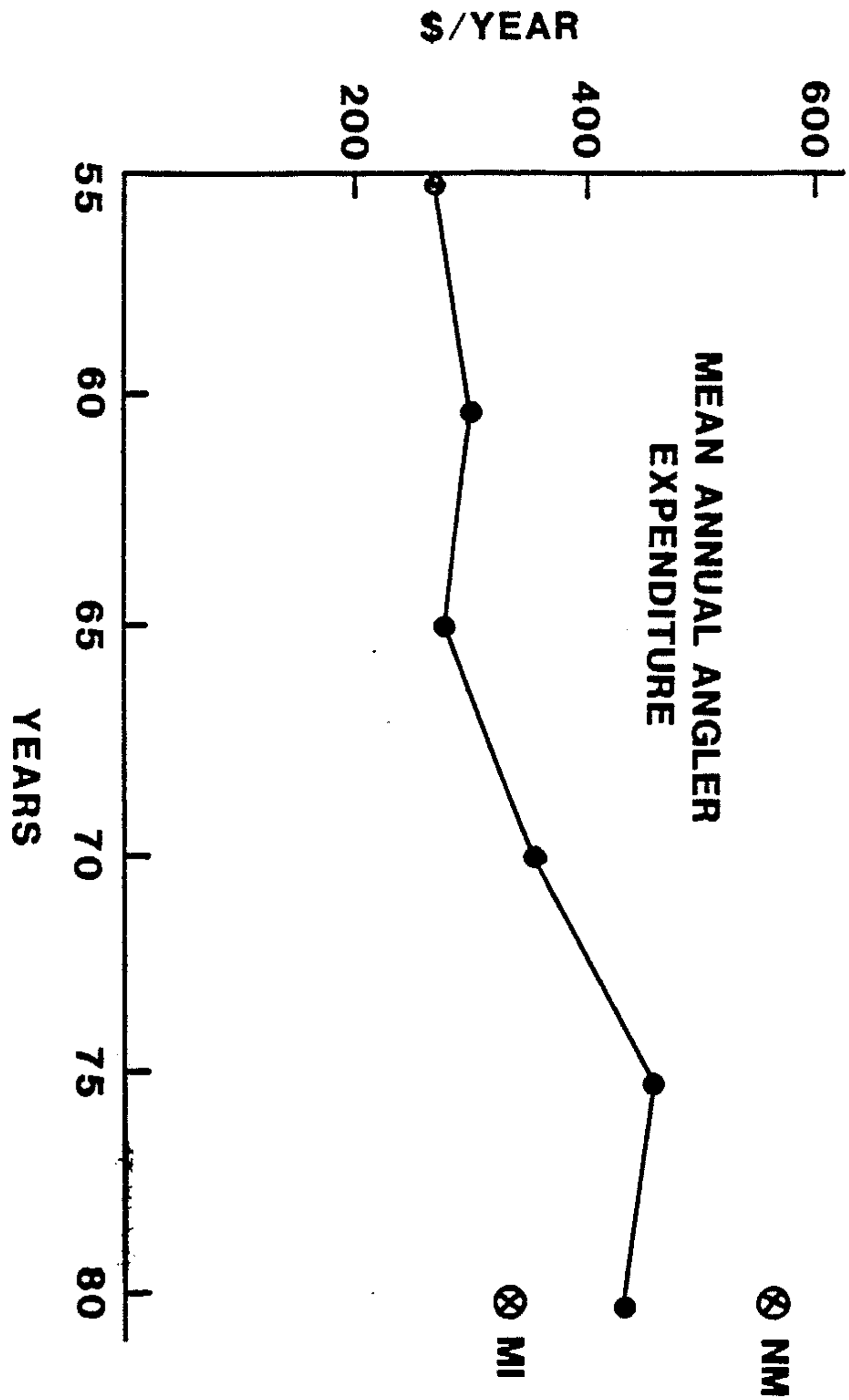

Figure 1. Per capita angler expenditure in the United States from 1955 to 1980 (corrected for inflation with 1980 dollars) and expenditures in New Mexico and Michigan in 1980.

past trends indicate that the fishing demand will increase by three to four times over the next 30 years. A challenge for fishery managers is to provide for increased demand in spite of limitations imposed by habitat availability and traditional aquacultural approaches.

