# ECONOMIC BENEFITS FROM INSTREAM FLOW IN A COLORADO MOUNTAIN STREAM

by

John T. Daubert
Robert A. Young

June 1979

COLORADO WATER RESOURCES RESEARCH INSTITUTE

Colorado State University
Fort Collins, Colorado

Colorado Water Resources Research Institute
Completion Report No. 91

# ECONOMIC BENEFITS FROM INSTREAM FLOW IN A COLORADO MOUNTAIN STREAM

Combined Completion Report

OWRT Project No. A-035-COLO
and
OWRT Project No. A-040-COLO

by

John T. Daubert and Robert A. Young

with

S. Lee Gray

Department of Economics
Colorado State University

submitted to

Office of Water Research and Technology
U. S. Department of Interior
Washington, D. C. 20240

June, 1979

The work upon which this report is based was supported (in part) by funds provided by the United States Department of the Interior, Office of Water Research and Technology, as authorized by the Water Resources Research Act of 1964, and pursuant to Grant Agreement No.(s) 14-34-0001-6006, 14-34-0001-7011, 14-34-0001-7012 and 14-34-0001-8006.

Colorado Water Resourses Research Insitute
Colorado State University
Fort Collins, Colorado 80523

Norman A. Evans, Director

## ABSTRACT

Water flowing in streams has value for various types of recreationists. Increasing instream flows from low levels may enhance the recreational experience for fishermen, white water enthusiasts and shoreline recreationists. Increasing instream flows in arid and semi-arid conditions may be in conflict with established withdrawal uses, for irrigation, industries and households. Instream flows have a public or collective good character, such that market prices are not observable. Estimating marginal values for instream flow which are commensurate with those for withdrawal uses presents well-known difficulties.

Following recently developed techniques for estimating the value of public goods, an interative bidding game was administered in 1978 to a sample of recreationists using a Colorado mountain stream to determine their willingness to pay for alternative rates of flow. Regression techniques were applied and the results were used to estimate the marginal value of instream flows for each month of the recreation season. The statistical reliability of the estimates was more than adequate, indicating the technique is suitable for aiding in instream flow management decisions.

TABLE OF CONTENTS

## LIST OF TABLES

LIST OF FIGURES

# CHAPTER 1

# INTRODUCTION

Farmers, mine operators, cities, and towns in Colorado have appropriated and developed the State's water resources since 1850. Unable to depend on rainfall in Colorado's semi-arid environment, they recognized that diverting water away from the natural stream channel would substantially increase their production possibilities. Even though withdrawal water uses (irrigation, household, and industrial) divert stream flow into the production of goods and services, many now believe that instream water uses (recreation and environmental quality) have an economic value large enough to warrant instream flow management strategies. However, major conflicts exist between withdrawal and instream water resources, since water in one capacity generally precludes its use in the other. This research first attempts to place an economic value on instream uses, then presents the economic and legal factors associated with different minimum flow management strategies.

Colorado's decision, early in its development as a state, to adopt water institutions that completely allocated water into crop production, mineral extraction, and domestic uses was economically wise. Instream flow water resources were abundant in relation to the amount farmers, miners, and towns could use. Stream recreation and aesthetic experiences were readily available compared with the urgent need and small supply of stream flow as production inputs. Diverting water flow away from the river transferred abundant water resources, having at the margin only a small economic recreational value, into uses having a very large marginal value.

Many water resource planners still hold the belief that water in its natural state has no value, and resist any change away from the existing allocation institutions that are biased toward water resource development. Market forces direct water flow into withdrawal uses where the economic return to water is known and understood. Since outdoor water recreation developed as a non-marketed good, instream flow for recreation use is not subject to the same marginal prices as in withdrawal use, and appears as a free input in relation to other water uses. Granted, we may not want the market to allocate free-flowing stream recreation, but that doesn't mean instream water resources for that use have zero economic value.

Other individuals, even though they recognize water in the instream has value, often argue that economic analysis cannot possibly quantify the social value. The experience, generating personal and aesthetic pleasures, may be difficult to value, but the notion that economic value can't account for similar experiences is misleading. The economic market does a good job valuing a ticket to a Denver Bronco football game, which is primarily an aesthetic and recreation experience. Many marketed commodities have some degree of aesthetic value, which can be effectively reflected by market exchanges. This report takes the position that instream flow value for recreation is fully equivalent with the economic value of those resources in crop production. Due to the public good characteristic of instream flows, the job imputing non-market economic values is difficult but not impossible.

Because many individuals believe either water left instream has little value or economics cannot assist in determining recreation value, Colorado's water allocation system continues to distribute water into the production of goods and services, especially irrigated crop production. The part market-part legal water allocation has driven water's marginal value in crop production very low. At the same time, rapid population growth has increased water diversions for household and industrial activities. Future energy development might also require large water diversions. But equally important, growing income, leisure time, and mobility has broadened interest in instream flows for recreation. Instream flow provides direct utility to recreationists and indirect returns to Colorado's major tourist industry. How can resource managers satisfy all these water customers?

Colorado responded to these changing water demands by passing minimum flow legislation.[1] The federal government, also concerned about maintaining environmental instream flow benefits, responded with the Wild and Scenic River Act.[2] But, before governmental agencies can formulate appropriate stream flow management policies, they need defensible instream flow value estimates. Even though instream flow valuation may be difficult, rational and informed decision making requires specific and complete information about water's marginal value in <u>all</u> uses. This paper, focusing on instream flow valuation, should help the water resource manager answer questions concerning the optimal instream flow level.

---

[1]Wayne Nelson, Gerry Horak, and Martin Lewis, "Instream Flow Strategies for Colorado," Fish and Wildlife Service, U.S. Department of the Interior, FWS/OBS-78/37 (May 1978), p. 12.

[2]Ibid., p. 25.

## Background

Even though withdrawal and instream users compete for water on most streams in Colorado, conflicts are especially evident in the Poudre River Canyon. As early as 1860, private companies began building irrigation canals providing water to land not adjacent to the Poudre River. The appropriation doctrine provided the framework to allocate water to irrigation companies. This legal institution allocates river flow by use and priority. Any individual with a beneficial water use (including household, irrigation, power, recreation, etc.) may apply for and receive a water right. Whenever appropriations on a stream exceed water supplies, each irrigator receives water based on his temporal priority. Farmers with senior water rights having the highest priority (earliest application date) divert water first, followed by junior irrigators having later application dates. This allocation system guarantees legal security to irrigators with senior water rights.

By 1900, irrigation companies and cities fully appropriated the stream flow in the study area, the Poudre River Canyon. Colorado water courts had decreed over 4,000 cubic feet per second direct flow rights to irrigators alone, even though the Poudre River seldom has instream flows exceeding 2,000 cfs.[3] None of the water rights have instream flow maintenance as their stated beneficial use. On any given summer day, irrigators could totally divert stream flows away from the Poudre River.

---

[3]A. Maass and R. L. Anderson, ...And the Desert Shall Rejoice Conflict, Growth, and Justice in Arid Environments (Cambridge, Mass.: MIT Press, 1978), p. 281.

Besides providing irrigation water, the Poudre River Canyon is an extremely attractive recreation site. During spring and early summer, certain river reaches form white water rapids that any kayaker or rafter can enjoy. By late summer, the stream flow drops low enough to support an excellent trout fishery. The National Forest Service even designated parts of the Poudre River as "wild trout" fishing sections for fly or lure fishermen. In addition, over 100,000 recreationists visited the Poudre Canyon to enjoy non-water contact activities, including camping, viewing, hiking, picnicking, etc.

Even though water allocation problems affect the entire Poudre River, they are especially troublesome throughout the lowest 30 stream miles where conflicts arise between recreationists, wanting the flow to remain instream, and farmers, diverting the water for crop production. The economic theory of optimal resource allocation supplies a framework for resolving these conflicts. The object is to distribute stream flow between competing users in order to produce the greatest social benefit. The operational criterion calls for reallocating stream flow until the marginal return in all uses is equal. Young and Gray[4] present substantial evidence on the marginal value of water in withdrawal uses. The research in this paper estimates the instream flow marginal value in the production of recreation and aesthetic experiences.

Although stream recreation obviously requires water flow, researchers have budgeted little time or effort into instream flow valuation. Instead, they have studied the instream flow requirements to sustain different levels of fishing, white water, or other

---

[4] R. A. Young and S. L. Gray, Economic Value of Water: Concepts and Empirical Estimates, Final Report to the National Water Commission, Report No. NWC-SBS-72-047, March 1972.

free-flowing recreation, or they have ordinally ranked and quantified streams and stream recreation.[5,6] An extensive literature search didn't reveal any published study that unequivocally places an economic value on instream flow commensurate with values generated by more familiar market mechanisms.

The recent economic studies valuating different environmental improvements provides theoretical direction. In 1974, Randall, et al.[7] estimated the economic benefits from air quality improvements in the Four Corners Region (southwestern United States). Brookshire, et al.,[8] following Randall's study, placed an economic value on aesthetic damages from additional coal-fired power plants in the Four Corners Region. Hammack and Brown,[9] later Randall and Brookshire,[10] established economic values for wildlife in a recreational experience. Although these studies impute synthetic resource values, they deal with substantially different environmental problems. The most relevant

---

[5]Ronald Hyra, Methods of Assessing Instream Flows for Recreation, Instream Flow Information Paper No. 6, Cooperative Instream Flow Service Group, Fort Collins, Colorado, June 1978.

[6]E. L. Michalson, "An Attempt to Quantify the Esthetics of Wild and Scenic Rivers in Idaho," River Recreation Management and Research Symposium, USDA, Forest Service, January 1977.

[7]Alan Randall, Berry Ives, and Clyde Eastman, "Bidding Games for Valuation of Aesthetic Environmental Improvements," Journal of Environmental Economics and Management (1974).

[8]David S. Brookshire, Berry C. Ives, and William D. Schulze, "The Valuation of Aesthetic Preferences," Journal of Environmental Economics and Management (1976).

[9]Judd Hammack and Gardner Brown, Waterfowl and Wetlands: Toward Bioeconomic Analysis, Resources For The Future (Baltimore: Johns Hopkins University Press, 1974).

[10]Alan Randall and David S. Brookshire, "Public Policy, Public Goods and Contingent Valuation Mechanisms," Staff Paper 68, University of Kentucky, Lexington, June 1978.

study valued water quality improvements in the South Platte River Basin, Colorado. [11]

Objectives

This research paper has two major objectives. Following the recent advances in environmental economics valuing air, water, and wildlife inputs into aesthetic experiences, the first objective is to estimate instream flow's marginal value for water-based recreation. As with the other environmental resources, instream flows have public good attributes that discourage private market allocation systems. In the absence of market prices, this paper inputes synthetic instream flow social values comparable and commensutate with those values in withdrawal uses.

The amount a recreationist is willing to pay for alternative flow levels represents instream flow's economic value. Stream recreation may depend on water flows, but decisions concerning resource allocations involve adding or subtracting small increments to the existing flow level. Regardless of the large aggregate value many individuals assign to stream recreation experiences, each person has a limit on how much they will give up to enjoy small additions to the instream flow. The appropriate decision-making value, corresponding to ones in the market economy, is the marginal willingness to pay for instream flows.

The second objective is to present the economic and legal factors associated with developing minimum flow strategies. For years, water allocation institutions encouraged diverting water from the stream into

---

[11] Richard G. Walsh, Douglas A. Greenley, Robert A. Young, John R. McKean, and Anthony A. Prato, Option Values, Preservation Values and Recreational Benefits of Improved Water Quality, U.S. Environmental Protection Agency, January 1978.

crop production or household use. Today, many Coloradoans are willing to sacrifice traditional water use outputs for more recreation amenities. Complete evaluation of decisions, changing instream flow levels, requires analyzing the economic tradeoffs associated with alternative instream flow allocations and the legal institutions structuring water right distributions.

Economic theory, alone, may lead to inappropriate minimum flow strategies unless the policy maker considers the legal regulations. How can water planners allocate instream flow between conflicting needs to produce the greatest social benefits becomes the economic question. Ignoring any intemporal problems, the traditional static rule for social benefit optimization calls for an allocation where the instream flow marginal return in all uses is the same.[12] But, economic solutions interact with the legal water rights regulations. Various water right laws may lead to different actual water allocations and different perceptions about the optimal water allocation.[13] Looking only at the economic concepts and information clarifies many issues, but unnecessarily limits any policy recommendations.

Procedures

This research uses a contingent valuation approach (direct consumer surplus technique) to estimate the recreationist's willingness to pay for instream flows. The inverse demand function is:

---

[12] J. Hirshleifer, J. C. DeHaven and J. W. Milliman, Water Supply (Chicago: University of Chicago Press, 1960).

[13] D. W. Bromley, "Property Rules, Liability Rules, and Environmental Economics," Journal of Economic Issues, Vol. 12, No. 1 (March 1978).

WTP = g(Flow, Income, Tastes).

The quantity variable, flow, representing the stream's discharge in cubic feet per second units models the changes in stream depth and velocity. At different sites, a given flow in the river may generate different depths and velocities depending on that site's physical configuration. But, flow rather than depth or velocity remains the primary economic quantity variable, since water managers can alter flow levels easier than changing the stream's contour.

D. F. Bradford formulated the theoretical base for contingent valuation methods.[14] The object is to trace out an aggregate willingness-to-pay function modeling an individual's ranking of alternative consumption bundles that differ with respect to the instream flow level and income. These bid functions have the same economic meaning as ordinary indifference curves. The slope measures the marginal substitution rate between income and instream flow levels. According to Bradford, the maximum bid responses for all instream flow levels models a total instream flow benefit curve having a first derivative equal to the marginal benefit function, otherwise known as a compensated demand curve.[15]

The contingent valuation technique, in this paper, uses a personal survey that solicits direct responses from recreationist about the maximum price he would pay for an increase in the flow level rather than do without. A hypothetical instream flow market forces the recreationist to choose between his need for instream flow and other

---

[14] D. F. Bradford, "Benefit-Cost Analysis and Demand Curves for Public Goods," Kyklos 23 (1970).

[15] Ibid.

expenditures. Thus, the willingness-to-pay survey resembles the actual market place, where the individual confronted with a range of commodities decides whether to buy or not to buy.

A well-constructed survey increases the reliability of the responses. The iterative bidding game survey included:

1. Color photographs showing eight different instream flow levels at four different sites. The photographs reduced the respondent's need to image the appearance of the Poudre River at each flow level, thus providing a uniform comparison base.

2. Hydrologic and fishery data on the Poudre River's depth, velocity, and fishing success at each flow level. This information caputred the non-visual stream changes for each instream flow.

3. Two detailed market situations forcing each respondent to visualize paying either an entrance fee or sales tax to use the instream flow. Both payment vehicles confronted the respondent with familiar public financial obligations.

4. Bidding game willingness-to-pay questions, where the enumerator iteratively increases the instream flow fee or sales tax until the respondent indicates his maximum payment for a specific change in the flow level.

Even though the hypothetical bidding game format may have responses different from actual behavior, a well-designed survey should minimize any bias.

A personal interview provided the willingness-to-pay values. Any household visiting the Poudre River, during the 1978 summer, was a potential member of the sample population. The survey design separated instream recreationists into fishing, shoreline, and white water activity groups. Fishing recreation included fly, lure, and bait fishermen. The shoreline group included stream-related activities (camping, hiking, viewing, etc.). The white-water class included tubing, kayaking, and rafting experiences. To insure a random sample, interviews took place on randomly selected days during each summer month. Although the sample sizes were relatively small (49 fishermen, 45 shoreliners, and 40 white water recreationists), the sample characteristics generally reflected recreationist socio-economic characteristics.

## Special Issues

Willingness-to-pay questions in the instream flow bidding game attempted to measure only the direct recreation user benefits. The research in this paper omits consideration of preservation values or congestion effects. Krutilla pointed out that certain environmental resources may have option, existence, and bequest benefits separate from recreationist's immediate willingness to pay.[16] Option value represents the extra amount recreationists would pay to preserve non-reproduceable environmental resources. Existence value measures the benefit individuals receive from the knowledge that he can at any time use the resource. And bequest value represents the individual's utility from preserving the environmental resource for future generations.

These non-user benefits may be very large for certain irreplaceable natural resources. For example, individuals are probably willing

---

[16]John V. Krutilla and Anthony C. Fisher, The Economics of Natural Environments, Resources For The Future (Baltimore: Johns Hopkins University Press, 1975).

to pay a great deal for the option, existence, and bequest benefits from the Grand Canyon. The key feature is irreversibility; no known technology exists that can reproduce the scenic beauty of the Grand Canyon. Decisions concerning irreversible actions must take into account any possible non-user benefits.

Alternative stream flow allocations do not meet Krutilla's definition of an irreversible decision.[17] Complete stream flow diversion into crop production eliminates any recreational or aesthetic uses of the Poudre River only for one period. Should that decision prove wrong, resource managers can restore the recreational services in the next year by maintaining instream flow levels and reintroducing trout. The costs may be relatively large, but the decision is not irreversible. Since preservation benefits are expected to be minor, I did not attempt to explicitly measure their magnitude.

The willingness-to-pay equation does not account for the disutility associated with congested recreation areas. After some threshold, each additional user reduces the satisfaction from an instream flow recreation experience. To the extent a change in the instream flow level, improving the recreation experience, also attracts more users the estimated value overstates the true value. The congestion problem is important when comparing decisions concerning instream flow for low density or high density recreation. For example, fishing is a relatively low-attendance but high-value use; while, shoreline activities represent a high-attendance low-value use. Both the physical recreation differences and the lower congestion levels make fishing a higher value use. But, water resource decisions on the Poudre River

---

[17]Ibid., p. 12.

are not between different recreation activities, rather between water allocations to withdrawal uses or recreation services. I assume that the existing participation rate won't change as water managers allocate water from irrigation to recreation or vice versa.

Study Plan

This study is divided into three interdependent sections. The next section, Chapter 2, discusses the economic framework for water resource valuation and the economic techniques estimating non-market instream flow benefits. Then, Chapter 4 and 5 deal with the data collection and statistical estimation of instream flow benefits. The last section, Chapter 5, evaluates different instream flow allocation strategies. Chapter 6 summarizes the major findings, conclusions, and recommendations.

# CHAPTER 2

## MODELING NON-MARKET INSTREAM FLOW BENEFITS: CONCEPTUALIZATION

Water allocations for free-flowing stream recreation activities occur outside the familiar market system. Even though individuals in Colorado can buy and sell water rights, the collective good aspect of instream flow--more flow for one recreationist means more flow for all participants--inhibits transactions between private water right owners and individuals wanting stream flow for recreation. In the absence of market prices, the researcher must estimate a surrogate value, a "shadow price," to represent the social worth of instream flows. Water managers can use these synthetic benefit estimates as they evaluate alternative stream flow investment decisions and instream flow allocation strategies.

This chapter discusses the conceptualization of an appropriate measure of the benefits that recreationists receive as they use instream flows, and outlines the technique used to measure instream flow value. The approach, termed a "contingent valuation method" estimates a total instream flow bid function that values the benefits over and above actual expenditures on the recreation experience. Since this report attempts to value incremental instream flow changes, the economic guide is marginal net benefits.

### Willingness to Pay as a Measure of Economic Value

In the market place the commodity price reflects economic exchange value. Market price, under certain circumstances, measures the marginal utility the individual receives from the last unit consumed. Differences in commodity prices, assuming that the effects of variation in user income those expenditures shouldn't be imputed to changes in the stream flow alone. Also, some expenditures provide utility directly to the user, even though he doesn't participate. Even if instream flows were eliminated, the recreationist could enjoy a benefit from a new expenditure pattern equal to the benefit from the original expenditure on stream recreation. The net benefit, willingness to pay for instream flows, is the incremental increase in utility over and above the actual expenditure.

Figure 1 illustrates the important features of the instream flow valuation problem. The total benefit function's first derivative, d'(F), represents the aggregate marginal benefit curve for instream flow. For changes in the existing instream flow, the appropriate measure of the social worth is marginal benefit, rather than total instream flow benefits. The curve, c'(F), shows the individual's own private marginal expenditure on equipment and other inputs he needs in order to enjoy the benefits from different instream flow quantities. The community also bears a cost to supply instream flows. The curve, k'(F), reflects both the marginal public cost to provide instream flows, and the marginal social opportunity cost of having the water flowing in the stream versus being diverted or stored for other productive uses. For example, managing stream flow at higher levels precludes diverting water for irrigated crop production. The social opportunity cost is equal to the decrease in farm benefits due to less irrigation water supply. Optimal instream flow quantity occurs at point E, (F*), in Figure 1, where net willingness to pay is equal to the marginal cost of supplying those flows (d'(F) - c'(F) - k'(F)).

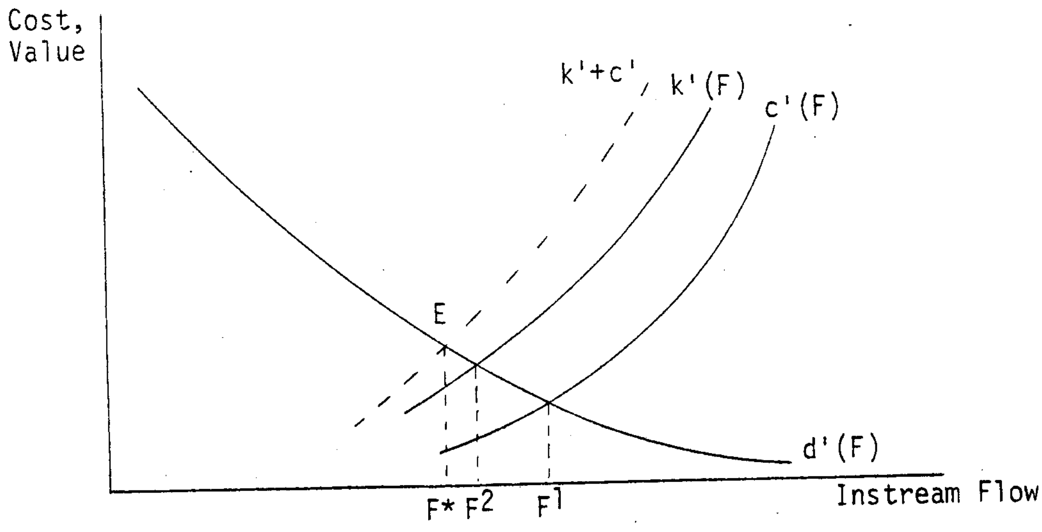



Figure 1. Instream Flow Valuation.

Techniques to measure instream flow benefits either estimate the willingness-to-pay function, d'(F), over the appropriate range of flow levels, or they directly estimate the optimal flow level. The gross expenditure method and the facilities cost approach try to estimate point E. The individual's own expenditures for the instream recreation activity is the gross expenditure benefit estimate. This approach assures that the recreation experience is at least worth the individual's expenditure on travel, equipment and daily area expenses. The quantity of instream flow provision is at point $F_1$. These expenditures measure the utility derived from the purchase of items and may contribute to the utility of recreation experience, but that estimate has little to say about the gain in utility due to increased instream flow.[2]

---

[2]Jack Knetsch and Robert K. Davis, "Comparisons of Methods for Recreation Evaluation," Allen Kneese and Stephen Smith, ed., Water Research (Baltimore: John Hopkins Press, 1966).

The cost method values instream flow benefits as the least cost method of providing more flow. Instream flow provision would be at point $F_2$. This method has the limitation that one can justify any recreational expenditure--benefits always equal cost--without knowing anything about the opportunity cost of public expenditures in some other use or anything about the decrease (increase) in recreation utility from lower (higher) instream flow levels.[3] Because these techniques don't satisfy theoretical economic requirements, most economists find them inappropriate. The correct instream flow value is the amount recreationists are willing to pay to enjoy an incremental increase in the stream flow level.

Contingent Valuation Approach

The contingent valuation method uses personal or mail interviews to make straight forward estimates of the recreationist's willingness to pay for instream flows. Correctly formulated sample survey solicits individual or household responses about the maximum price the recreationist would pay for a specific recreation input, rather than do without. Intuitively, the individual makes utility maximizing choices concerning his time and expenses to enjoy a recreation activity. If the recreation experience, or in this report a recreation input, had a market price, the individual would choose between the need for the recreation input to the experience and other expenditures. The interview provides the tool for determining the synthetic price he would be willing to pay if the recreation opportunity were marketed.

This technique effectively aids water resource management. An appropriately worded questionnaire values the net contribution of the recreation input to the experience. The approach can easily focus on the incremental

[3]Ibid.

illustrates a set of hypothetical individual bid functions. The vertical axis represents negative changes in a numeraire good (usually in terms of the recreationist's dollar income); the horizontal axis represents positive changes in the stream flow level. The researcher constructs these curves by asking the household to estimate his maximum bid, in terms of the numeraire, for a potential instream flow change. Consider an initial state,

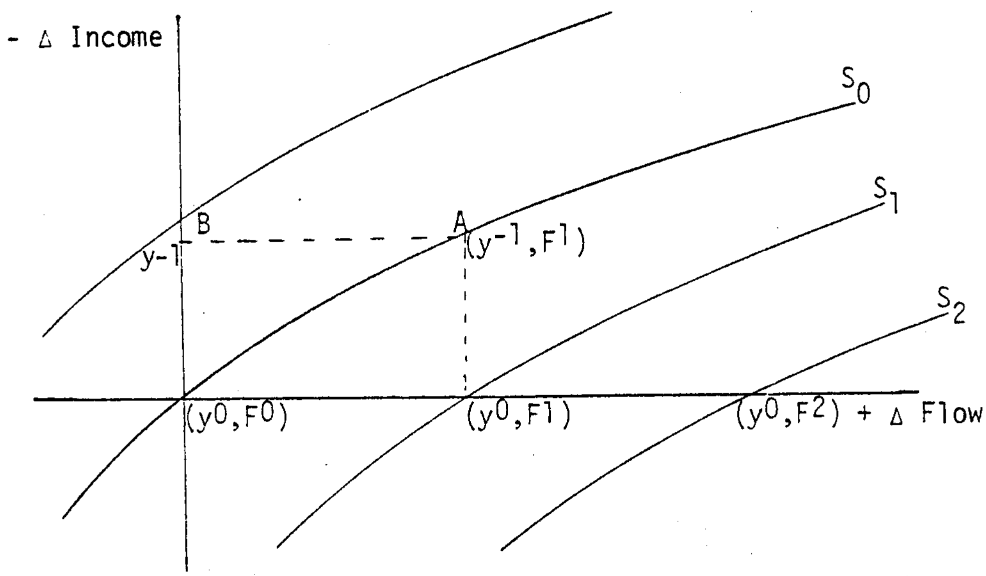



Figure 2. The Bradford Public Good Valuation Model.
Source: Randall and Brookshire, 1978.

$Y^0$ income and $F^0$ instream flow, if the household has a positive preference for both the numeraire and instream flow, the curve $S_0$, represents one Bradford bid function. At point A, the individual's maximum bid to have stream flow level, $F_1$, is equal to the distance 0.B. The curve passes through the origin since he would not give up income if the instream flow level does not increase. Constructing an instream flow indifference bid curve is the hypothetical bidding game's objective. The researcher may ask survey participants either a willingness-to-pay (WTP) or willingness-to-accept compensation (WTA) question to generate an indifference bid curve.[13]

[13]Randall and Brookshire, op. cit.

Either willingness-to-pay question relating to a specific Hicksian consumer surplus can be a compensation or equivilent welfare measure. The questions differ with respect to the initial instream flow and income endownment, with respect to the water property rights, and with respect to the direction of instream flow change. Assume that the recreationist has no rights to any stream flow. Given the initial endowment ($Y^0$, $F^0$) in Figure 2, the WTP compensating surplus questions the recreationist about his maximum bid to obtain an increase instream flow to $F^2$. That payment, equal to the distance OB, leaves the household on his initial indifference curve, $S_0$, with less income but more intream flow. If the initial endowment is $Y^0$,$F^1$, the answer to a WTP equivalent surplus question reveals the maximum payment to avoid a decrease in stream flow to $F^1$. This compensation (OB) leaves the household on his subsequent indifference curve $S_0$ instead of $S_1$, at point A.

Now, provide the recreationist an instream flow property right of $F^1$. If the initial endowment is at $Y^0$, $F^1$, the appropriate equivalent surplus bidding game asks the household about its maximum willingness to accept the lower stream flow, $F^0$; and if the initial endowment is at point A the WTAC compensation surplus measures the income the household needs in order to voluntarily accept the lower instream flow at $F^0$.

Summarizing these relationships, then:

$$WTP^C = WTP^E \leq M \leq WTAC^C = WTAC^E$$

where M is the Marshallian consumer surplus. One very important question concerns the relationship between WTP, WTAC and M. According to Randall and Stoll [14]

---

[14]Alan Randall and John Stoll, "Consumer Surplus in Commodity Space," working paper, Department of Agricultural Economics, University of Kentucky, Lexington, Kentucky, 1978.

# CHAPTER 3

# DATA COLLECTION AND ANALYSIS PROCEDURES

Direct consumer surplus estimation, more than any other empirical study, demands a specific problem area, appropriate sample selection, careful survey instrument formulation, and proper statistical models. The Poudre River Canyon is an ideal study location. Although, it may be too small to permit generalizations of the results to Eastern rivers, it does illustrate Western water allocation problems where over-appropriation is the basic problem. Currently, those who divert the stream flow have rights to the total water supply, regardless of the water's instream recreation value. The outstanding recreation possibilities in the Poudre River Canyon emphasize the economic allocation problem, thus reduce the bidding game abstraction. Similarly, a well constructed sample survey can help make the bidding game results more believable. Color photographs and recognizable payment vehicles place the respondent into a familiar economic situation. Choosing the correct statistical model is especially difficult. Economic theory suggests a range of possibilities each have advantages and disadvantages.

## The Study Area

The study area includes the Cache la Poudre River Canyon from the intersection with the eastern boundary of the Roosevelt National Forest, just northeast of Fort Collins, Colorado, up to the river's source at Poudre Lake in Rocky Mountain National Park (see Figure 3).

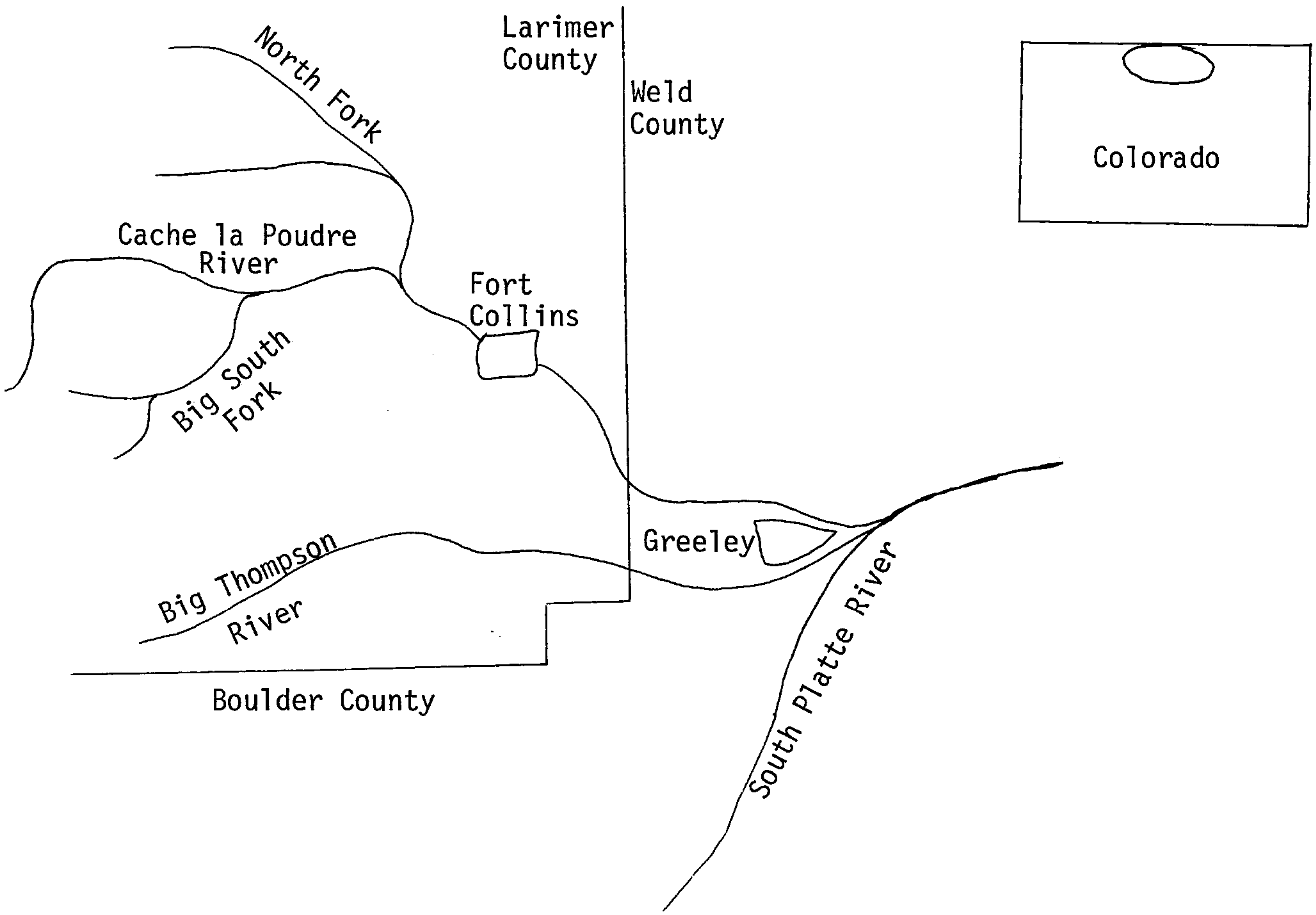



Figure 3. The Study Area.

Table 3-1. Average Rate of Flow, (Selected Months) Cache la Poudre River, 1961-1975.

| Year | May | June | July | August | September |
|---|---|---|---|---|---|
| | (average cubic feet second) | | | | |
| 1975 | 306 | 1459 | 1283 | 281 | 100 |
| 1974 | 1282 | 1816 | 601 | 107 | 79 |
| 1973 | 1454 | 2074 | 1066 | 372 | 63 |
| 1972 | 586 | 1445 | 413 | 84 | 105 |
| 1971 | 1014 | 2381 | 919 | 217 | 161 |
| 1970 | 962 | 1828 | 910 | 280 | 105 |
| 1969 | 822 | 1248 | 580 | 112 | 126 |
| 1968 | 469 | 1728 | 666 | 330 | 113 |
| 1967 | 428 | 1275 | 706 | 116 | 70 |
| 1966 | 485 | 561 | 158 | 102 | 99 |
| 1965 | 526 | 2180 | 1260 | 415 | 129 |
| 1964 | 583 | 1106 | 512 | 176 | 75 |
| 1963 | 444 | 635 | 199 | 190 | 124 |
| 1962 | 1121 | 1427 | 748 | 184 | 37 |
| 1961 | 1142 | 1963 | 520 | 305 | 196 |
| Average for Years 1961-1975 | 775 | 1542 | 703 | 218 | 105 |
| (Standard Deviation) | (361) | (529) | (338) | (107) | (40) |

Source: U.S. Department of the Interior *Water Resources Data for Colorado* (1961-1975) (observations are for canyon mouth gauge)

Approximately five miles above the canyon mouth the Poudre River splits into the main stem and the north fork. When the stream runoff is high, this short section provides an excellent white water rapids for kayakers and river rafters at all skill levels. Throughout the next 30 miles, until one reaches the small town of Rustic, Colorado, the river makes numerous twists and turns in an increasingly narrow canyon. The U.S. Forest Service has built three picnic grounds and four campgrounds at places where the canyon wides slightly. Excellent fishing abounds in this section, with part of the river designated a "wild-trout" fishing stretch for fly or lure fishermen. The District Forest Ranger estimates that this lower reach receives 60 to 70 percent of the total recreation use.[1]

Above Rustic, the river flows through a relatively broad mountain canyon. Although this stretch is unquestionably beautiful much of it is privately owned. Thus, there are two picnic sports and only one campground. The highest few miles, where the stream leaves the highway and is accessible only by foot, provides an excellent high mountain backpacking trail. The low-flow problem effects the whole Poudre Canyon, but it is most important in the lowest 30 miles, from Rustic down to the canyon mouth, where conflicts arise between recreationists wanting the flow for recreation and farmers diverting the flow for crop irrigation.

The average instream flow (discharge) is relatively small, but the flow varies widely during the year and across years. The 15-year (1961-1975) average flow was 248 cfs at Rustic, Colorado and 613 at the canyon mouth. The maximum instream flow over that 15-year period was 7,483 cfs, during a flood, while the minimum was 10.3 cfs. The stream flow, during

---

[1]James W. Carlson, District Ranger, Arapahoe and Roosevelt National Forests, Fort Collins, Colorado (September 1978).

the year, also fluctuates from high flow in mid-June to low flow in early spring and late summer (see Table 3-1).

The instream flow peak runoff depends on how rapidly the winter snow accumulation melts. Spring rains and high temperatures in 1962 caused an early rise in the ream flow. Instream flow in June was much lower than normal that year. The 1978 spring runoff was one of the highest, peaking in mid-July at approximately 5,000 cfs and continuing to have above average flow into August. Usually, the Poudre River has approximately 700 cfs in July and 218 cfs in August.

In addition to snow melt, the Poudre River receives water from seven transmountain diversions from the North Platte River drainage. The average diversion between 1966-1970 was: 301 acre feet (af) from the Cameron Pass and Michigan ditches, 1,980 af from the Skyline ditch, 15,200 af from the Laramie-Poudre tunnel, and 2,430 af from the Wilson supply ditch.