Another challenge for fishery managers is to provide a better benefit-cost ratio for New Mexico anglers, who presently incur higher than average sportfishing costs. New Mexico residents spent nearly $600 each in 1980 for fishing experiences that cost the average U.S. angler about $450 (figure 1). Fishing costs more in New Mexico mostly because the average angler in New Mexico has to travel about twice as far as the average U.S. angler. Because anglers pay most of the bills for managing fisheries, the management agencies owe it to the anglers to provide more cost-effective angling, whenever possible.

Estimates of fish production and stocking in high- and low-water years illustrate the management challenges. Because total habitat and the mean fish productivity per unit habitat both decrease as waters fall from high-to low-water years, the total supply of fish varies from a high of about 21 million pounds to a low of about 4 million pounds with onset of drought (table 1). Because 1985 and 1986 were record high water years, recent natural production of fish has been nearly 20 million lbs per year, while the

Table 1. Estimates of natural production and stocked weight of fish (thousands of pounds) in high and low water years (based on mean estimates of production for state waters) and estimated demand for fish sampled in 1980 and 2010.

ESTIMATED SUPPLY AND DEMAND FOR FISHERIES (THOUSANDS OF LBS)

	HIGH WATER	LOW WATER
SUPPLY (1985)		
STOCKING	1,100	1,100
"NATURAL"		
FLOWING WATER	3,000	400
MAIN RESERVOIR	13,500	1,900
SMALL RESERVOIRS	4,000	500
TOTAL SUPPLY	21,600	3,900
TOTAL DEMAND		
1980	3,400	3,400
2010	11,000	11,000

annual angler demand has been about 3.5 million lbs (10 lbs per angler). If 1985 had been a drought year the demand would have been at best equal to the total supply, and probably would have exceeded the available supply. Not all of the total supply is available to anglers because fish production in large water bodies is substantially inaccessible to the average angler. While small water bodies often yield 85 percent or more of fish stocked or naturally produced in them, large water bodies are likely to yield less than 25 percent of their potential. Because more than half the natural fish production in New Mexico occurs in large water bodies, the available supply is substantially lower than the total calculated fish production. If a drought occurs in the near future, the fishery demand will exceed the available supply. In thirty years, demand could exceed available supply even in high-water years. Thus alternative management approaches need to be considered.

A basic management strategy for analyzing alternatives was initiated in 1980 to develop a comprehensive planning tool -- a fishery management model for the Rio Grande. That model, completed in 1985, has served as a prototype for more comprehensive versions to be completed about 1990 for most of the the fishable waters in New Mexico. Model development has been financially supported by the N.M. Department of Game and Fish, the Water Resources Research Institute at New

Mexico State University, the Agricultural Experiment Station at NMSU, the N.M. Interstate Stream Commission, the U.S. Bureau of Reclamation and N.M. State Parks. An interdisciplinary research team was organized at NMSU in 1980 to develop the model, which simulates real-world linkages between hydrologic, biologic and economic elements for Rio Grande reservoirs and connecting waters (figure 2). The hydrologic component mathematically recreates flows of water, nutrients, and other materials over a nine-year period from 1975 to 1984. The biologic component estimates fish production through simulations of ecological processes that originate with water and nutrient flows, other material flows and solar energy influx. From the estimated fish production and various other social considerations (distance travelled, access, environmental considerations), the economic component estimates total angler benefits and county income generated. A model user applies a management alteration to the simulation of the historical (status quo) condition in the river and observes the affect on various hydrologic, biologic and economic outputs.

A sequence of management changes is applied at different intensities to develop an optimization curve through reiterative use of the model. Model users can alter water distributions, water flows, nutrient flows, suspended solids, fish stocked, fishing regulations, fishing access

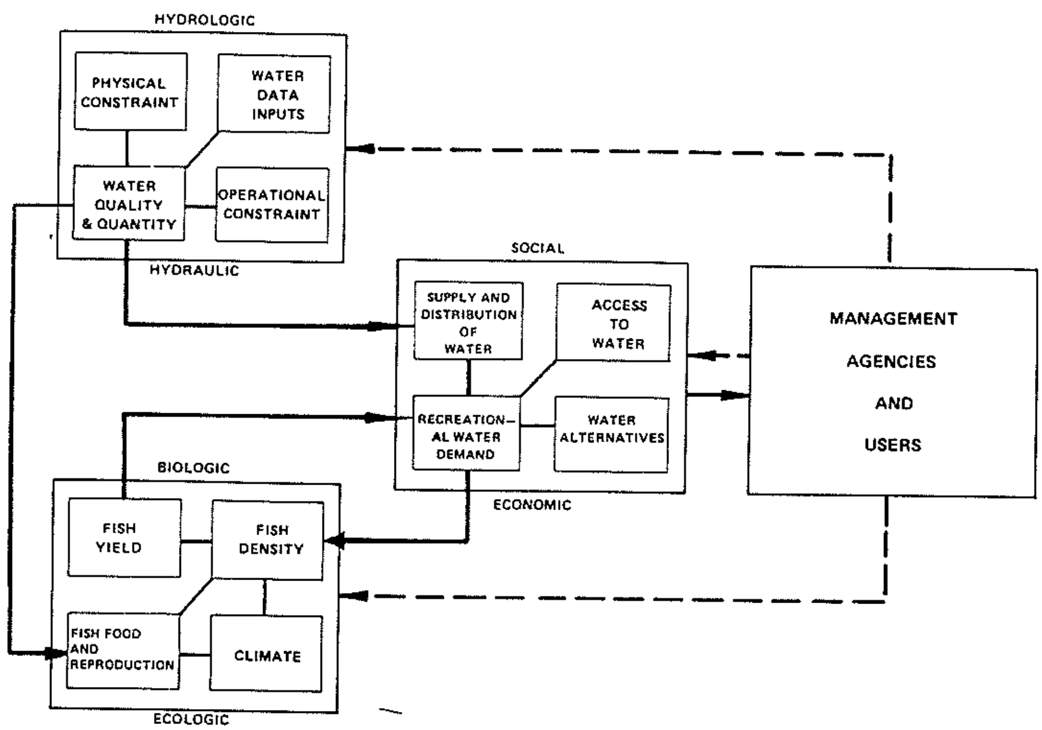

Figure 2. A schematic representation of the main components in the fishery management model RIO FISH, which simulates hydrologic, biologic and economic processes on the Rio Grande Basin.

and other policy related aspects. They can observe management impacts on water quantity and quality, fish population dynamics, fish food production, economic benefits and local income generated. The model has been made user-friendly so that managers with no computer experience can use it.

One example of model use is the analysis of instream flow considerations in the lower Rio Grande. One possible way to develop greater available fish supply is to improve connection-water habitat by maintaining year-round flows. Year-round flows would be desirable also because the connecting waters run past the most populated areas in New Mexico, thus anglers would have closer fishing and greater benefits. However, analyses with the model reveal some problems.

The primary problem is the potential impact on reservoir fish production. Under present water management policies, reservoir water levels fluctuate close to a desirable scenario for fishery management in many years (figure 3). Optimum natural sportfish production, without stocking, occurs when water levels rise before spawning occurs (usually about early March) and are held high until early life history is complete when the water is dropped back to low cool-season levels. The major difference between desired and realized water fluctuations occurs about