The Poudre River Canyon is an extremely popular recreation area. In 1977, 146,500 people used the canyon for fishing, camping, kayaking, etc.[2] A well maintained, surfaced highway parallels most of the river channel. When the flow is high, the river provides white water rapids for kayakers and rafters at all skill levels. The river and canyon, with high, wooded mountains, form a picturesque mountain setting. In fact, the large majority of visitors come to the canyon just to relax and enjoy the scenery, at one of the camp or picnic grounds. For those

[2] Recreational Information Management System, USDA, Forest Service, Fort Collins, Colorado, personal communication (1978)

who do fish, the Poudre River temperature, turbidity, and flow attributes produce an excellent trout habitate. The primary species are rainbow and brown, with a few brook and cutthroat (see Table 3-3). Table 3-3 shows the Poudre River recreational use from 1971 to 1977.

Table 3-2. Recreation Use Rates for Fishing, Shoreline, and White Water Activities (no. annual visitor days - x 1,000).

| Activity | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 |
|---|---|---|---|---|---|---|---|
| Fishing[A] | 18.7 | 20.6 | 20. | 22. | 26.3 | 37.5 | 39.5 |
| Shoreline[B] | 120.2 | 140.6 | 123.0 | 137.2 | 145.1 | 106.0 | 108.4 |
| White water[C] | .2 | .3 | .5 | .6 | .7 | .7 | 1.6 |

[A]Fly, lure, and bait trout fishermen.

[B]Viewing, camping, hiking, picnicking, etc. activities.

[C]Kayaking, rafting, tubing, canoeing.

Source: Recreational Information Management Service, U.S. Forest Service, Fort Collins, Colorado (1977).

Farmers in the area have diverted Poudre River stream flow for irrigation since 1864. They irrigate sugar beets, corn, beans, alfalfa, and small grains on approximately 50,000 acres of land. Water rights for irrigation have been decreed in excess of 4,000 cfs, much less than the average summer runoff. The state is only now acquiring water rights to maintain instream recreation activities.

Table 3-3. Estimates of Brown and Rainbow Trout Populations in a Campground and Wild Study Section of the Poudre River (over 14 cm).

| Year | Month | Species | Mean Number Campground | Mean Number Wild Section |
|---|---|---|---|---|
| 1971 | April | Brown | 163 | 133 |
| | | Rainbow | 208 | 198 |
| | | Combined | 371 | 331 |
| | Oct. | Brown | 217 | 180 |
| | | Rainbow | 233 | 229 |
| | | Combined | 450 | 409 |
| 1972 | April | Brown | 123 | 159 |
| | | Rainbow | 184 | 184 |
| | | Combined | 307 | 343 |
| | Oct. | Brown | 213 | 207 |
| | | Rainbow | 231 | 189 |
| | | Combined | 444 | 396 |

Source: Thomas L. Marshall, "Trout Populations, Angler Harvest and Value of Stocked and Unstocked Fisheries of the Cache la Poudre River, Colorado," Ph.D. Thesis, Colorado State University, Fort Collins, Colorado (June 1973), p. 56.

Sample Procedure

A complete measure of instream flow value would require interviewing all individuals who participated in stream recreation activities. Without question, that task would be too expensive and time-consuming. A simpler method selects only a few recreators then makes inferences about all recreationists from the sample.

Any household visiting the Poudre River, during the 1978 summer, was a potential member of the recreation sample population. The actual sample included 134 persons who participated in fishing, shoreline, and white water activities. The sample is estimated to represent .1 percent of the fishermen, 2.5 percent of the white water recreationists, and .04 percent participants in shoreline recreation activities. The sample survey design stratified the recreation population into the three recreation activities, then selected a random sample from each group.

One of the authors (Daubert) conducted the interviews. Although this labor-intensive procedure increases the survey cost, it also increases the response rate. Very few people refused to respond when confronted in person. A high response rate reduces the possibility of bias, since the sample should more closely resemble the population. A personal interview is especially helpful in a hypothetical bidding game situation, since the interviewer can note specific reactions and eliminate any misunderstanding about the questions in the survey. But, the interviewer must always avoid interjecting his own bias during the interview.

To lower the cost, the survey design separated instream recreation activities into fishing, shoreline, and white water groups and limited the survey area. The most specific group was fishing, which included fly, lure, and bait fishermen. The white water category included tubing, kayaking, and rafting. The shoreline class represented all other instream and stream-related activities such as camping, swimming, picnicking, wading, hiking, viewing, etc. Because the shoreline group is heterogeneous, one should use the results cautiously.

Only participants in the lower one-half of the study area, from the canyon mouth to Rustic, Colorado, were randomly sampled. This study area reduction and recreation groupings limited the population, possibly introducing sample bias, but they substantially lower cost and effectively included most (60-70 percent) of the recreational activity in the Poudre Canyon.

To achieve randomness, such that every sample of size n has the same chance of being selected, we originally chose a random number of days to interview each month. It was obvious from the first interview day that following the original plan would be impossible. The Poudre River spring runoff in 1978 was one of the highest and longest on record. During many interview days, from early June to mid-July, when the runoff was especially high, there were few if any recreationists to be found. In fact, during one ten-day time span, the river flow was so high and dangerous that authorities closed the canyon to all water contact recreation use.

The irregular flow conditions resulted in an increase in white water interviews early in the season and an increase in fishing interviews late in the season. Table 3-4 shows the distribution of interview days for each recreation activity.

Table 3-4. Number of Interviews for Each Recreation Activity by Month, 1977.

| | Month | | | | | |
|---|---|---|---|---|---|---|
| Activity | May | June | July | August | September | Total |
| Fishing | | 12 | 13 | 14 | 10 | 49 |
| Shoreline | | 15 | 15 | 15 | | 45 |
| White water | 12 | 13 | 10 | 5 | | 40 |

The interview process, on any given sample day, attempted to eliminate any systematic time or location bias. Each day, the six camp or picnic grounds were randomly ordered to organize the interview.

After completing an interview, we selected the next household we encountered then moved to the next site, the process continued until two households were contacted on each site. Since there is no reason to suspect any systematic ordering of recreationists this section should generate a random sample. Initially, the goal was to interview at the site. However, many white water recreationists and a few recreation parties, who were there for a day picnic, refused to use their recreation time for an interview. These interviews were completed in their own homes at a more convenient time.

The most difficult sample construction decision was to choose an appropriate sample size. The sample information quality depends on the sample size and the data variation. An increase in the sample size will increase the probability that sample parameter accurately estimates the true population parameter. Since information collection is not free, the researcher must tradeoff increases in statistical accuracy with collection costs. Mendenhall has suggested a formula for selecting stratified sample size, n, to estimate a population total or mean, given a specific bound on the estimation error:[3]

$$n = \frac{\sum_{i=1}^{L} \frac{N_i^2 \sigma_i^2}{W_i}}{N^2 D + \sum_{i=1}^{L} N i \sigma_i^2}$$

where

$W_i$ is the fraction of observation from recreation activity i (i = 1, 2, 3)

---

[3]W. Mendenhall, L. Ott, and R. L. Scheaffer, Elementary Survey Sampling (Belmont, Calif.: Duxbury Press, 1971), p. 61.

$\sigma_2^i$ is the population variance for recreation activity i

N is the population size

$D = \frac{B^2}{4}$ when estimating the population mean, $\mu$, or

$D = \frac{B^2}{4N^2}$ when estimating the population total t

B is the specified bound on the sample estimate.

Solving for the sample size is rather difficult since the population variance is unknown. One solution is to use the sample variance from a prior experiment. If this information is not available, the Empirical Statistical Rule states that the range is approximately equal to four standard deviations.[4] But, little information is known about the instream flow bid variance, and because one could only guess at the possible bid range, the number of observations was a function of available time and effort.

Even though the survey was long--the average interview lasted between 30 and 45 minutes and a few lasted over an hour--the rate of acceptance was over 80 percent. Shoreline participants had the highest response rate, only 7 percent refused, since they generally had more time to relax and sit through the survey. Fishermen were also very receptive to the survey, 86 percent responded; they as a group had the most to gain from instream flow management. Kayakers and rafters had the lowest response rate. We could understand why white water recreators were unwilling to leave the stream and participate in an on-site interview; but it was disappointing that only 62 percent were willing to set aside time for an interview at their own convenience.

The household was the basic sample unit. The interviewer took time to insure that the spokesman gave answers that represented the family.

---

[4]Ibid., p. 7.

Admittedly, this choice reduces the taste and preference variable's reliability. The survey could explicity ask for an individual willingness-to-pay response, but to obtain individual answers you would have to physically separate the respondet, which is not each when they came to the Poudre River especially for group recreation. The separation alienating some individuals results in poor responses to questions and lower survey response rates. Since most users participate with a household group, part of the enjoyment comes from interaction between family members. Using the household as the basic economic unit, besides making the survey more enjoyable for the interviewer and the respondents should improve the accuracy of the key variable, willingness to pay.

Although the sample sizes were relatively small, the sample parameters are quite representative of the population. Using demographic data from the Fort Collins area as a comparison base, the sample estimates generally reflected local socio-economic characteristics. Table 3-5 lists the Fort Collins and sample characteristics. Fishing, shoreline, and white water sample male/female ratios differed from the Fort Collins ratio. In most households, male members still do most of the fishing or kayaking. And, in those households where both sexes fished or kayaked, the male generally supplied the socio-economic data. In contrast, the female members of households participating in shoreline activities dominated those responses. The average income of fishing recreationists was considerably higher than the Fort Collins average. However, this finding is consistent with other studies indicating individuals having the time for leisure activities tend to have higher incomes. The only other major difference was that kayakers are generally younger and have less income than typical individuals. Note that most recreationists are local residents except for the shoreline category.

Table 3-5. Fort Collins and the Sample Survey Socio-economic Characteristics, 1977.

| Characteristic | Fort Collins[A] | Fishing | Shoreline | White Water |
|---|---|---|---|---|
| Male/Female Ratio | 53/47% | 88.6/11.4% | 45.4/54.6% | 75.7/24.3% |
| Age (average) | 40.5 | 38.1 | 37.0 | 30.9 |
| 18-24 | 23.2 | 11.4 | 15.2 | 26.2 |
| 25-49 | 48.5 | 55.1 | 58.7 | 69.8 |
| 60-64 | 16.8 | 19.7 | 15.8 | 4.0 |
| 65> | 11.6 | 13.8 | 10.3 | 0.0 |
| Education (years) | 12.6 | 15.0 | 14.1 | 14.4 |
| Average Income (x 1,000) | 13.5 | 18.2 | 14.8 | 12.5 |
| Income Distribution | | | | |
| <6,000 | 11.1 | 7.1 | 12.3 | 14.2 |
| 6,000- 8,499 | 13.5 | 11.4 | 12.9 | 16.0 |
| 8,500-10,999 | 11.0 | 11.6 | 12.3 | 20.3 |
| 11,000-15,999 | 25.9 | 24.8 | 27.1 | 16.4 |
| 16,000> | 38.5 | 45.1 | 35.4 | 33.1 |
| Non-Res./Res. | | 35.2/64.8 | 45.8/54.2 | 40.4/59.6 |

[A]Source: Colorado Division of Planning (October 1978).

The on-site interview procedure has one inherent bias. Those who stay longer have a higher probability of being chosen for the interview. Thus, responces which are a function of length of stay might be biased. For example, recreationists staying in the river canyon longer and having a higher willingness to pay for instream flows might bias the results upward, since they have a higher probability of being in the survey. Lucas suggested that weighting the household responses by the linear inverse of the difference between the sample average and its number of annual days use.[5] Accordingly, we weighted the responses from households staying in the canyon by the reciprocal of the difference between the number of days they stayed in the study area and the sample average.

## Questionnaire Design

The survey questionnaire is the most important factor determining the success or failure of a direct consumer surplus estimation attempt. Because there is no single question design that can guarantee that respondents won't over- or understate their preferences, the research methodology included the possibility of misrepresentation. The question structure also made it easy for the respondent to give accurate answers, by using an experimental situation that is realistic and based on routine behavior. Especially important, questions should not ask the individual to respond to alternatives beyond the range of his experience. Ajzen and Fishbein have identified the psychological conditions that enable hypothetical behavior to model actual behavior.[6]

---

[5]Robert C. Lucas, "Bias in Estimating Recreationist's Length of Stay from Sample Interviews," Journal of Forestry (December 1963), pp. 912-914.

[6]I. Ajzen and M. Fishbein, "Attitude-Behavior Relationships: A Theoretical Perspective and Review of Empirical Research," Psychological Bulletin 84 (1977), pp. 888-918.

Method of Payment

The questionnaire (see Appendix A) includes two question formulations that reduce the hypothetical nature inherent in most bidding game techniques. Each respondent must pay an entrance fee or a sales tax before he can use the instream flow. Resource managers have used both methods to finance changes in the provision of recreational public goods. Both payment obligations, placing the respondent in realistic positions, made it easier for him to supply accurate responses.

Most visitors to the Poudre Canyon were familiar with both methods financing public recreation. Many National parks require a daily vehicle entrance fee. At many campground areas, users must purchase an overnight camping fee. Since they realize that resource managers use those fees to supply many recreation-related services, it was easy for them to see how an entrance fee could finance instream flows. Individuals also understood how water managers could use sales tax revenues to finance instream flows. The Denver metropolitan area has a district sales tax that provides regional transportation services. Public officials in Pitkin County Colorado use a district sales tax to buy land for public recreation purposes. Colorado residents routinely pay sales taxes on market purchases.

Preceding each payment obligation, the questionnaire had an introductory statement about the interview's purpose. After a few short questions establishing the respondent's recreation preferences, the interviewer asked him to reveal his willingness to pay using both payment methods. Prior to the bidding process, the interviewer stated that all recreators would pay the sales tax (entrance fee) before they could enjoy the new stream flow levels. This provision should help to avoid some free rider problems. The specific form of each repayment obligation is given by:

> Assume that to gain access to the Poudre River Canyon to _________ for _____ day(s) of annual use all users must pay a daily entrance fee. All of this daily fee would be used to provide the best stream flow for your (fishing, shoreline, white water) enjoyment. This daily fee is the only way of financing the various water quantities in the photographs. All users will pay the same fee as you do. This fee will permit use for all members of your household going (fishing, shoreline, white water) for _____ day(s) of annual use.
>
> I would like to play a somewhat different bidding game with you. Suppose that you were going to use the Poudre River to _________ for _____ day(s) of annual use. Assume also that a local governmental agency collected an annual district recreational sales tax to finance the provision of different stream flows for your (fishing, shoreline, white water) enjoyment. This annual tax is the only way to finance the program. All area residents and visitors to the Poudre River recreation district would pay the annual sales tax. This sales tax will permit use for all members of your household going _________ for _____ day(s) of annual use.

Notice that both formulations explicitly state that the payment is the only way to finance instream flows. This condition eliminated many zero bids from those who had objections to the specific payment. If any respondent still bid zero, or if the bids from one payment were substantially different from the other, a series of questions designed to discover his motivation were posed. If the recreationist responded with the answer that his willingness to pay was zero because he did not perceive any benefits from an increase in the stream flow level, his bid was recorded as zero. But, if he responded that sales taxes were already too high, or that it is improper to charge an entrance fee to public property, or any other protest against the specific game, the respondent was not playing the game and later analysis treated his answer as a non-response. This check identifies many inappropriate responses, but it overlooks downward biased bids in protest to the method of payment.[7]

Table 3-6 shows the number and percentage of radically lower and zero protest bids. Recreationists were more likely to protest the sales tax game. Those, with low marginal instream flow utility, realized that they would help pay for other's enjoyment. Shoreline participants had the highest rate of protest against either game. Unlike the use in fishing and white water activities, instream flows are not crucial to enjoy shoreline recreation. This recreation group has less motivation to pay, and more motivation to avoid taxes or entrance fees.

These two games determine an interval for the aggregate willingness-to-pay curves.[8] The entrance fee forces the participant to pay an amount equal to his stated willingness to pay. Respondents biasing their entrance fee answers probably gave bids lower than their true willingness to pay, hoping that the aggregate payment would be large enough to suggest provision of more flow at a fee lower than their true willingness to pay. Conversely, recreationists may have an incentive to overstate their willingness to pay during the sales tax game. A sales tax is a fee that all individuals must pay independent of the times they use the Poudre River. Since any increase in sales taxes to provide more instream flow is likely to be small, those with strong preferences toward river flow have an incentive to overstate their bid, maximizing the chance that public officials increase the instream flow quantity.

---

[7]Randall, Ives, and Eastman, op. cit., p. 138.

[8]Bohm, "Estimating Access Values," op. cit., p. 193.

Table 3-6. The Frequency of Protest Bids

| | Fishing | | Shoreline | | White Water | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Entrance Fee | Sales Tax | Entrance Fee | Sales Tax | Entrance Fee | Sales Tax | Entrance Fee | Sales Tax |
| No. of Non-response Zero Bids | 1 | 2 | 2 | 5 | 1 | 2 | 4 | 9 |
| (%) | (2%) | (4%) | (4%) | (11%) | (3%) | (5%) | (3%) | (7%) |
| No. of Downward Biased Protest Bids | 2 | 2 | 3 | 3 | 1 | 1 | 6 | 6 |
| (%) | (4%) | (4%) | (7%) | (7%) | (3%) | (3%) | (4%) | (4%) |

The Bidding Procedure

The bidding questions are very similar to the iterative approaches in the Randall and Brookshire studies. The interviewer asks each respondent to reveal his/her willingness to pay for instream flow in terms of a percentage increase in the present sales tax rate and an increase in an entrance fee. Always beginning with the lowest instream flow quantity, the interviewer asked the household how much it would be willing to pay for the next highest instream flow situation. For example, the recreationist would respond with a "yes" or "no" answer to the following question:

> If the entrance fee cost $_____ per day, would you pay the fee so the members of your household could travel up the Poudre River Canyon to (activity) for _____ day(s) of annual use, if that amount resulted in an increase in water flow from those in Picture A to Picture B?

The interviewer started the bids at $1.00 for the entrance fee game and a .1 percent increase in the sales tax for the sales tax game. If the respondent answered with a "yes," the interviewer raised the bid by $.25 or .1 percent increments until the respondent answered "no." The interviewer, then, lowered the bid, until he received another "yes" answer. The dollar amount at the last "yes" response represents the household's maximum willingness to pay for the specific instream flow improvement.

Since few individuals knew what a percentage increase in sales taxes would mean to them, prior to the bidding process the interviewer presented a table showing the annual dollar equivalent of the percent change in sales taxes. The tables showed the current sales tax payment in dollars, depending on the family size and income, and the additional dollar amount he could expect to pay if sales taxes increased. The data was calculated from the 1978 Colorado State Income Tax Information Booklet.

## Color Photographs

Color photographs showing eight different instream flow levels at four different sites helped the hypothetical bidding game to model a realistic situation. These levels were well within the range of most recreation experiences. The photographs minimized the respondent's need to imagine how the Poudre River looks at different flow levels, and provided a uniform comparison base. Figure 4 shows the color photographs for four flow levels at one site in the Poudre River Canyon.

The four chosen sites best illustrated the potential change in the instream recreation utility after a change in the flow level. Even though all pictures were taken on the same day, the instream flow was not the same. Two sites are above a large irrigation diversion and the north fork of the Poudre River. Ideally, the photographs should be identical except for the instream flow quantity. However, nature, and not man, controls the stream flow--high in the spring and low in the fall. To capture different levels, the pictures had to be taken during four different months in 1977 resulting in different site backgrounds. Also, the water quality varies as the high spring runoff makes the river "muddy" when compared to other instream flow levels.

## Hydrologic Data

Color photographs realistically illustrate the change in the recreation experience, but, they fail to capture the non-visual changes from diffent instream flow quantities. The survey interviewer provided additional information on depth, velocity, and the change in trout

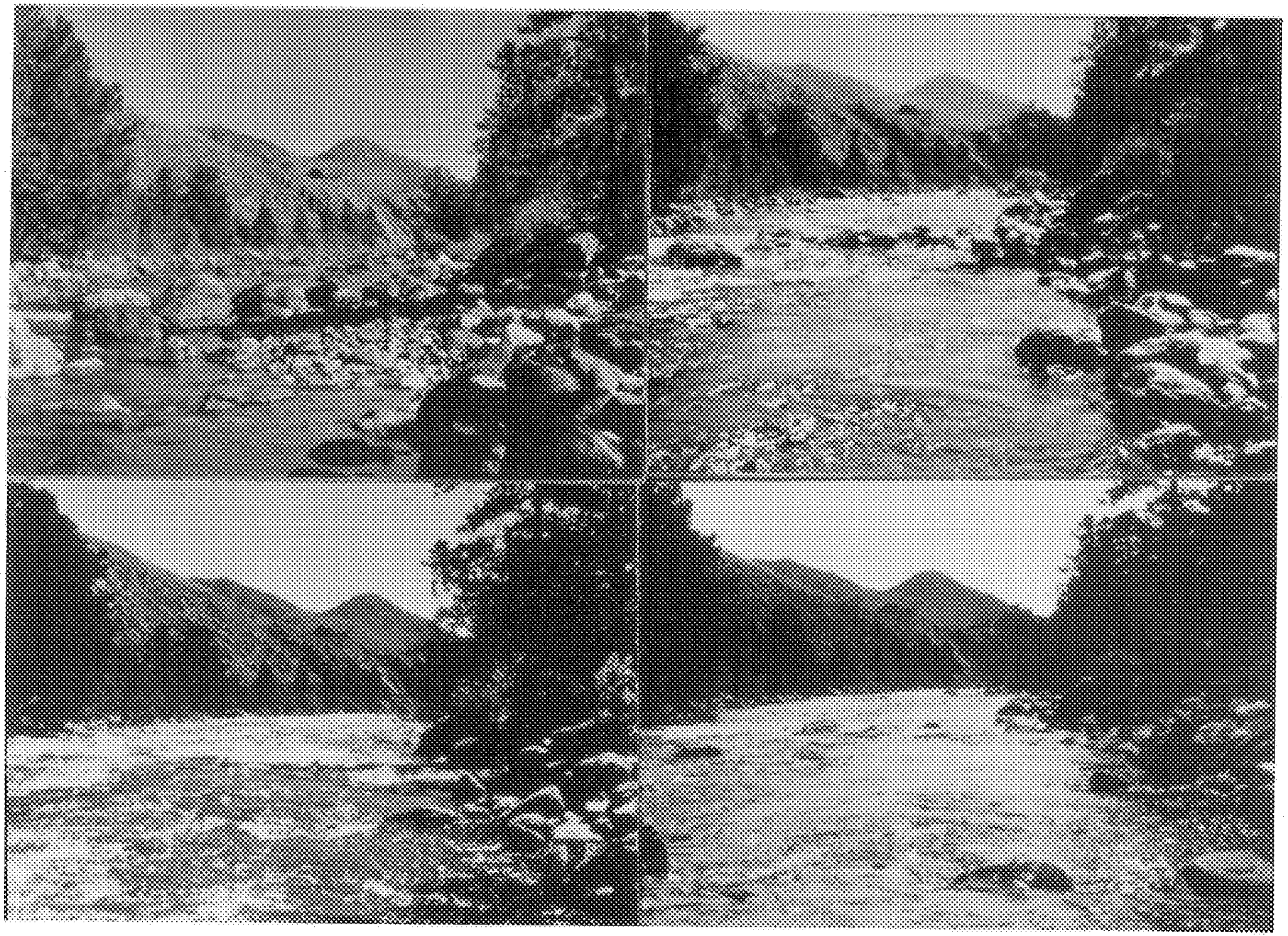


Figure 4. Four Instream Flow Levels, Poudre River Colorado, 1978.

catch rate for each cfs flow rate. A river gaging station at the canyon mouth provided data on the cfs rate at the sites below the irrigation diversion points on the days the pictures were taken. Subtracting the North Greeley Canal diversion generated the cfs rate at the other sites.

Depth and velocity predictions for each cfs discharge rate required river cross section survey at each site. Given the stream cross section profile and the stream substrata at each site, a water surface profile computer program can forecast the depth and velocities at the stream at different discharge rates.[9] Each respondent was shown a picture of the stream cross section similar to the one in Figure 5.

The Cooperative Instream Flow Service Group (IFG) fish habitat model calculates the probability of a trout being in a specific reach of river, given different flow regimes.[10] The model uses the hydrologic output from the water surface profile program along with trout behavior to generate an ordinal index measuring the Poudre River suitability for a trout habitat. The term for this measure is "weighted usable surface area" (WUSA) (see Appendix B and C).

Probability-of-use curves describe the trout behavior. These curves assume that trout prefer areas in a stream that have ideal conditions, but they will live in less favorable velocity and depth

---

[9]Hydrology Branch of the Division of Project Investigations, U.S. Department of Interior, Bureau of Reclamation, Guide for Applications of the Water Surface Profile Computer Program, Denver, Colorado (December 1968).

[10]Ken D. Bovee and Tim Cochnauer, Development and Evaluation of Weighted Criteria - Probability of Use Curves for Instream Flow Assessment: Fisheries, Cooperative Instream Flow Service Group, Fort Collins, Colorado (December 1977).

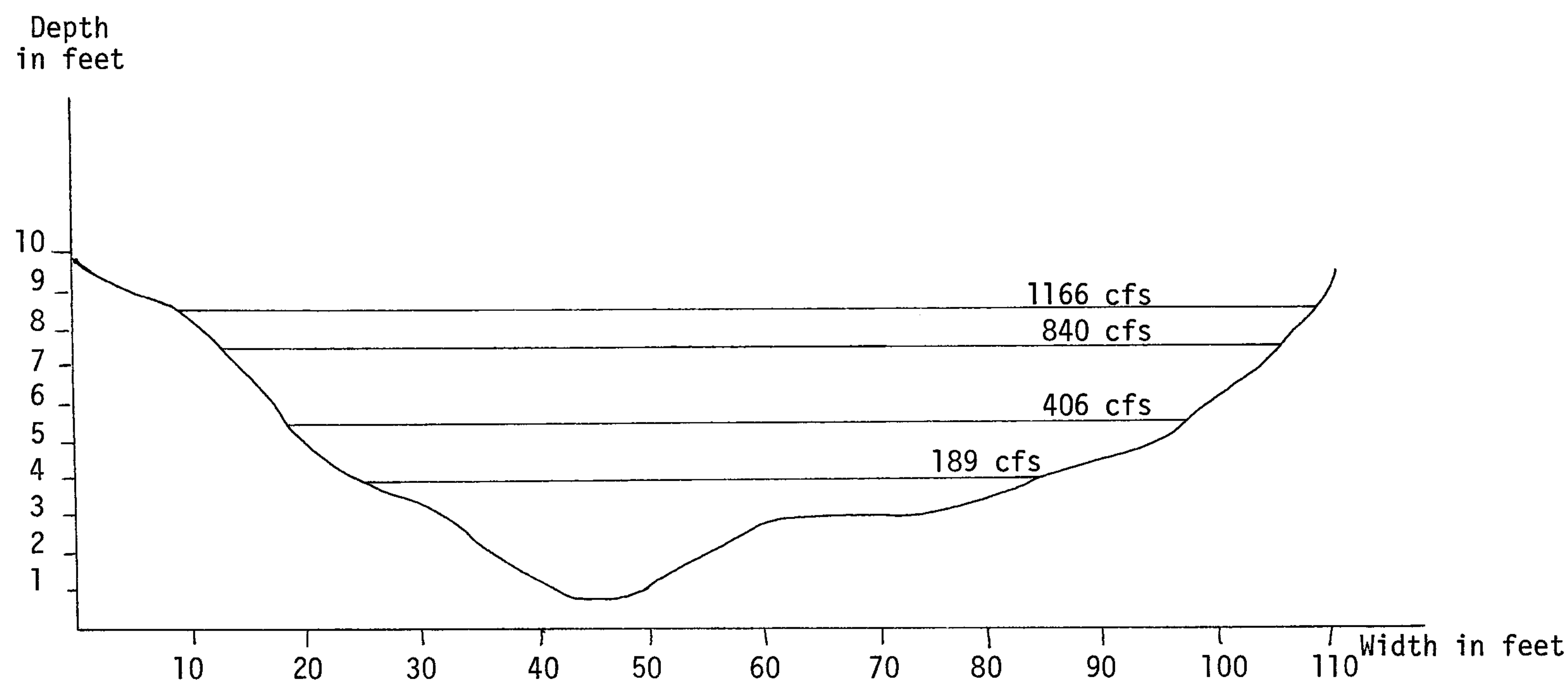



Figure 5 . Cross Section of Site C, Poudre River Canyon, 1978.

conditions according to a diminishing probability of use. The model also assumes that trout will vacate a stream reach before the flow becomes lethal. For example, if the stream depth and velocity is perfectly suited for trout, then the WUSA and actual stream surface area would be the same. The probability of finding a trout in that stream reach would be 1. A reach with velocity and depth different from the ideal conditions has a lower chance of containing a trout. If the probability of a trout living in the river section where the velocity is two cfs equals .5 and the probability a trout is there if the depth equals 1' is .1, then the joint probability is .5 times .1 = .05. Even though the stream surface area may be 100, the WUSA is only 5. The actual 100 sq. ft. of surface area will contain only five sq. ft. where the probability of finding a trout, in a specific life stage, is 1. Any one of the 100 sq. ft. is equally likely to be the one of the five WUSA with a trout. Appendix C shows the probability curves for rainbow trout in the adult life stage and the WUSA for rainbow and brown trout.

Estimating the catch rate for each flow level required two tenuous but necessary assumptions: (1) a one-to-one direct relationship between standing crop and the catch rate. Any increase or decrease in WUSA from the base flow changes the average catch rate. Table 3-7 shows the percentage change in the catch rate and the average rate per hour of effort, given the calibration catch rate of .65 trout/hr. at an instream flow of 30 cfs.[11] The calibration catch rate is the weighted average over: fly, lure, and bait fishermen; at stocked and unstocked Poudre River sections; of rainbow and brown trout; at adult and

---

[11]Thomas L. Marshall, op. cit., p. 56.

juvenile life stages. This additional information helped the respondent to make honest and accurate willingness-to-pay bids.

Table 3-7. Trout Catch Rates per Hour of Effort at Each Site and Stream Flow Quantities.

| | Site | | | |
|---|---|---|---|---|
| Quantity of Flow | A | B | C | D |
| (cfs) | (catch rate/hr.) | | | |
| 58 | .9 | .86 | | |
| 189 | 1.58 | 1.08 | 1.67 | .67 |
| 255 | 1.67 | 1.02 | | |
| 309 | | | 1.77 | .70 |
| 406 | | | 2.37 | .72 |
| 840 | | | 1.94 | .70 |
| 984 | 1.04 | 1.00 | | |
| 1,166 | | | 1.87 | .67 |

Statistical Analysis

The hypothesis, in this thesis, is that willingness to pay is a function of flow and particular socio-economic parameters. A general linear multiple regression model approximates the specific underlying relationships. In matrix notation the model is:

$$Y = X\beta + \varepsilon$$

where

Y = an NX1 vector of willingness-to-pay value or transformations of these values

X = NXK matrix of independent variable observations

$\beta$ = a KX1 column vector of unknown parameters

$\varepsilon$ = an NX1 column vector of stochastic disturbances

The assumptions of the classical linear regression model are given by the following:

The elements of X are fixed and have finite variance.

X has a rank, K, which is less than the number of independent observations, N.

$\varepsilon$ is normally distributed with $E(\varepsilon) = 0$ and $E\,(\varepsilon\varepsilon') = \sigma^2 I$, where

I is an NXN identity matrix.

Y is normally distributed, $E(y) = X\beta$ and $E\{[y-E(y)][y-E(y)]'\}=\sigma^2 I$

If the model satisfies these assumptions then the ordinary least-squares estimator (OLS) of $\beta$ is the best among the linear unbiased estimators. However, few bidding game research studies have data that satisfy all the assumptions.

Survey information, in this thesis, may result in multicollinearity, heterosedasticity, mis-specification of the model, and non-normally distributed sample values. These statistical problems may bias the estimators. Perfect multicollinearity occurs when at least one independent variable is a linear combination of the others. This condition causes the number of variables to exceed the number of independent equations. Less than perfect multicollinearity arises when the independent variables are highly correlated with each other. For example, education and income might be highly correlated. Heteroscedasticity violates the assumption that the error term has a constant variance. It is possible that the bid variances at very low or high instream flow levels are small, but large for optimal water flow conditions. Omitting important inclusing inappropriate independent variables may also violate one or more classical assumption. The statistical tests of each violation didn't reveal any major statistical problems.

Overall, the results in the following chapter depend on the complete and correct data collection and model estimation procedure in this chapter. Each step, from the study area choice to sample selection and survey decision, and last the statistical estimation, must attempt to reduce the possibility of sample, hypothetical, and statistical bias. The validity of the instream flow value estimate rests on the model construction.

# CHAPTER 4

# EMPIRICAL RESULTS

In Colorado, agencies managing wildlife and recreation have long known that water flowing instream is worth something to the recreationist. But, they have lacked specific information on the instream flow economic value necessary to evaluate alternative stream flow investment and management strategies. This chapter reports the empirical bidding game estimates of willingness to pay for instream flows. The first section presents the ordinary least squares statistical estimate of the total instream flow bid functions for fishing, shoreline, and white water activities. The next, and most important, section develops the individual and aggregate marginal instream flow economic values. The marginal instream flow benefits are comparable with values in other uses. The last section analyzes the significant socio-economic variables effecting the recreationist's total bid. Water managers can use the marginal instream flow values in their water allocation decision making process.

## Variable Description

The bidding game procedure approximates the "Bradford" bid function. Recall that from the discussion of Chapter 2 this function maps out the maximum income the recreationist would give up for changes in the stream flow level. Thus, the Bradford bid curve becomes the total expenditure curve, equal to the intergral of a compensated instream flow demand curve.[1] The basic function form is,

[1]Bradford, op. cit., p. 783.

$$TWP_{ijf} = \alpha_{ij} + \gamma Q_{ij} + \sum_{k=1}^{k} \beta X_{ijk} + e_{ijk}.$$

The left-hand term, $TWP_{ijf}$, is the total bid for activity i by household j for instream flow f. In this study, the total willingness to pay is a per day value. Entrance fee questions asked the household to respond specifically with a daily bid; responses to the sales tax questions were in annual amounts. For consistency, the sales tax annual values were converted into daily terms by dividing each bid by the number of days the household participated in the recreation activity. TWP represents the Hicksian compensating surplus measure of consumer surplus.

Total willingness to pay is a function of the instream flow quantity, $Q_{ij}$. River stage, in cubic feet per second, is the flow index. The interviewer, using color photographs, varies the flow throughout the experiment to assess its impact on the total willingness to pay. This index may oversimplify changes in the stream flow. Alternative river stages and the same stage at different sites on the river have different velocity and depth characteristics that separately may have important impacts on willingness to pay. Including information on the velocity and depth at each site for different river stages, hopefully, reduced the separate effects. The river shape controls the site velocity and depth characteristics, while the water manager can only control the cfs rate.

Uncontrollable independent parameters describe the household's tastes and preference for instream flow in a specific recreation activity. The most important socio-economic variables are income, setting limits on the respondents' ability to pay for additional instream flow, substitution possibilities at other river sites, and physical descriptions, like: age, education, and sex. Table 4-1 summarizes the model variables.

Table 4-1. Possible Equation Variables.

**Dependent Variable**

| | | |
|---|---|---|
| | Total daily bid for recreation activity i, household j, instream flows; in 1978 for each bidding game vehicle of payment | TWP |

**Independent Variables**

| | | |
|---|---|---|
| 1 | River stage in cubic ft. second (instream flow) | Flow |
| 2 | (River stage)$^2$ | (Flow)$^2$ |
| 3 | Total number of activity i days in the Poudre River Canyon | TD |
| 4 | (Total number of activity i days in the Poudre River Canyon)$^2$ | (TD)$^2$ |
| 5 | Total number of activity i days in other river canyons | SUB |
| 6 | Total number of years the respondent has participated in activity i | YEAR |
| 7 | Income | IN |
| 8 | (Income)$^2$ | (IN)$^2$ |
| 9 | Age of respondent | AGE |
| 10 | Sex of respondent | SEX |
| 11 | Education | ED |
| 12 | Site of color photographs | $SITE_i$ (i=1...4) |
| 13 | Occupation of respondent (1-Professional, 2-Owner, 3-Skilled, 4-Salesman, 5-Clerical, 6-Unskilled, 7-Housewife, 8-Retired, 9-Student) | $OC_i$ (i=1...9) |
| 14 | Employer of Respondent (1-Mfg., 2-Const., 3-Retail, 4-Financial, 5-Health, 6-Education, 7-Public Amn., 8-Agr., 9-Unemployed) | $EMP_i$ (i=1...9) |
| 15 | Population size of previous residence (1-large city, 2-medium city, 3-small city, 4-town, 5-farm) | $POP_i$ (i=1...5) |
| 16 | Date of Interview | DI |

Ordinary Least-Squares Estimates of the Total Willingness-to-Pay Functions

Both art and science play important roles when estimating a willingness-to-pay instream flow relationship. The economic models, in Chapter 2, and the non-market instream flow measurement techniques provide only general equation formulations, and partial guidelines concerning the important recreation attributes. Since no unique economic model or statistical estimation procedure exists, personal judgement aids in formulating the bid equation. Selecting a demand relationship involves analyzing each equation according to the following three criteria:

1) For reliable predictions, include as many independent variables as possible. The $\bar{R}^2$ measures the equations' power to explain the variance in willingness to pay between recreationists, and informally represents the prediction potential of all the independent variables combined in one equation.

2) Another goal is to estimate stable structural parameters. A coefficient is stable if it remains relatively constant and has the same sign throughout the equation estimations. Again, the objective is to include any stable independent variable, even if it explains very little bid variation.

3) The last criterion involves the economics of scarcity. Because adding variables is not costless, requiring computer and data collection time, the objective is to include as few variables as possible, yet still describe the important relationships.

The compromise between these criteria ends by selecting the best regression equation.