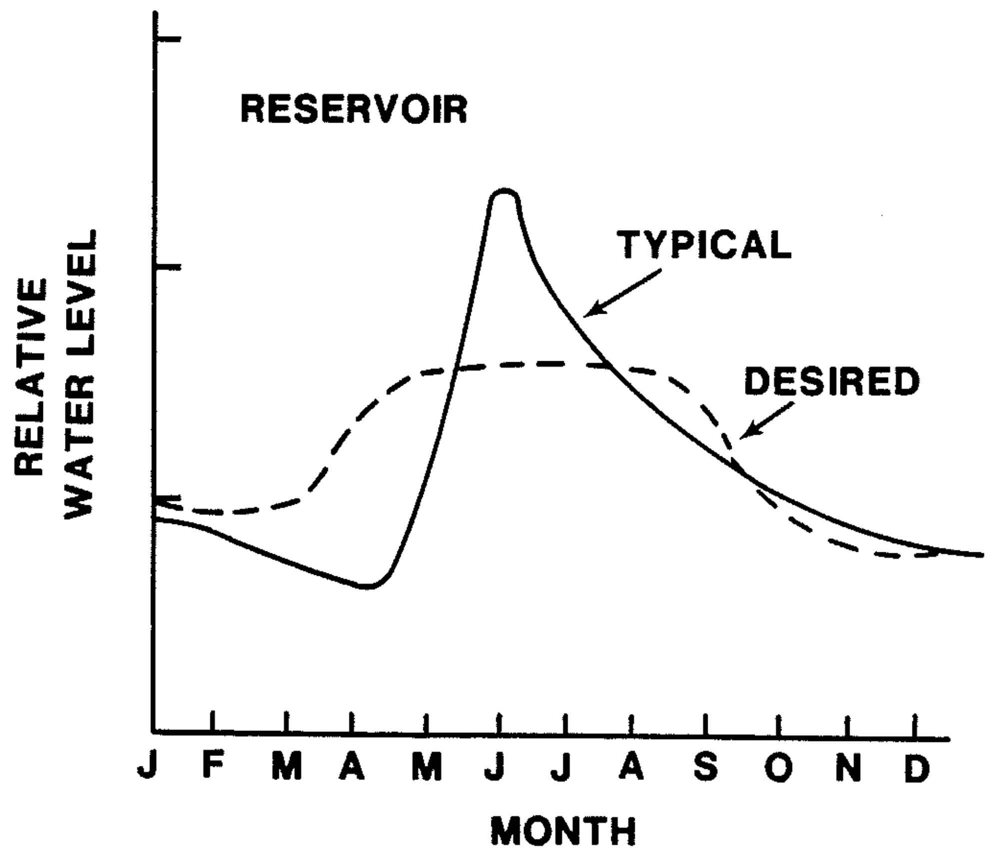

Figure 3. A "typical" high-water pattern of water-level fluctuation in New Mexico irrigation reservoirs contrasted with a desirable fluctuation for optimal fish production.

March through May when irrigation demands can cause water levels to drop sharply during early spawning before snowmelt runoff counter balances drawdown. A little later in the season, rapid snowmelt runoff can far exceed irrigation demand and sharply rising waters can inhibit other spawning. The lower the initial reservoir water level, the greater the relative impact on fish reproduction. The model quantifies these impacts and, in a future version, will enable the fishery manager to mitigate impacts through appropriate stocking or harvest regulations, or, possibly, through some modification of reservoir release rates.

In contrast with reservoir fluctuations, the flow through connecting waters in the lower Rio Grande usually varies greatly from a desirable flow for most sportfish (figure 4). Desirable flows vary depending on species, but a flow approaching constant with short periods of higher discharge to remove fine sediment from spawning sites, is a commonly encountered scenario. The desired flows differ greatly from the status quo conditions and would require large river-management modifications to develop. However, because connecting waters are strategically placed, such scenarios are worthy of consideration among model analyses of management alternatives.

Such a scenario is represented in a simplified schematic shown in figure 5. In a scenario established to