For additions to the instream river flow, economic theory suggests that total willingness to pay increases at an increasing rate, continues to increase at a decreasing rate until willingness to pay reaches a maximum bid for some instream flow, then finally, for higher instream quantities, willingness to pay decreases. Both low order polynomial and logarithmic functions can model that relationship, and both forms were tested in the data. It was found that the polynomial equation estimates consistently explained more variance in the individual bids. Tables 4-2 through 4-7 present the quadratic model for fishing and shoreline activities, and a linear model for white water activites. The number under the column labeled "order" reflects the sequence the explanatory variable entered the equation during a stepwise estimation procedure. Each time a variable enters the equation, the stepwise technique checks the other variables in the equation to determine if they should remain in the model. Appendix D presents the stepwise statistical models of alternative sets of the independent variables.

After making estimates, the next objective of statistical inference is to make judgements (hypothesis tests) about population parameters from the sample estimates. Performing the following three multiple regression hypothesis tests, we assumed that the sample parameters come from a normal population distribution, that provides the correct statistical model. The first test checks to see if the intercept equals zero.[2] The test statistic, $H_0$, is

$$\frac{\hat{B}_k - \gamma_k}{S_{\hat{B}k}} \sim t_{n-k}$$

---

[2] Jan Kmenta, Elements of Econometrics (New York: Macmillan Publishing Co., 1971), p. 366.

Table 4-2. Ordinary Least-Squares Estimates of Entrance Fee Bidding Game: Total Willingness to Pay per Day for Instream Flow in the Production of Recreational Fishing Activities, Poudre River, 1978.

| Explanatory Variable | Regression Coefficient | Standard Error of Coefficient | t-statistic | Order of Entry |
|---|---|---|---|---|
| Instream Flow (CFS) | .1295 | .72 E-1 | 3.55 | 3 |
| Instream Flow Squared (CFS) | -.138 E-3 | .52 E-4 | 5.28 | 1 |
| No. of activity days in Poudre | -.13 | .21 E-1 | 5.97 | 4 |
| No. of activity days in Poudre squared | .21 E-2 | .63 E-3 | 3.21 | 13 |
| No. of years of fishing experience | .43 E-1 | .88 E-2 | 4.85 | 11 |
| Education in years | -.71 | .14 | 4.91 | 6 |
| Site dummy 2 | -.36 | .14 | 2.50 | 2 |
| Employment dummy | | | | |
| Housewife | -1.37 | .31 | 4.40 | 8 |
| Clerical worker | -1.28 | .30 | 4.30 | 5 |
| | -.52 | .20 | 2.64 | 14 |
| Employer dummy | | | | |
| Manufacturing | .81 | .18 | 4.76 | 9 |
| Health services | 1.14 | .42 | 2.73 | 12 |
| Financial | .85 | .21 | 4.08 | 10 |
| Size of residence dummy | | | | |
| Rural area or town | .56 | .12 | 4.60 | 7 |
| Constant | 2.14 | 4.13 | 1.55 | |

$\bar{R}^2$ = .41
F = 26.98
N = 49

Table 4-3. Ordinary Least-Squares Estimates of Sales Tax Bidding Game: Total Willingness to Pay per Day for Instream Flow in the Production of Recreational <u>Fishing</u> Activities, Poudre River, 1978.

| Explanatory Variable | Regression Coefficient | Standard Error of Coefficient | t-statistic | Order of Entry |
|---|---|---|---|---|
| Instream Flow | .1761 | .12 E-1 | 4.65 | 3 |
| Instream Flow Squared | -.1563 E-3 | .90 E-4 | 5.78 | 1 |
| No. of activity days in Poudre | -.18 | .38 E-1 | 6.79 | 2 |
| No. of activity days in Poudre squared | .28 E-2 | .32 E-3 | 3.60 | 12 |
| No. of years of fishing experience | .28 E-1 | .13 E-1 | 2.15 | 11 |
| Income | .13 E-2 | .47 E-3 | 2.09 | 13 |
| Site dummy 2 | -.67 | .20 | 3.37 | 6 |
| Employment dummy | | | | |
| Housewife | -.97 | .41 | 2.35 | 5 |
| Skilled worker | .48 | .19 | 2.56 | 7 |
| Clerical worker | -.35 | .11 | 3.19 | 10 |
| Employer dummy | | | | |
| Education | .88 | .19 | 4.53 | 14 |
| Manufacturing | .35 | .15 | 3.19 | 9 |
| Size of residence | | | | |
| Medium size city | 1.65 | .25 | 6.51 | 4 |
| Large city | -.83 | .16 | 5.14 | 8 |
| Constant | 3.11 | 4.52 | 1.31 | |

$\bar{R}^2$ = .43
F = 29.01
N = 49

Table 4-4. Ordinary Least-Squares Estimates of Entrance Fee Bidding Game: Total Willingness to Pay per Day for Instream Flow in the Production of Recreational Shoreline Activities, Poudre River, 1978.

| Explanatory Variable | Regression Coefficient | Standard Error of Coefficient | t-statistic | Order of Entry |
|---|---|---|---|---|
| Instream Flow | .1485 E-1 | .41 E-2 | 2.29 | 7 |
| Instream Flow Squared | -.1045 E-4 | .29 E-5 | 2.18 | 8 |
| No. of activity days in Poudre | .20 | .41 E-1 | 5.30 | 2 |
| No. of activity days in Poudre squared | -.97 E-2 | .39 E-2 | 2.48 | 17 |
| No. of years of shoreline experience | -.10 | .28 E-1 | 6.02 | 3 |
| Income | -.86 E-2 | .29 E-2 | 2.18 | 6 |
| Age in years | .66 E-1 | .72 E-2 | 6.13 | 9 |
| Sex (0=male 1=female) | .32 | .91 E-1 | 3.47 | 16 |
| Education (in years) | -.28 | .98 E-1 | 6.34 | 4 |
| Employment dummy | | | | |
| Salesman | .76 | .14 | 5.34 | 1 |
| Housewife | 1.91 | .27 | 6.94 | 13 |
| Student | 1.51 | .24 | 6.32 | 15 |
| Employer dummy | | | | |
| Manufacturing | -.55 | .11 | 4.80 | 12 |
| Health services | .59 | .12 | 4.92 | 11 |
| Education services | .20 | .31 | 2.83 | 14 |
| Size of residence | | | | |
| Small city | 1.01 | .26 | 3.88 | 10 |
| Medium-size city | .73 | .14 | 5.26 | 5 |
| Constant | 1.40 | 4.10 | .34 | |

$\overline{R}^2$ = .52
F = 24.68
N = 45

Table 4-5. Ordinary Least-Squares Estimates of Sales Tax Bidding Game: Total Willingness to Pay per Day for Instream Flow in the Production of Recreational Shoreline Activities, Poudre River, 1978.

| Explanatory Variable | Regression Coefficient | Standard Error of Coefficient | t-statistic | Order of Entry |
|---|---|---|---|---|
| Instream Flow | .178 E-1 | .77 E-2 | 2.61 | 10 |
| Instream Flow Squared | -.1375 E-4 | .56 E-5 | 2.56 | 11 |
| No. of activity days in Poudre | .24 | .20 E-1 | 5.06 | 4 |
| No. of activity days in Poudre squared | -.54 E-2 | .68 E-3 | 3.94 | 6 |
| No. of years of shoreline experience | -.19 | .81 E-1 | 5.23 | 14 |
| Income | -.75 E-2 | .64 E-3 | 2.09 | 8 |
| Age in years | | | | |
| Employment dummy | | | | |
| Housewife | 2.51 | .29 | 8.41 | 1 |
| Clerical worker | 1.09 | .21 | 5.25 | 3 |
| Employer dummy | | | | |
| Public administration | -1.07 | .24 | 4.43 | 7 |
| Manufacturing | -1.39 | .19 | 4.45 | 2 |
| Health services | .44 | .11 | 4.09 | 9 |
| Education services | .33 | .15 | 2.23 | 13 |
| Size of residence | | | | |
| Small city | .56 | .31 | 2.63 | 12 |
| Medium-size city | .91 | .15 | 6.00 | 5 |
| Constant | 1.25 | .25 | 4.94 | |

$\bar{R}^2$ = -50
F = 54.21
N = 45

Table 4-6. Ordinary Least-Squares Estimates of Entrance Fee Bidding Game: Total Willingness to Pay per Day for Instream Flow in the Production of Recreational White Water Activities, Poudre River, 1978.

| Explanatory Variable | Regression Coefficient | Standard Error of Coefficient | t-statistic | Order of Entry |
|---|---|---|---|---|
| Instream Flow | .1011 | .25 E-1 | 15.05 | 1 |
| Instream Flow Squared | | | | |
| No. of activity days in Poudre | .18 | | 6.35 | 3 |
| No. of activity days in Poudre squared | -.43 E-2 | | 3.51 | 6 |
| No. of years of white water experience | .42 E-1 | .73 E-2 | 5.69 | 7 |
| Age in years | -.55 E-1 | .23 E-1 | 2.34 | 9 |
| Site dummy 4 | -.34 | .16 | 2.11 | 10 |
| Employment dummy | | | | |
| Unskilled | -.61 | .27 | 2.21 | 5 |
| Employer dummy | | | | |
| Education services | -.87 | .31 | 2.76 | 4 |
| Construction | 1.59 | .38 | 4.21 | 2 |
| Size of residence | | | | |
| Medium-size city | .49 | .19 | 2.59 | 8 |
| Constant | .50 | .26 | 1.19 | |

$\bar{R}^2$ = .52
F = 52.11
N = 40

Table 4-7. Ordinary Least-Squares Estimates of Sales Tax Bidding Game: Total Willingness to Pay per Day for Instream Flow in the Production of Recreational White Water Activities, Poudre River, 1978.

| Explanatory Variable | Regression Coefficient | Standard Error of Coefficient | t-statistic | Order of Entry |
|---|---|---|---|---|
| Instream Flow | .288 | .27 E-1 | 21.68 | 1 |
| Instream Flow Squared | | | | |
| No. of activity days in Poudre | 1.13 | .17 E-1 | 7.55 | 2 |
| No. of activity days in Poudre squared | -.28 E-2 | .48 E-3 | 2.92 | 7 |
| No. of years of white water experience | .59 E-1 | .97 E-2 | 6.08 | 3 |
| Age in years | -.62 E-1 | .21 E-1 | 2.91 | 8 |
| Site dummy 4 | -.17 | .28 E-1 | 6.07 | 5 |
| Employer dummy | | | | |
| Health services | -.82 | .27 | 3.07 | 6 |
| Size of residence | | | | |
| Medium-size city | 1.17 | .26 | 4.36 | 4 |
| Constant | -.90 | .51 | 1.71 | |

$\bar{R}^2$ = .66
F = 76.29
N = 40

where

$\hat{B}_k$ is the estimated slope coefficient

$S_{\hat{B}k}$ is the estimated standard error of $B_k$

t is the appropriate t- statistic

$\gamma_k$ is equal to zero.

A priori, one expects this test would fail to reject the hypothesis that the intercept equals zero. Those participating in stream activities are probably not willing to pay for a zero instream flow increase. Except for the sales tax-shoreline regression model, the intercept is not statistically different from zero at the 95 percent test level.

The next test looks at the possibility that the explanatory variables do not have any effect on recreationist willingness to pay.[3] If this hypothesis is true, then the bid variation is not a function of the survey variables. The null hypothesis is

$$H_0 = B_2 = B_3 = \ldots = B_k = 0,$$

and the appropriate statistic is

$$\frac{\frac{\text{Sum of squares due to regression}}{(k-1)}}{\frac{\text{Sum of squares due to residual}}{(n-k)}} \sim F_{k-1,\, n-k}$$

At the 95 percent confidence level, the test rejects the null hypothesis; variables in the regression equation do influence individual willingness to pay for instream flows. The regression equation explains more bid variation than the mean value.

---

[3] Ibid.

Tables 4-2 to 4-7 present two regression equations, a sales tax and an entrance fee, for each recreation activity. Theoretically, the repayment obligation may cause respondents to bias their willingness to pay. Statistically, the sales tax bid function slope and position may be different from the entrance fee slope and position. Testing the equality between two regression equations involves a null hypothesis that the function parameters are the same.[4] If the sales tax function is

$$TWP = B_1 + B_2X_{i2} + \ldots + B_kX_{ik} + E \qquad (i=1\ldots n),$$

and the entrance bid function is

$$TWP = A_1 + A_2X_{i2} + \ldots + A_kX_{ik} + E \qquad (i=n+1, n+2, \ldots, n+m)$$

then the null hypothesis is

$$H_0 : B_1=A_1,\ B_2=A_2,\ \ldots,\ B_k=A_k$$

The test statistic using the OLS sales tax function, OLS entrance fee function, and an OLS function from the combination of both data sets is

$$\frac{(SSE - SSE_S - SSE_E)/_k}{(SSE_S + SSE_E)/_{(n + m - 2k)}} \sim F_{k,\ (n+m-2k)},$$

where SSE is the sum of squared residual from the combined equation, $SSE_S$ is the sum of squared residuals from the sales tax equation, and $SSE_E$ is the sum of the squared residuals from the entrance fee

[4] Ibid., p. 373.

equation. At the 95 percent confidence level the sales tax function is different from the entrance fee bid function, for all activities.

Besides testing hypotheses, one must check to insure the sample satisfies the classical linear regression assumptions concerning multicollinearity and heteroscedasticity. In some models income was correlated with either age or education, and sex was related to particular dummy employments and employers. For example, the female sex variable was highly correlated to the dummy employment, housewife. If a model had highly correlated parameters, one of the variables was omitted from the regression. Overall, the OLS regression equations didn't suggest problems of multicollinearity. Most predictors had large t-values, even when the $R^2$ was small.

Heteroscedasticity, violating the constant error variance assumption, might also occur. The bid variance at low and high instream flows, where few people fish, might be less than the bid variance at medium instream flows. Both the Bartlett and Goldfeld-Quant tests[5] failed to reject the null hypothesis that the variance between different groupings of willingness to pay had equal variances. Also, a generalized least-squares estimation procedure failed to improve the ordinary regression model's fit or stability.

All estimates of the total Bradford bid curve resulted in, at least for bidding game cross section studies, a reasonable fit. The statistic $\bar{R}^2$, corrected for the number of independent variables in the equation, measures the proportion of the variation in the willingness to pay the multiple regression equation explains. For example, the $\bar{R}^2$

[5]Robert S. Pindyck and Daniel L. Rubinfeld, Econometric Models and Economic Forecasts (New York: McGraw-Hill, 1976), pp. 103-106.

in the fishing, entrance fee model (.41) means that the regression equation explains 41 percent of the bid variance. Note, model comparisons by $\bar{R}^2$ are not appropriate, because the equations have different independent variables. If the variable list in Table 4-1 completely specifies the instream flow willingness-to-pay relationship, then $\bar{R}^2$ does explain how well the model fits the data.[6]

Another objective, other than obtaining the largest $\bar{R}^2$, is to estimate stable and reliable structural parameters. All six models included coefficients with relatively large t-ratios. The t-ratio:

$$t_j = \frac{\hat{B}_j}{S_j}$$

represents the ratio of the estimated coefficient to its standard error. A coefficient is statistically significant if the $|t_j|$ exceeds the t-value at a particular significance level. For large samples, (n-k = 30), if the t-ratio exceeds two, then the coefficient is significant, and the parameter does effect the recreationist's willingness to pay for instream flow. Larger t-ratios imply rejection of the null hypotheses is harder. That is to say, willingness to pay is linearly dependent on the specific paramater.

According to the t-ratio, instream flow quantity is the principle determinate of fishing and white water recreationist value, but, not of shoreline value. Flow and its companion variable, $(\text{Flow})^2$, are highly significant (t-ratios between 3.55 and 5.78) in the fishing models. Flow by itself is highly significant in the white water model (t-ratios of 21.68 and 15.05). Even though Flow and $(\text{Flow})^2$ are statistically

---

[6]Ibid., p. 58.

significantly in the shoreline models, their t-ratios are much smaller (between 2.18 and 2.61).

The variation in bids explaind by Flow and $(Flow)^2$ substantiates the importance of instream flows in fishing and white water activities, and its lesser significance in shoreline activities. Flow and $(Flow)^2$ explained 20 percent of the bid variation in the sales tax fishing regression and 21 percent in the entrance fee fishing model. In the white water sales tax and entrance fee equations, Flow alone explained 38 percent and 53 percent of the bid variation. But, both variables could explain only 3 percent and 6 percent of the shoreline sales tax and entrance fee bid variation.

The stability, magnitude, and signs of Flow and $(Flow)^2$ estimates also indicate that instream flow quantity and recreationist willingness to pay are closely associated. Flow and $(Flow)^2$, serving as proxy measures for the total change in recreation and aesthetic improvements from stream flow changes, have appropriate functional forms. Those two variables describe a quadratic relationship between instream flow quantities and willingness to pay for fishing and shoreline activities, and a linear function for white water activities. The maximum total willingness to pay for instream flow in fishing experiences occurs at between the 450 and 550 cfs instream flow. At this point, first derivative and the marginal willingness to pay equals zero. This economic maximum corresponds closely with the trout catch rate/hr. peak indicated by the hydrologic and biological model in Chapter 3. Fishermen, without the complex physical model guides, know which flow level provides the best fishing. The economic values only confirm that knowledge.

Like the fishing equation, the shoreline model is also quadratic in terms of Flow and $(\text{Flow})^2$, but, the total willingness to pay didn't peak until the instream flow was approximately 750 cfs. High instream flows still provide shoreline utility, since recreationists don't need to enter the stream to enjoy their activities. Shoreline total bids increase over a larger range of instream flows, but the absolute magnitude is much smaller than the fishing total bids. As long as the Poudre River isn't dry or over bank full, the shoreline recreationist is relatively indifferent between alternative instream flow levels.

The white water regressions, in contrast to the equations representing the other two activities, included the variable Flow, but the variable $(\text{Flow})^2$ failed to enter the equation. Total willingness to pay increased over the instream flows shown in the color photographs. Most likely a maximum exists, but at a flow level beyond those in the pictures, when the river becomes very dangerous to kayak or raft (approximately 3,000-4,000 for the Poudre River). At those extremely high flow levels many white water recreationists would reduce their willingness to pay. Had the survey included photographs at very high flow levels, the resulting white water equation would have resembled the other two activity equations.

## Aggregate Instream Flow Marginal Values

Overall, the instream flow level seems to predict total value well. But, water managers comparing the benefits and costs of alternative instream flow quantities need information about marginal values rather than the total value. Economic choices focus on the incremental benefits from increased instream flow compared to the incremental benefits from water diversions. So that water planners can set minimum flow regulation, they must know the instream flow shadow price for recreation, and that value must be commensurate and comparable with the marginal value in withdrawal uses. The instream flow aggregate marginal values were computed using the following steps:

1. Multiply all significant coefficients in the total bid function by the mean, except for the variables Flow and $(\text{Flow})^2$. Next, add those amounts to the regression constant to form a "reduced" regression model relating total individual willingness to pay and the instream flow level.[7]

2. The first derivative of the total bid curve at each instream flow level corresponds to the conventional economic marginal demand function, mathematically:

$$\frac{\partial TWP_{ij}}{\partial Flow} = b_1 + b_2 \text{ (Flow)}$$

   i = recreation activity

   j = type of bidding game

3. Steps 1 and 2 combine to produce a function that determines individual willingness to pay (per day) for each additional cfs of water flowing in the Poudre River. Because instream flows are public goods, it becomes necessary to aggregate the individual bid over an appropriate user population for a specific time period. For example, assume the river flow is at 100 cfs aggregating over all fishermen using the Poudre River per day produceses a value for an additional cfs of water for recreational fishing

[7] J. A. Sinden, "An Utility Approach to the Valuation of Recreation and Aesthetic Experiences," American Journal of Agricultural Economics, Vol. 56, No. 1 (February 1974).

activities equal to $23.23.

Tables 4-8, 4-9, and 4-10 show the individual and aggregate marginal willingness to pay for instream flow in the Poudre River, assuming that the 1978 projected activity use rates represent the true recreation population. Policy makers should use these marginal values for decision making concerning alternative instream flow levels.

The marginal curves exhibited reasonable economic behavior. Each additional cfs for fishing activities is worth less than the previous one. When the flow is low, 50 cfs or below, the instream value for fishing experiences is very high, $26.38 per cfs/day. The marginal value falls as the flow in the river increases. A river stage at or above 500 cfs has a marginal instream flow value equal to zero or even negative.

Similarly, the marginal instream value for shoreline activities diminishes, turning negative if the river flow exceeds 700 cfs. At low stream flow, the marginal value for shoreline activities is much less than the marginal value for fishing experiences. Marginal shoreline value also diminishes at a slower rate over a longer range of flow in the river. Shoreline households had positive preferences for having flow in the river, but changes in the flow level provided very little additional utility.

White water marginal instream flow value is slightly different. Over the flow range in the photographs, the total bid increased according to a linear function. Thus, the first derivative (marginal value of water) is a constant. Extra instream flow units for white water activities are all worth approximately $9.55.

Table 4-8. Individual and Aggregate Marginal Willingness to Pay per Day for Instream Flow in the Production of Fishing Recreational Experiences, Poudre River, 1978.

| | Entrance Fee Game | | | Sales Tax Game | | |
|---|---|---|---|---|---|---|
| Flow (cfs) | Individual Marginal WTP/Day | Aggregate[a] Marginal WTP/Day | Confidence[b] Interval ± | Individual Marginal WTP/Day | Aggregate[a] Marginal WTP/Day | Confidence[b] Interval ± |
| 0 | | | | | | |
| 50 | $.116 | $26.38 | $7.66 | $.160 | $36.59 | $9.60 |
| 100 | .102 | 23.23 | 6.75 | .145 | 33.02 | 8.02 |
| 150 | .088 | 20.09 | 5.91 | .129 | 29.46 | 6.95 |
| 200 | .074 | 16.94 | 5.04 | .114 | 25.90 | 6.20 |
| 250 | .061 | 13.79 | 4.33 | .098 | 22.33 | 5.99 |
| 300 | .047 | 10.65 | 3.86 | .082 | 18.77 | 5.70 |
| 350 | .033 | 7.50 | 3.32 | .067 | 15.21 | 5.59 |
| 400 | .019 | 4.35 | 2.97 | .051 | 11.64 | 5.18 |
| 450 | .005 | 1.21 | 2.69 | .035 | 8.78 | 5.03 |
| 500 | -.009 | -1.94 | 2.45 | .020 | 4.51 | 4.85 |
| 550 | -.022 | -5.09 | 2.40 | .004 | .95 | 4.80 |
| 600 | -.036 | -8.23 | 2.68 | -.011 | -2.61 | 5.11 |
| 650 | -.050 | -11.38 | 3.01 | -.027 | -6.18 | 5.32 |
| 700 | -.064 | -14.52 | 3.49 | -.043 | -9.74 | 5.86 |
| 750 | -.078 | -17.67 | 4.00 | -.058 | -13.30 | 5.92 |
| 800 | -.091 | -20.82 | 4.62 | -.074 | -16.87 | 6.13 |
| 850 | -.105 | -23.96 | 5.39 | -.090 | -20.43 | 6.52 |
| 900 | -.119 | -27.11 | 6.12 | -.105 | -23.99 | 7.19 |

[a] The average number of fishermen per day (228) represents the aggregate population.

[b] The confidence interval is at the 5 percent level.

Table 4-9. Individual and Aggregate Marginal Willingness to Pay per Day for Instream Flow in the Production of Shoreline Recreational Experiences,[a] Poudre River, 1978.

| Flow (cfs) | Entrance Fee Game | | | Sales Tax Game | | |
|---|---|---|---|---|---|---|
| | Individual Marginal WTP/Day | Aggregate[b] Marginal WTP/Day | Confidence[c] Interval ± | Individual Marginal WTP/Day | Aggregate[a] Marginal WTP/Day | Confidence[b] Interval ± |
| 0 | | | | | | |
| 50 | $.027 | $17.48 | $17.56 | $.033 | $21.16 | $21.55 |
| 100 | .026 | 16.15 | 16.61 | .031 | 19.53 | 20.16 |
| 150 | .023 | 14.83 | 15.71 | .028 | 17.91 | 18.85 |
| 200 | .021 | 13.51 | 14.88 | .026 | 16.28 | 17.62 |
| 250 | .019 | 12.19 | 14.13 | .023 | 14.65 | 16.50 |
| 300 | .017 | 10.86 | 13.47 | .021 | 13.03 | 15.49 |
| 350 | .015 | 9.54 | 12.92 | .018 | 11.40 | 14.64 |
| 400 | .013 | 8.22 | 12.50 | .015 | 9.77 | 13.97 |
| 450 | .011 | 6.89 | 12.20 | .013 | 8.15 | 13.51 |
| 500 | .009 | 5.57 | 12.06 | .010 | 6.52 | 13.28 |
| 550 | .007 | 4.25 | 12.06 | .008 | 4.89 | 13.29 |
| 600 | .005 | 2.92 | 12.22 | .005 | 3.27 | 13.53 |
| 650 | .003 | 1.60 | 12.51 | .003 | 1.64 | 14.01 |
| 700 | .44E-3 | .28 | 12.95 | .2E-4 | .01 | 14.69 |
| 750 | -.002 | -1.04 | 13.51 | -.003 | -1.61 | 15.55 |
| 800 | -.004 | -2.36 | 14.17 | -.005 | -3.24 | 16.56 |
| 850 | -.006 | -3.69 | 14.93 | -.008 | -4.87 | 17.70 |
| 900 | -.008 | -5.01 | 15.77 | -.010 | -6.49 | 18.93 |

[a] Shoreline activities include picnicking, hiking, camping, swimming, wading, viewing, etc.

[b] The average number of shoreline users per day (633) represents the aggregate population.

[c] The confidence interval is at the 5 percent level.

Table 4-10. Individual and Aggregate Marginal Willingness to Pay per Day for Instream Flow in the Production of White Water Recreational Experiences, Poudre River, 1978.

| | Entrance Fee Game | | | Sales Tax Game | | |
|---|---|---|---|---|---|---|
| Flow (cfs) | Individual Marginal WTP/Day | Aggregate[a/] Marginal WTP/Day | Confidence[b/] Interval ± | Individual Marginal WTP/Day | Aggregate[a/] Marginal WTP/Day | Confidence[b/] Interval ± |
| 0 | | | | | | |
| 50 | $.191 | $9.55 | $5.96 | $.288 | $14.40 | $8.93 |
| 100 | .191 | 9.55 | 5.80 | .288 | 14.40 | 8.50 |
| 150 | .191 | 9.55 | 5.63 | .288 | 14.40 | 8.32 |
| 200 | .191 | 9.55 | 5.41 | .288 | 14.40 | 8.17 |
| 250 | .191 | 9.55 | 5.19 | .288 | 14.40 | 8.05 |
| 300 | .191 | 9.55 | 5.03 | .288 | 14.40 | 7.88 |
| 350 | .191 | 9.55 | 4.95 | .288 | 14.40 | 7.69 |
| 400 | .191 | 9.55 | 4.79 | .288 | 14.40 | 7.61 |
| 450 | .191 | 9.55 | 4.61 | .288 | 14.40 | 7.55 |
| 500 | .191 | 9.55 | 4.54 | .288 | 14.40 | 7.49 |
| 550 | .191 | 9.55 | 4.50 | .288 | 14.40 | 7.47 |
| 600 | .191 | 9.55 | 4.56 | .288 | 14.40 | 7.51 |
| 650 | .191 | 9.55 | 4.65 | .288 | 14.40 | 7.59 |
| 700 | .191 | 9.55 | 4.83 | .288 | 14.40 | 7.68 |
| 850 | .191 | 9.55 | 4.99 | .288 | 14.40 | 7.93 |
| 900 | .191 | 9.55 | 5.09 | .288 | 14.40 | 8.07 |

a/ The average number of white water users per day (50) represents the aggregate population.

b/ The confidence interval is at the 5 percent level.

Theoretical Tests of the Bidding Game Outcome

The statistical equations represent the recreationist's willingness to pay assuming the respondents didn't bias their bids and that a different income distribution won't change the demand curve position. Economists have shown that respondents may potentially conceal their true willingness to pay. Fortunately, the research outcomes indicated that these theoretical problems are insignificant. Willingness to pay depends on the marginal utility of instream flows, rather than the marginal utility of income. Income was significant only in the sales tax, fishing model and both shoreline models. Recalling Figure 3-4 in Chapter 3, if the b coefficient in the utility function approximates zero, then the indifference curves become vertically parallel. Thus, the recreationist's willingness to pay for instream flow and income are independent. A non-linear estimate of the sales tax fishing b was .678 E-6, while it was .346 E=5 for the sales tax, shoreline utility function, and .389 E-5 for the entrance fee shoreline utility function. Given the small b value, the aggregate marginal instream flow benefit curve slope or position would appear to be relatively insensitive to changes in the distribution of income.

Survey bid outcomes also indicated that respondents did reveal their true willingness to pay for instream flows. According to Brookshire,[8] the bid distribution should be flatter than normal, if respondents did, as a group, bias their willingness-to-pay responses. Individuals favoring higher instream flows would respond with very high bids; individuals against flow increases would respond with zero bids.

[8]Brookshire, Ives, and Schulze, op. cit.

The bid distributions in Table 4-11 do not reveal abnormal or biased behavior. The fishing models have the largest proportion of high bids probable because fishermen have strong preferences for instream flow. The stream's ability to produce a quality fishery is very sensitive to large or small flow levels. Many respondents did bid zero, but it represented their true willingness to pay. Flow increases beyond some upper limit actually decrease the quality of the fishing or shoreline experience. Thus, individuals were not willing to pay for very large increases in the stream flow. Similarly, white water recreationists needed more than small flow changes before the river can support kayaking and rafting activities.

Table 4-11. Bid Distribution by Type of Recreation Activity.

| | Activity | | |
|---|---|---|---|
| Bid ($) | Fishing (no.) | Shoreline (no.) | White Water (no.) |
| 0 | 202 | 199 | 402 |
| 0-1 | 55 | 155 | 23 |
| 1-2 | 178 | 392 | 88 |
| 2-3 | 87 | 215 | 89 |
| 3-4 | 172 | 96 | 76 |
| 4-5 | 160 | 27 | 49 |
| 5-6 | 103 | 15 | 49 |
| 6-7 | 63 | 19 | 18 |
| 7-8 | 46 | 14 | 12 |
| 8-9 | 72 | 3 | 9 |
| 9-10 | 51 | 2 | 7 |
| 10-11 | 39 | | 9 |
| 11-12 | 13 | 1 | 2 |
| 12-13 | 7 | | |
| 13-14 | 6 | 2 | |
| 14-15 | | | 1 |
| 15-16 | 1 | | |
| 16-17 | 1 | 1 | 1 |

Socio-economic Variables

Previous bidding game studies, in particular, Randall's[9] Four Corners air pollution study, have shown that certain socio-economic variables will effect the recreationist's willingness to pay for aesthetic improvements. The regression model in this thesis included linear, dummy, quadratic, and cross product parameters. Each socio-economic variable was significant at the 95 percent confidence level. The variables income, age, education, and number of years experience entered the equation as linear terms; the respondent's sex, occupation, and size of previous city of residence were significant dummy variables; the number of years the respondent has used the Poudre River for his specific recreation activity entered as a quadratic. Together these attributes explained 20 percent and 23 percent of the entrance fee and sales tax fishing bid variation, 48 percent and 47 percent of the entrance fee and sales tax shoreline bid variation, and 7 percent to 14 percent of the entrance fee and sales tax white water bid variation.

The coefficient attached to the linear parameters measures the change in willingness to pay associated with a small change in the respective variable. The change, however, is not unit free. A one-unit change in the independent variable changes the willingness to pay by one dollar. The sign attached to the coefficient determines the direction of the change. One word of caution: due to the heterogenous nature of the shoreline group, the results from the shoreline models should be used carefully.

---

[9]Randall, Ives, and Eastman, op. cit., pp. 132-149.

Income

Fishermen using the Poudre River have the highest mean income, ($18,200 for fishermen, $14,800 for shoreline, and $12,500 for white water recreationists) statistically different from the other groups' mean incomes. White water recreationists have the lowest mean income, but it is not statistically different from the mean income of the sample shorelines or from the Fort Collins mean income. These results are consistent with Walsh's reports of fishermen with large incomes and kayakers with low incomes on other rivers in Colorado.[10]

Even though changes in the income distribution probably don't change the aggregate marginal willingness to pay, income does effect individual bids. A $1,000 increase in income causes the sales tax fishing bid to increase by $.013 per day, the sales tax shoreline bid to decrease by $.009 per day, and the entrance fee shoreline bid to decrease by $.008 per day. Income does not effect the entrance fee fishing and white water bids.

The magnitude of the change is relatively insignificant, but the income coefficient signs suggest very important behavior patterns. Fishing activities compared with shoreline activities require large individual investments in terms of time and equipment. Perhaps income in the shoreline model has a negative sign because low income individuals can't afford the costly fishing equipment, nor can they invest the time into learning the skills needed for trout fishing. Thus, shoreline recreation, and the instream flow for that activity, is one of the few activities lower income individuals can enjoy. But, as the

---

[10]Richard G. Walsh, Ray K. Ericson, and Daniel J. Arosteguy, An Empirical Application of a Model for Estimating the Recreational Value of Instream Flow, Draft Completion Report No. A-036-COLO (October 1978).

individual's income increases, he can afford to change his recreation behavior switching from the simple low cost shoreline activity to expensive trout fly fishing experiences.

Age

An individual's age does influence shoreline and white water instream flow bids. White water participants are significantly younger than recreationists in the other activities (white water mean age = 30.9, fishing mean age = 38.1, and shoreline mean age = 37.0). Younger participants are willing to pay more for instream flow in white water activities and less for instream flow in shoreline experiences. A year increase in age increases the entrance fee, white water total bid by $.062 per day, and it increases the sales tax, white water total bid by $.055 per day. But, a year increase in age decreases the shoreline total bid by $.07 per day. Age has a negative effect on white water bids, but a positive effect on shoreline bids because the physical effort the participant must make to enjoy the activities is quite different. Paddling a kayak against a strong flow requires large amounts of strength, agility, and daring. These attributes usually reach a peak at a young age. As one grows older and wiser, it may become easier and more enjoyable to relax by the river bank.

Experience

The number of years the recreationist has invested in fishing or white water activities will change his total willingness to pay for instream flows. A year increase in experience increases the total bid for instream flows in fishing activities by $.04 per day (entrance fee game) or $.03 per day (sales tax game). More experience will increase white water, instream flow total bids by $.06 per day (entrance fee game) and $.04 per day (sales tax game). The more years an individual participates in an activity, the more he should enjoy it, producing a higher value for the instream flows. But, the shoreline model experience coefficients are conflicting, since experience is positively related to willingness to pay in the sales tax game while negatively related in the entrance fee game. We have no explanation for that anomaly.

Education

The education coefficients are also ambiguous. Similar to many recreation studies, the average years of education are higher than the national average. But, the education coefficient sign is negative, suggesting that if an individual stays in school longer, he is willing to pay less for instream flows.

Dummy Variables

Certain socio-economic variables cannot take values over some continuous range, rather they represent either-or qualitative facts. Dummy variables are employed to account for the qualitative data's influence on instream flow willingness to pay. Any single dummy variable can distinguish between only two characteristics, otherwise it would introduce a scaling effect where the results would depend on the specific scale for the dummy variable. Dummy variables described the respondent's sex, occupation, employer, residence, and the site of the color photographs.

The sex and occupation-employment dummy variables indicated that women pay less for instream flow in fishing activities, but more for instream flow in shoreline activities. In the questions without occupation variables, men bid more for fishing instream flow while women bid more for shoreline instream flow. Occupation and employer variables model similar behavior in the final equations. Housewives, clerical workers, and retired individuals bid lower in the fishing models, higher in the shoreline models. Skilled labor, manufacturing, and financial variables modeled the opposite effect; higher in fishing models, lower in shoreline models. As women increase their participation in fishing activities, the difference between male and female willingness to pay is likely to become less significant.

The size of the recreator's former permanent residence, if they now live in Fort Collins, helps determine willingness to pay. Willingness to pay for instream flows in the production of fishing experiences is inversely related to the population of the recreator's former residence. Those who move from rural areas may have a higher bid as they attempt to retain the high quality fishing experience that they may have been accustomed to in less populated areas. Conversely, shoreline and white water instream flow bids are higher for individuals that moved to Fort Collins from medium- and larger-size cities.

The site where the photographs were taken is not as important as one might expect. All site dummies were insignificant in the shoreline models. Fishing at Site 2, a seldom-fished spot, results in lower instream flow fishing bids. White water bids for Site 4, an inappropriate kayaking and rafting reach of the river, were also lower. The river channel varies enough, so that by moving a few hundred yards up or down stream, the recreator can find a better site for his recreation purposes.

## Quadratic Variables

The recreationist's bid could conceivably be a quadratic function of income, age, or recreation days in addition to flow. But, only the number of activity days in the Poudre River Canyon entered the willingness-to-pay models as a quadratic variable. According to economic theory the marginal effect of days on willingness to pay should be positive but decreasing. The marginal utility of an additional day, at the same instream flow level, should be worth less than the previous one. The partial derivative of the total bid regression equation, with respect to days, represents the marginal effect of activity days, or

$$\frac{\partial \text{bid}}{\partial \text{days}} = b_{10} + 2b\ (\text{days}).$$

where

$b_{10}$ is the coefficient on the linear days variable,

$b_9$ is the coefficient of $(\text{days})^2$,

bid is the total willingness to pay for some constant instream flow quantity,

days represents the number of days the respondent spends in the Poudre River for a particular recreation activity.

Tables 4-12 and 4-13 present the change in total willingness to pay for instream flow given a specific number of recreation days in the Poudre River Canyon for shoreline and white water activities. Both exhibit normal diminishing marginal returns for additional activity days. After approximately 11 days of shoreline recreation, an additional day will not add anything to the willingness to pay for instream flows. Similarly, after 22 days of white water recreation, an additional day will not add to the recreationist's marginal value of instream flows.