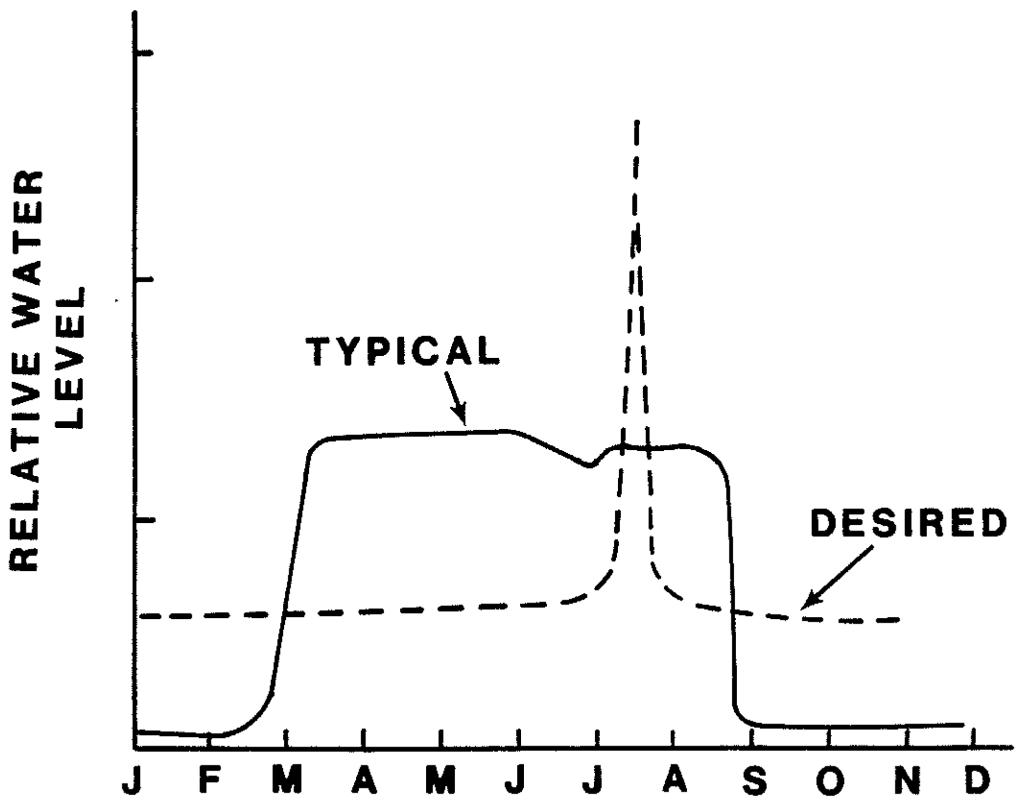

Figure 4. A "typical" pattern of water discharge fluctuation in connecting waters between irrigation reservoirs contrasted with one possible alternative flow for optimal fish production.