Table 4-12. Marginal Effect of Number of Days Participation in the Poudre River Canyon on the Instream Flow Total Bid, Shoreline Activities, 1978.

| No. of Days | Change in Total Willingness to Pay Entrance Fee Game | Change in Total Willingness to Pay Sales Tax Game |
|---|---|---|
| 1 | $ .181 | $ .129 |
| 2 | .161 | .188 |
| 3 | .142 | .106 |
| 4 | .122 | .095 |
| 5 | .103 | .084 |
| 6 | .084 | .073 |
| 7 | .064 | .062 |
| 8 | .045 | .05 |
| 9 | .025 | .039 |
| 10 | .006 | .028 |
| 11 | -.013 | .017 |
| 12 | -.033 | .006 |
| 13 | -.052 | -.006 |

Table 4-13. Marginal Effect of Number of Days Participation in the Poudre River Canyon on the Instream Flow Total Bid, White Water Activities, 1978.

| No. of Days | Change in Total Willingness to Pay Entrance Fee Game | Change in Total Willingness to Pay Sales Tax Game |
|---|---|---|
| 1 | $ .21 | $ .171 |
| 3 | .113 | .154 |
| 5 | .102 | .137 |
| 7 | .091 | .120 |
| 9 | .080 | .103 |
| 11 | .068 | .085 |
| 13 | .057 | .068 |
| 15 | .046 | .051 |
| 17 | .035 | .034 |
| 19 | .024 | .017 |
| 21 | .012 | -.0006 |
| 23 | .0012 | -.018 |
| 25 | -.01 | -.035 |

The impact of days on instream flow is slightly different for fishing recreation. The marginal bid function with respect to days increases. Individuals who fish over 31.5 days in the Poudre River have a higher bid for each additional day. These intensive users have satisfaction functions shaped so that the more days they can fish, the greater is their marginal utility they receive from more instream flow. Again, be cautious when applying these results. We interviewed only four households that fished over 30 days in one year and only one who fished 58 days.

Table 4-14. Marginal Effect of Number of Days Participation in the Poudre River Canyon on the Instream Flow Total Bid, Fishing Activities, 1978.

| No. of Days | Change in Total Willingness to Pay Entrance Fee Game | Change in Total Willingness to Pay Sales Tax Game |
|---|---|---|
| 1 | $ -.126 | $ -.17 |
| 5 | -.109 | -.15 |
| 10 | -.088 | -.12 |
| 15 | -.067 | -.096 |
| 20 | -.046 | -.068 |
| 25 | -.025 | -.04 |
| 30 | -.004 | -.012 |
| 35 | .017 | .016 |
| 40 | .038 | .044 |
| 45 | .059 | .072 |
| 50 | .08 | .10 |
| 55 | .101 | .128 |
| 60 | .122 | .156 |

# CHAPTER 4

## EVALUATING INSTREAM FLOW STRATEGIES

For years, Colorado's water resource policy has encouraged farmers, mine operators, and cities to appropriate and develop the state's water supplies. Diverting water from streams, they substantially increased farm crop production, expanded mineral extraction, and improved municipal water services. Even though uses other than recreation fully appropriated the South Platte, Arkansas, and Poudre Rivers numerous other mountain rivers remained where the instream flow supported excellent fishing and maintained the natural stream environment.

Today, Colorado residents demanding more recreation and amenities are willing to sacrifice the outputs traditional from water uses. But, how can Colorado allocate its scarce water supplies between all competing users? To answer that question, resource planners should look toward a more general analysis that compares the economic non-market instream flow recreation value with intermediate market value in other productive uses and recognizes the interdependence between economic outcomes and legal institutions.

The general economic analysis in this chapter, concerned with community or social welfare from different instream flow allocations, examines the following three issues: 1) Since water is limited, resource reallocations from one use will ultimately reduce the output from some other use. The economist's familiar production possibility curve highlights the economic tradeoffs between competing instream flow employments. 2) A static efficiency analysis ignores many temporal problems. A general analysis looks at the possibility that today's efficient allocation may not satisfy future water demands. 3) A completely general model combines economics with water right institutions. Different water laws can change the actual water allocation and the perceptions about the optimal allocation.

Water Resource Allocation and General Economic Equilibrium

Policy decisions concerning alternative instream flow allocations fall within the sub-discipline, welfare economics, that considers the criteria for optimal allocation of goods and services in the economy. Since water resources are limited, a general welfare analysis compares the input and output decisions of all firms and individuals competing for the resource, rather than analyzing each actor's isolated decision making process. Water planners shouldn't consider instream flow allocations in one sector independent of others. In some situations, to expand one sector's output, another's must decrease; at other times, expansion in one may cause output increases in another. The interdependence depends on the physical relationships, the demand urgency, and the production costs of all sectors using instream flows.

Irrigation, municipal, and recreation activities compete for the Poudre River's flows. Water input decisions in each sector alter the quantity, quality, time, and location characteristics of water, thereby influencing the other sector's economic decision making process. To conceptualize the problem, this section treats management of the Poudre River as if a river basin firm were empowered to allocate instream flow inputs between recreational fishing and irrigation production activities. The economic tool, production possibility curve (PPC-Figure 6), illustrates fishing and irrigation output combinations the basin firm can produce from a specific instream flow quantity and technology level. Points on the curve represent the maximum fishing and irrigation outputs the basin can produce. This curve helps determine the firm's most desirable instream flow allocation between the competing sectors.

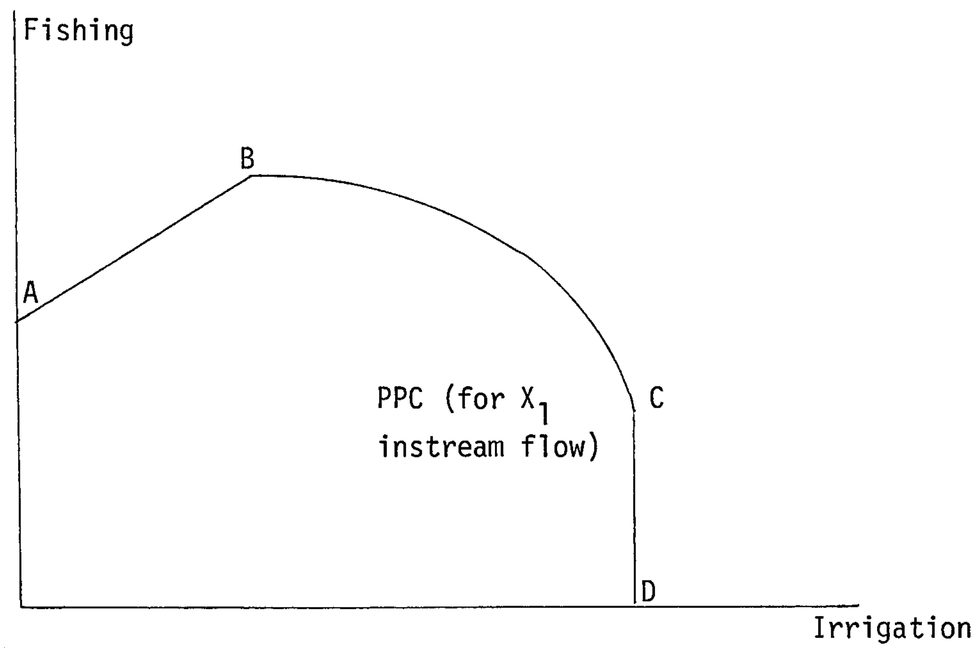



Figure 6. Instream Flow Production Possibilities Curve.

Different instream flow allocations will at certain times and locations lead to competitive, complementary, or supplementary relationships between fishing and irrigation. Along the section BC on $PPC_1$, fishing and irrigation compete for instream flows. Water transfers from fishing to irrigation increase the fishing instream flow marginal product, while decreasing the irrigation instream flow marginal product. For example, if the Poudre River instream flow falls below 500 cfs, irrigation diversion increases crop output but reduces fishing return. Robert Smith suggested measuring three benefit components before making the final allocation decision:[1]

1. the private return from additional irrigation diversion;
2. the producer surplus the farmer may receive; and
3. the public fishing benefits from maintenance of instream flows.

This analysis identifies the consumer surplus each alternative must generate before making the basin better off.

Recently, Martin, Tinney, and Gum[2] used consumer and producer surplus measures to compare private and public tradeoffs from land allocations in Arizona between cattle producers and hunting activities. Since the consumer-producer surplus from cattle production was five times the surplus in hunting activities, the economic analysis indicated resource managers should allocate more land to cattle producers. But, the analysis ignores many important distributional impacts from a change in land allocations. Even though the private alternative warranted more land inputs, the benefit accrues to a relatively small group of ranchers; the loss is spread over numerous recreationists. This difficult problem arises when one attempts to aggregate individual consumer surplus. Does a reallocation that increases one group's consumer surplus by $20, but reduces another group's consumer surplus by $4, increase total social welfare by the net of $16? Answering this question, the analysis assigns a weight to each individual consumer surplus; but, what are the correct weights?

---

[1]Robert J. Smith, "Problems of Interpreting Recreation Benefits from a Recreation Demand Curve," Recreation, Economics and Analysis, G. A. C. Searle (ed.) (New York: Longman Group Hd., 1975), p. 73.

[2]William E. Martin, J. Craig Tinney, and Russell L. Gum, "A Welfare Economic Analysis of Potential Competition Between Hunting and Cattle Ranching," Western Journal of Agricultural Economics, Vol. 3, No. 2 (December 1978), pp. 87-97.

values. For additional output, the basin must sacrifice successively large amounts of recreation. In the spring, fishing and irrigation complement each other (AB section of the $PPC_1$). When Poudre River instream flows exceed 500 cfs, incremental increases in irrigation diversion produce more crops and make the fishing experience more attractive. Along section CD, the basin outputs are supplements; increasing fishing output doesn't reduce crop output. A supplementary relationship in the Poudre River occurs in late fall, after the growing season, when water allocation to fishing activities doesn't effect that year's crop production.

The basin manager, moving resources from one output to another, should carefully consider all economic and physical interrelationships. If the basin has unlimited water resources or if all outputs are complements and supplements, then the manager simply allocates the economic optimum instream flow quantity to each activity as if it were the only production activity. Water allocation in the Poudre River is more difficult, because the flow is limited and outputs are usually competitive. What economic theory can be used to deal with the entire basin's welfare from water reallocations between irrigation and fishing?

Economists have recommended two objectives: (1) maximizing net consumers and producers surplus and (2) satisfying the Pareto efficiency conditions. The first requires reliable estimates of the derived demand curve for instream flows producing irrigated crops and fishing experiences. Given these functions, the basin manager compares the area under each demand curve between the prospective price and quantity changes, then allocates water to the output having the highest

To avoid the interpersonal comparisons, the basin manager can use the second general equilibrium tool, Pareto efficiency. An efficient allocation exists if any reallocation increases some economic activity while reduces another activity. Formally, an instream flow allocation is efficient if no one can be made better off without making someone else worse off.[3] This criterion, tactfully avoiding direct interpersonal consumer surplus comparisons, skillfully hides its own value judgements: 1) the sum of individual tastes defines social welfare and 2) the initial endowment of resources was correct.

The basin firm, using the efficiency definition, will operate on the production possibilities curve. An allocation at some position in the interior of the $PPC_1$ is inefficient. Suppose the Poudre basin firm produces crop irrigation ($Y_1$) and fishing recreation ($Y_2$), given an instream flow quantity ($\overline{X}$). The basin's objective is to maximize the net return from each activity ($V_1Y_1+V_2Y_2$) subject to the total instream flow supply, where $y_1 = f_1(X_1)$ and $y_2 = f_2(\overline{X}-X_1)$

$$\max V_1f_1(X_1) - V_2f_2(\overline{X}-X_1),$$

the first order condition for a maximum is

$$V_1f_1'(X_1) = V_2f_2'(\overline{X}-X_1).$$

Thus, the basin will operate efficiently when the manager allocates instream flows so that the net marginal benefits of flow in crop irrigation equals the net marginal benefits of flow in fishing experiences. If the marginal returns are not equal, the basin is not operating

---

[3]Henderson and Quant, op. cit.

efficiently. For example, if the fishing instream flow marginal return is $10 and $6 for crop irrigation, then transferring one flow unit to fishing activities increase the basin output by $4. Fishermen could give irrigators $6, keeping them as well off as before the reallocation, and still be better off by $4.

The Pareto equi-marginal principle provides the water resource manager in Colorado a tool to analyze the tradeoff between allocations for crop irrigation and fishing activities. Table 5-1 presents the aggregate instream flow marginal benefits (per acre foot) for fishing activities during each summer month. Marginal benefits vary each month as the number of fishermen, willing to pay for instream flows according to the bidding game results, increases from 68/activity days in June to 397/activity days in July and August. Table 5-2 presents the short-run instream flow marginal benefits in crop production given two possible water supply conditions. Estimated benefits from a farm model of the Lower South Platte River valley in northeastern Colorado were available to approximate the marginal benefits in the Poudre valley.[4] The approximation is judged to be quite accurate because the cropping and irrigation practices are very similar. Even the precipitation is almost identical. Note, even though Table 5-1 shows the entrance fee and sales tax game marginal values, we will use only the entrance fee amounts when comparing fishing and irrigation benefits.

First, to fulfill the Prato efficient conditions, the basin manager should allocate instream flows into all complementary and

[4]John Daubert, "Conjunctive Ground and Surface Water Allocation: The Economics of a Quasi-Market Solution," M.S. Thesis, Colorado State University, Fort Collins, Colorado, Fall 1978.

Table 5-1. Aggregate Marginal Willingness to Pay for Instream Flow in the Production of Recreational Fishing Experiences by Month, Poudre River, 1978.

| | Entrance Fee Game Aggregate Marginal WTP/day (per acre foot) | | | | | | |
|---|---|---|---|---|---|---|---|
| Flow | May | June | July | August | Sept. | Oct. | Average over Season |
| (cfs) | $ | $ | $ | $ | $ | $ | $ |
| 50 | 7.72 | 3.96 | 23.21 | 23.21 | 11.99 | 7.72 | 13.30 |
| 100 | 6.79 | 3.50 | 20.41 | 20.41 | 10.54 | 6.79 | 11.71 |
| 150 | 5.85 | 3.02 | 17.61 | 17.61 | 9.09 | 5.85 | 10.13 |
| 200 | 4.92 | 2.54 | 14.81 | 14.81 | 7.65 | 4.92 | 8.54 |
| 250 | 4.06 | 2.09 | 12.21 | 12.21 | 6.30 | 4.06 | 6.95 |
| 300 | 3.13 | 1.61 | 9.40 | 9.40 | 4.86 | 3.13 | 5.37 |
| 350 | 2.20 | 1.13 | 6.60 | 6.60 | 3.41 | 2.20 | 3.78 |
| 400 | 1.26 | .65 | 3.80 | 3.80 | 1.96 | 1.26 | 2.19 |
| 450 | .33 | .17 | 1.00 | 1.00 | .52 | .33 | .61 |
| 500 | -.60 | -.31 | -1.80 | -1.80 | -.93 | -.60 | -.98 |
| 550 | -1.46 | -.75 | -4.40 | -4.40 | -2.27 | -1.46 | -2.56 |
| 600 | -2.40 | -1.23 | -7.20 | -7.20 | -3.72 | -2.40 | -4.15 |
| 650 | -3.33 | -1.71 | -10.01 | -10.01 | -5.17 | -3.33 | -5.74 |
| 700 | -4.26 | -2.19 | -12.81 | -12.81 | -6.61 | -4.26 | -7.32 |
| No. of Fisherman/day[1] | 132 | 68 | 397 | 397 | 205 | 132 | 228 |

Table 5-1. Continued

| Flow | Sales Tax Game Aggregate Marginal WTP/day (per acre foot) May | June | July | August | Sept. | Oct. | Average over Season |
|---|---|---|---|---|---|---|---|
| (cfs) | $ | $ | $ | $ | $ | $ | $ |
| 50 | 10.65 | 5.48 | 32.02 | 32.02 | 16.53 | 10.65 | 18.44 |
| 100 | 9.65 | 4.97 | 29.01 | 29.01 | 14.98 | 9.65 | 16.64 |
| 150 | 8.58 | 4.42 | 25.81 | 25.81 | 13.33 | 8.58 | 14.85 |
| 200 | 7.58 | 3.91 | 22.81 | 22.81 | 11.78 | 7.58 | 13.05 |
| 250 | 6.52 | 3.36 | 19.61 | 19.61 | 10.12 | 6.52 | 11.26 |
| 300 | 5.46 | 2.81 | 16.41 | 16.41 | 8.47 | 5.46 | 9.46 |
| 350 | 4.46 | 2.30 | 13.41 | 13.41 | 6.92 | 4.46 | 7.67 |
| 400 | 3.39 | 1.75 | 10.21 | 10.21 | 5.27 | 3.39 | 5.87 |
| 450 | 2.33 | 1.20 | 7.00 | 7.00 | 3.62 | 2.33 | 4.40 |
| 500 | 1.33 | .69 | 4.00 | 4.00 | 2.07 | 1.33 | 2.27 |
| 550 | .27 | .14 | .80 | .80 | .41 | .27 | .47 |
| 600 | -.73 | -.38 | -2.20 | -2.20 | -1.14 | -.73 | -1.32 |
| 650 | -1.80 | -.93 | -5.40 | -5.40 | -2.79 | -1.80 | -3.11 |
| 700 | -2.86 | -1.47 | -8.60 | -8.60 | -4.44 | -2.86 | -4.91 |
| No. of Fisherman/day[1] | 132 | 68 | 397 | 397 | 205 | 132 | 228 |

[1] Interview with James W. Carlson, District Ranger, Arapahoe and Roosevelt National Forest, Fort Collins, Colorado, December 1978.

Table 5-2. Marginal Willingness to Pay for Instream Flow in Crop Production, Lower South Platte River Valley, 1978.

| | May | June | July | August | Sept. | Oct. | Average over Season |
|---|---|---|---|---|---|---|---|
| Average Instream Flow | $1.75 | $3.30 | $ 9.00 | $15.00 | $ 7.22 | - | $ 7.25 |
| Dry Instream Flow | $1.75 | $3.30 | $45.10 | $40.00 | $21.90 | - | $22.41 |

supplementary production activities until the reallocation changes to a competitive relationship. The reasonining is straightforward. A complementary relationship is inefficient, since reallocations exist which improve welfare in both sectors. A supplementary relationship is inefficient, since at least one individual's welfare will increase without a decrease in another's welfare position.