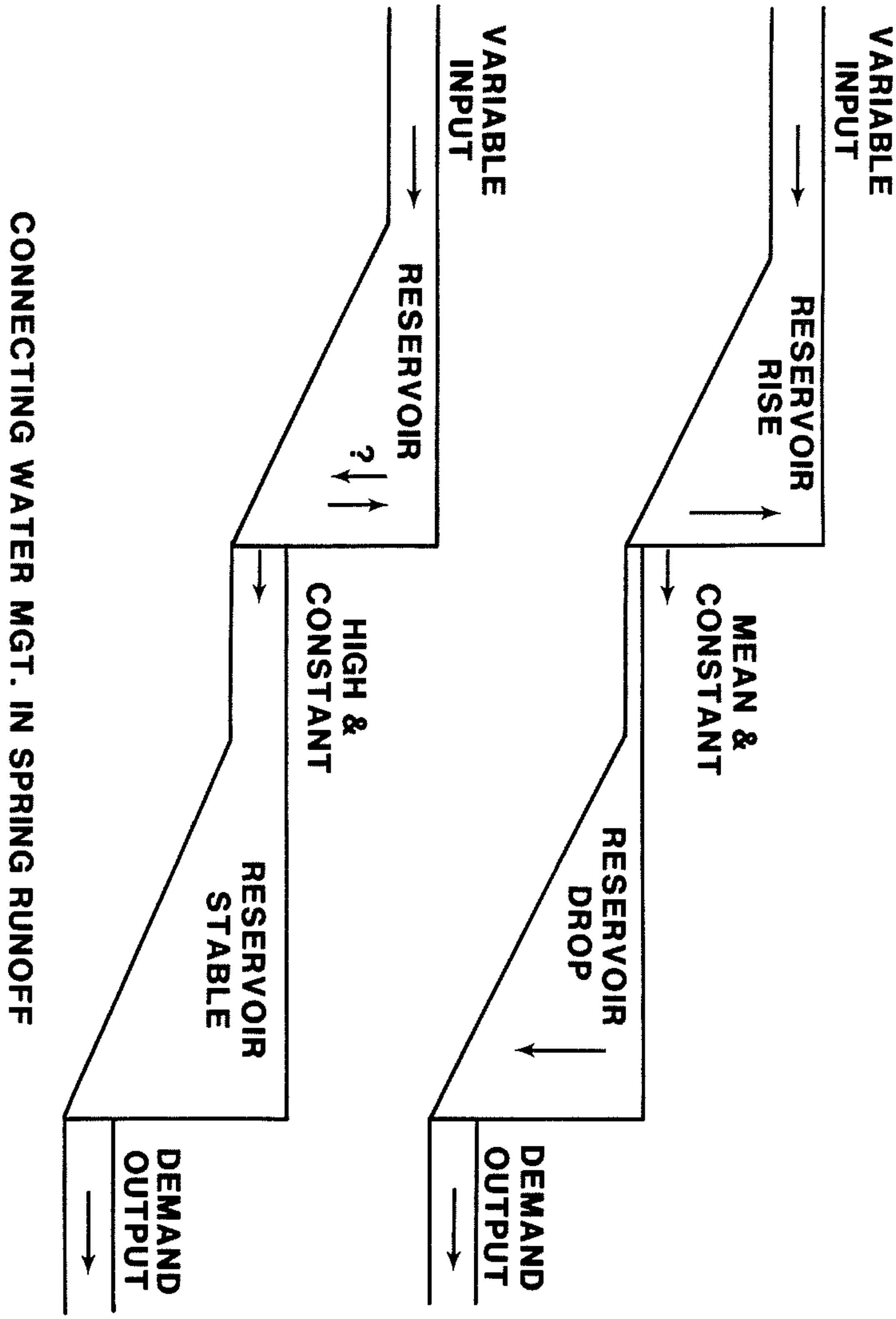

Figure 5. Two scenarios exemplifying the relative impact of different instream flow maintenance on reservoir water levels during the spring runoff and time of most reservoir fish spawning. In the upper example, connecting water flows held at an average annual discharge causes high elevational fluctuation in upper and lower reservoirs. In the lower example, connecting water flows held at the irrigation demand flow cause more stable water levels in both reservoirs.

maximize production in a connecting water by maintaining a constant mean annual flow between two reservoirs, dramatic ramifications occur in the reservoirs during the spawning period. At that time irrigation demands exceed mean annual river flows and water level in the lower reservoir drops. Simultaneously in most years, the snowmelt discharge into the upper reservoir increases water levels. Levels in both reservoirs shift rapidly in low-water years, causing large, if not total, reproductive losses of many game species. In such a situation, benefits gained in the connecting-water fishery would be countered by losses in the reservoirs; possibly to the extent that overall reservoir and connecting-water fish yield decreased. Thus, such a scenario would not be the most desirable for managing fisheries.

An alternative scenario, managing the flow of connecting water so that it closely matches the irrigation demand and the upstream inputs, would result in better reservoir conditions. This scenario would sacrifice high productivity in the connecting water but result in a greater combined fish productivity, yield and economic benefit in reservoirs and connecting water. Of course some intermediate operational state between the two presented in figure 5 may be the best scenario for fishery management.

A more complicated analysis could be conducted with incorporation of other water uses such as, for example, boating on the reservoirs and rafting on the connecting waters. As long as economic values were available for boating and rafting under various hydrologic regimes, scenarios could be developed that optimized for their use as well as for fishing. An expanded model could calculate water-based recreational values directly, but this one does not now do so.

Important model limitations are now being investigated to increase model utility. For example, because of the greater inherent fish production in reservoirs, more attention has been paid to reservoirs than to the connecting waters. The model is being expanded to allow analyses of the fishery economic consequences of diverting flows from the connecting waters into ponds and small streams managed specifically for fisheries before the water is returned to the river.

Preliminary analyses (ballpark figures) have indicated that half the fishery demand for Albuquerque in 30 years could be provided with intense management of about 3,000 surface acres in small lakes constructed on the river floodplain. The annual cost in consumed water would be about 20,000 acre-foot/year. At $60/acre-foot, the water used would cost $12 per angler annually. It would also cost $100 million to dredge the lakes (20 feet deep) and maintain them over the 30-year period. Prorated annually, a yearly cost of $3 million would add another $24 per year per angler to the management bill. Stocking would cost another $5 per angler per year. The cost for the urban fishery would be about $40 per angler each year for half of his or her fishing. In the process, the angler's travel bills would be reduced to about $400 per year and the total cost would be reduced from $600 to $450, close to the mean annual value for the United States as a whole. Thus, the expected demand in 30 years could in theory be met by redistributing water of certain connecting waters into intensively managed urban fisheries. The expanded model should allow more precise examination of costs and benefits.

The existing model is limited to the mainstream river and does not include small waters in the peripheral watershed. Because many of these small reservoirs are intrinsically more manageable than the larger water bodies, they provide at least half of the total stocked and natural fish yielded in New Mexico. Therefore, watershed modeling is being incorporated with the existing model to enable fisheries management in waters outside the mainstream river. A watershed approach will also allow direct analysis of various watershed management scenarios on water quantity and quality. The present model relies entirely on U.S. Geological Survey gauges for information on water flow.

Substantial water enters reservoirs without being gauged, thus a watershed approach ultimately will provide a more accurate model.

The model is also being extended to the river basins of the Pecos, Canadian, San Juan and Gila rivers over the next several years. In its final form, the model will allow economic impact analyses of management in one watershed, on water used in other watersheds, and it will include roughly 85 percent of the state fisheries. Model validation is underway and will continue as the model is developed.