During certain times and at specific locations, diversion for crop irrigation will complement or supplement trout fishing experiences. In May, June, and July, when the average instream flow at the Poudre River Canyon mouth exceeds 450 cfs (775, 1,542, and 703 cfs, respectively), fishing and irrigation become complementary basin outputs. Incremental increases in irrigation diversions, during those months, increase the basin's crop production by \$1.75/af, \$3.30/af, and \$9.00/af given normal flow conditions, and even more if drought conditions prevail. The diversions also increase instream flow fishing value by at least \$4.26/af, \$2.19/af, and \$12.81/af. Pareto efficiency dictates that the basin manager increase irrigation diversions at least until the two products become competitive. In October, fishing and irrigation become supplementary outputs. Since that year's growing season is over, marginal value of instream flow for crop irrigation equals zero. Leaving more flow in the river, the basin manager could increase fishing output by \$6.79/af (October's average flow is 124 cfs) without reducing that year's crop output.

Even without this study, the economic supplementary and complementary output possibilities in the Poudre River basin are fairly obvious. But as fishing and crop irrigation become competitive outputs, water allocation decisions assume a new dimension; reallocating flow will increase one output only at the expense of the other. According to the equi-marginal principal, the basin manager will maximize that social return to instream flows when the marginal return in fishing equals the marginal return in crop irrigation. Existing instream flow allocations, in August, seem efficient. The marginal return to crop irrigation is $15/af, in a normal year, approximately equal to the fishing marginal return of $14.81/af given the average instream flow of 218 cfs.

But, in September, current basin management practices may not allocate instream flow resources efficiently. The average year instream flow at the canyon mouth, 105 cfs, results in a marginal fishing return equal to $10.54/af and a marginal crop return equal to $7.22/af. To fulfill the efficiency conditions, the Poudre River instream flow should be 200 cfs where the marginal returns in both uses are approximately equal. (Marginal fishing return = $7.68/af, marginal crop irrigation return = $7.22/af.)

Basin managers, changing storage reservoir management from a competitive to a complementary or supplementary relationship, could improve some of the direct flow allocation efficiency to some degree. Many irrigation companies begin filling high mountain storage reservoirs in September and plains reservoirs in the spring. In fact, they store over 1,000 af in high mountain reservoirs in September and 2,000 af in October that could have augmented the river's normal flow by 33 af/day and 66 af/day.[5] In September, additional instream flow is worth

[5]Robert Aukerman, William T. Springer, and James F. Judge, Inventory of Colorado's Front Range Mountain Reservoirs, Colorado State University Environmental Resources Center, Information Series No. 23, May 1977.

approximately $10/af to the fisherman, and approximately $7/af in October. Transferring the timing of reservoir storage water rights between high mountain and plains reservoirs changes a competitive relationship into a complementary relationship. Basin welfare increases by $10/af and $7/af for fishing as water runs down the stream into plains reservoirs in the fall, and in the spring high mountain storage reduces instream flows also increasing the fishing experience value.

Reallocating water supplies from high mountain reservoirs to plains reservoirs could substantially increase total benefits from basin water use in the fall. For example, if the basin let the 1,000 af stored in September flow downstream into plains reservoirs, then total fishing benefits would increase by $380/day or approximately $10,000/mo. In October, another major high mountain reservoir, Chambers Lake, stores approximately 20/af per day.[6] Total basin benefits would increase by at least $11,000 in October.

This water right dramatically increases fishing basin benefits without decreasing next year's crop output. Water remains the same, only the timing changes. (Note that all seepage and evaporation losses must be accounted for.)

This general analysis helps highlight the efficiency tradeoffs between instream flow for crop irrigation and recreational fishing experiences; but it limits the analysis to the production possibilities frontier. Along that frontier all efficient allocations differ with respect to the output distribution. The Poudre River is not a basin firm, instead, distinct groups enjoy the benefits from different

---

[6] John Neutz, District Water Commissioner, Fort Collins, Colorado, personal interview. (March 1979)

instream flow allocations. The economist can only present the sacrifices society must make as it moves from one efficient allocation to another; the political system must subsequently decide the best point on the curve.

Future Instream Flow Values

Static Pareto analysis describes an efficient natural resources allocation if current consumption of the resource service flow does not effect future flows, and if consumption benefits or losses can not be transferred forward or backward in time.[7] For example, water for irrigation use in one period doesn't deplete the future service flow, nor can the farmer transfer service flows into another period, with the exception of small storage possibilities. The water right owner not consuming the service flow loses that period's specific water services, and must wait until the next period's replacement runoff. In principal, irrigation diversion in the Poudre River basin doesn't involve intertemporal problems; efficient allocations occur independently in each period where the marginal social cost equals the marginal social benefit or until the irrigator fully diverts the water supplies.

Once the basin considers instream flows as final consumption goods, providing amenity and recreational inputs into a consumer's household production, a static analysis may suggest inappropriate water resource allocations. Basin allocation decisions today may change future consumption benefits. Before one can learn to fish, a minimum flow must exist and be accessible. Changes in the river flow may shift the level of future demand. In addition, basin decisions that preclude

[7]John McInerney, "The Simple Analytics of Natural Resource Economics," Journal of Agricultural Economics (January 1976), pp. 31-52.

the instream service flow, say constructing a dam on the Poudre River to increase irrigation storage supplies, introduce irreversible transformations and significant intertemporal allocation problems.

Cicchetti, Seneca, and Davidson suggested that an increase in recreation supply might cause a positive change in demand.[8] Inaccessible facilities tend to decrease recreation participation rates. For example, when the Poudre River instream flow falls below the level needed for productive fishery, area residents must travel large distances before they find a quality fishing alternative. Recreationists unable to afford the travel costs may still use the Poudre River, but for recreational purposes other than fishing. However, if the basin increases the minimum river instream flow to a quality fishery, then fishing activities become more accessible, encouraging shoreline recreationists to participate in fishing activities. Since fishermen tend to value instream flow more, the willingness to pay increases.

Fishing activities also require higher skill levels than shoreline activities. Skills that individuals develop only if quality recreation facilities are nearby. Again, as the basin manager provides instream flows for fishing, the opportunity to upgrade fishing skills increases. Instream flows for fishing tends to increase the number of participants, plus as individuals improve their fishing skills, instream flows benefits become even larger.

The household production model, adopting the notion that household's combine market and non-market inputs to produce commodities, can explain why instream flow supply increases changes instream flow

---

[8]Charles J. Cicchetti, J. S. Seneca, and P. Davidson, The Demand and Supply of Outdoor Recreation: An Econometric Analysis, Bureau of Economics Research, Rutgers, New Brunswick, New Jersey, 1969.

valuation.[9] Instream flow management for fishing, reducing the travel cost to quality fishing locations, causes the implicit instream flow price to fall. The rational recreationist reacting to the price reduction shifts production toward commodities that intensively use instream flow (shoreline recreation to fishing activities) and shifts toward production technologies that use relatively more instream flow (fishing to fly fishing activities). Production theory indicates that the larger the elasticity of substitution between instream flow as water input, the more instream flow the recreationist demands.

Similarily, a rise in the marginal product of instream flows, holding factor prices constant, shifts demand. The recreationist minimizing production costs uses more instream flows in the production process, thereby reducing the relative cost of fishing experiences. Because his relative income has increased, the fisherman demands more of all commodities having a positive income elasticity. The water resource planner ignoring these intertemporal demand shifts may bias allocations toward irrigation away from recreation.

Development of Storage Reservoirs

Even more difficult are the intertemporal decisions involving irreversible changes in the environment. This period's decision allocating instream flow for recreation or irrigation withdrawal is reversible. The water resource planner can correct the faulty decision by changing the allocation in the next production and instream flow regime. However, a change from using the Poudre River for free-flowing recreation activities and irrigation, into using the Poudre River

[9]Michael and Becker, op. cit., p. 363.

Canyon as a storage reservoir for flat water recreation and irrigation is irreversible. Once a storage decision is made the opportunity costs, benefits from a free-flowing stretch of the Poudre River, become permanent. To make this decision, the water planner needs a model showing the gain or loss in future consumption and production benefits from the Poudre River in both uses, and reflecting the changing demand growth rates for instream flows in each use.

Krutilla and Fisher have proposed a dynamic model comparing current and future development or preservation.[10] The objective is to maximize:

$$\max \sum_{t=j}^{T} \theta_t[(B_t^P \cdot P_t) + (B_t^D \cdot D_t) - I_t],$$

subject to constraints on total available water flows, that the development takes place over time, and that the investment is indeed irreversible:

$$P_t + D_t = W$$

$$SI = D$$

$$I = 0$$

where

$B_t^P$ = the preservation benefits in period t,

$B_t^D$ = the development benefits in period t,

$P_t$ = free-flowing water supplies,

---

[10]Krutilla and Fisher, op. cit., pp. 39-78.

$D_t$ = storage water development,

$I_t$ = investment cost,

$\theta_t$ = discount factor, and

W = total water supplies.

This function traces out the optimal time path of resource development. Preservation is the optimal solution if net development benefits turn out negative $[\sum_t^T \theta_t (B_t^D - I_u)]$. If they are positive, then the planner should compare both water use growth rates. When development benefits grow slower than preservation benefits, the decision to preserve remains optimal. Table 5-3 presents future instream flow preservation benefits. The growth rate is approximately 8 percent, while the irrigation real growth rate has fluctuated between 10 and 1 percent per year.[11] Note, this analysis is only an example. A thorough analysis would include the effect of potential congestion on the Poudre River as use doubles. The congestion imposes a disutility on the fisherman reducing his marginal willingness-to-pay relationship. In any event, the dynamic model reflecting the growth in demand for natural environments accentuates the problems concerning resource use through time.

Instream Flow Legal Strategies and the Economic Implications

Most Colorado residents agree that the state should manage the Poudre River for both recreational and irrigation activities. Even the farmer depending on water for crop irrigation understands the need to leave some flow in stream to support aquatic life. But, few agree on the exact amount of minimum flow, or on the legal institutions needed

[11]USDA, Economics, Statistics, and Cooperatives Service, State Farm Income Statistics Supplement Bulletin to No. 609 (September 1978), p. 18.

Table 6-3. Future Instream Flow (Fishing) Aggregate Marginal Value Schedules, Poudre River, 1978.[1]

| | Entrance Fee Game | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CFS | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| | ($/acre foot) | | | | | | | | | | |
| 50 | 13.22 | 14.38 | 15.60 | 16.76 | 17.92 | 19.08 | 20.30 | 21.52 | 22.68 | 23.84 | 25.00 |
| 100 | 11.63 | 12.65 | 13.72 | 14.74 | 15.76 | 16.78 | 17.85 | 18.92 | 19.94 | 20.96 | 21.98 |
| 150 | 10.03 | 10.91 | 11.84 | 12.72 | 13.60 | 14.48 | 15.40 | 16.30 | 17.20 | 18.08 | 18.96 |
| 200 | 8.49 | 9.18 | 9.95 | 10.69 | 11.43 | 12.17 | 12.95 | 13.73 | 14.47 | 15.21 | 15.95 |
| 250 | 7.07 | 7.69 | 8.34 | 8.96 | 9.58 | 10.20 | 10.85 | 11.50 | 12.12 | 12.75 | 13.36 |
| 300 | 5.47 | 5.96 | 6.46 | 6.84 | 7.42 | 7.90 | 8.40 | 8.90 | 9.38 | 9.86 | 10.34 |
| 350 | 3.88 | 4.22 | 4.58 | 4.91 | 5.25 | 5.59 | 5.95 | 6.31 | 6.65 | 6.99 | 7.33 |
| 400 | 2.28 | 2.48 | 2.69 | 2.89 | 3.09 | 3.29 | 3.50 | 3.71 | 3.91 | 4.11 | 4.31 |
| 450 | .68 | .74 | .81 | .87 | .93 | .99 | 1.05 | 1.11 | 1.17 | 1.23 | 1.29 |
| 500 | -1.14 | -1.24 | -1.34 | -1.44 | -1.55 | -1.65 | -1.75 | -1.86 | -1.96 | -2.06 | -2.16 |

[1]Future instream flow growth rates for fishing assuming a linear trend (in 1978 prices).

Table 5-3. Continued

| CFS | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sales Tax Game | | | | | | | | | | |
| | ($/acre foot) | | | | | | | | | | |
| 50 | 18.24 | 19.84 | 21.52 | 23.12 | 24.72 | 26.32 | 28.00 | 29.68 | 31.28 | 32.88 | 34.48 |
| 100 | 16.64 | 18.10 | 19.64 | 21.09 | 22.56 | 24.02 | 25.55 | 27.08 | 28.54 | 30.00 | 31.46 |
| 150 | 14.82 | 16.12 | 17.49 | 18.79 | 20.09 | 21.39 | 22.75 | 24.12 | 25.42 | 26.72 | 28.02 |
| 200 | 12.99 | 14.13 | 15.33 | 16.47 | 17.61 | 18.75 | 19.95 | 21.15 | 22.29 | 23.43 | 24.57 |
| 250 | 11.17 | 12.15 | 13.18 | 14.16 | 15.14 | 16.12 | 17.15 | 18.18 | 19.16 | 20.14 | 21.12 |
| 300 | 9.35 | 10.17 | 11.03 | 11.85 | 12.67 | 13.49 | 14.35 | 15.21 | 16.03 | 16.85 | 17.61 |
| 350 | 8.66 | 9.42 | 10.22 | 10.98 | 11.74 | 12.50 | 13.30 | 14.10 | 14.86 | 15.62 | 16.38 |
| 400 | 5.93 | 6.45 | 6.99 | 7.51 | 8.03 | 8.55 | 9.10 | 9.65 | 10.17 | 10.69 | 11.21 |
| 450 | 4.10 | 4.46 | 4.84 | 5.20 | 5.56 | 5.92 | 6.30 | 6.68 | 7.04 | 7.39 | 7.76 |
| 500 | 2.28 | 2.48 | 2.69 | 2.89 | 3.09 | 3.29 | 3.50 | 3.71 | 3.91 | 4.11 | 4.31 |
| 540 | .46 | .50 | .54 | .58 | .62 | .66 | .70 | .74 | .78 | .82 | .86 |
| 600 | -1.37 | -1.49 | -1.61 | -1.73 | -1.86 | -1.97 | -2.10 | -2.23 | -2.35 | -2.47 | -2.59 |

to set the minimum instream flow level. Economic theory, helping to determine the instream flow value, may lead to inappropriate solutions unless the researcher considers the legal regulations. Nor can legal solutions exist independent from economic considerations.

Different property right institutions structuring the bargaining process between private water right owners and public recreation interests may generate different minimum flow outcomes.[12] For example, assume individual A owns private property rights to divert all the stream flow, while individual B would like more instream flow for recreaction. If A refuses to permit a minimum flow at the price B offers, the analyst might say the outcome, complete instream flow diversion, is optimal. Next, assume B has property rights to all instream flow. If A cannot persuade B to let him use some instream flow for crop irrigation, then the same analyst might conclude that the instream flow level B sets is optimal. Each property right structure resulted in different notions concerning the ideal instream flow level.

According to the Coase Theorem, however, economic negotiations between irrigators and fishermen generate optimal instream flow allocations regardless of the property right institutions.[13] Irrigators, owning property rights to instream flow, should be indifferent between income from irrigated crop production or payments for instream flow from fishermen. Similarly, fishermen should be indifferent between benefits from a quality fishery and damage payments from irrigators. The Coase Theorem does, however, assume the bargaining takes place

[12] E. J. Mishan, "The Economics of Disamenity," Natural Resources Journal (January 1974), pp. 55-86.

[13] R. H. Coase, "The Problem of Social Cost," Journal of Law and Economics (October 1960), pp. 1-44.

between two parties each having unique marginal instream benefits functions and no transaction costs.

The Poudre River instream flow allocation problem violates the Coasian assumptions. Instream flows serve as private good inputs into the irrigator's crop production, and as public good inputs into the fishermen's consumption of recreational experiences. The bargaining process involves a single irrigator, on one side, and as many as 40,000 fishermen on the other side. The analyst should expect the non-zero transaction costs to influence the water allocation outcome.

The public good characteristic also causes a non-unique recreation benefit function that depends on the water rights distribution. Property rights forcing the collective group, fishermen, to pay for instream flow services result in a minimum instream flow level different from the level produced by a right structure forcing the individual irrigator to bid water resources away from fishermen. In the first case, individual income limits the willingness to pay for instream flow. In the second case, each fisherman has a reservation price to sell, willingness to accept compensation, that income doesn't constrain. Since the fisherman may not have a unique marginal benefit function, economics and the legal institutions interact to allocate instream flows.

Colorado's specific instream flow regulations fit within one of Bromley-Calabresi and Melamed entitlement categories: property rules, liability rules, and inalienable rights.[14,15] Under a property rule,

[14]Daniel W. Bromley, "Property Rules, Liability Rules, and Environmental Economics," Journal of Economic Issues (March 1978).

[15]Guido Calabresi and Douglas Melamed, "Property Rules, Liability Rules, and Inalienability: One View of the Cathedral," Harvard Law Review (April 1972), pp. 1089-1128.

B cannot interfere with A's resource ownership unless B has A's consent. Liability rules permit B to interfere with A's ownership, but he must later compensate A for the loss. Under an inalienable right, B cannot, given any circumstances, interfere with A.

Each legal entitlement has an associate economic transaction cost. Property rules have relatively large transactions costs, since interested parties must bargain prior to any action. Liability rules have somewhat lower transaction costs, since actions can occur with only the knowledge that compensation must be made at a later date. Inalienable rights have infinite transactions costs, since they prevent any resource reallocations.

Different economic goods, also, have an associated transaction cost. Private goods have a small transaction cost, because interested parties can bargain through the market place rather than face to face. Public goods are characterized by high transaction cost, since a large number of individuals have an interest in the allocation. Public goods have additional non-rival characteristics that prevent a low cost market system.

Because high transaction costs hinder Coasian efficient and neutral trading solutions, certain legal entitlements work better for certain economic goods. Property rules efficiently allocate private goods consumers trade in the market place, and inefficiently allocate public goods that impact a large number of individuals. Liability rules permit action to proceed with later compensation and transactions costs and may aid efficient reallocation of public good resources. Inalienable rights best regulate those economic actions resulting in the loss in human life.

The overriding entitlement, in Colorado, allocating water resources is the doctrine of prior appropriation. This doctrine allocates water resources, separate from the adjacent land, according to use and priority. Any individual having a beneficial use for water (including domestic, municipal, power, and recreation) may apply for a water entitlement. Whenever appropriations on a stream exceed water supplies, each water entitlement holder receives water according to his temporal priority. Senior appropriators having the highest priority (earliest application date) divert water first, followed by junior appropriators having later application dates. The appropriation doctrine establishes a full property rule. Junior appropriators cannot interfere with a senior water right unless he gains consent or purchases the right.

Irrigation companies, in the Poudre River system, supplying water to local farmers and area municipalities, own senior rights to all Poudre River instream flow. Fishermen, wanting a minimum flow, have to pursuade irrigation companies to divert less water, purchase water rights, or be content with the existing flow allocation. Fishermen might be able to pursuade a few environmentally-conscious farmers to divert less, but the minimum flow is still subject to the farmer's self-interest. Allocations according to the strict appropriation doctrine are equally inappropriate. Since the appropriation doctrine allocates water flows using a priority data established over 50 years ago, today's changing social needs can cause the historical distribution to become inefficient.

Without some mechanism to transfer water rights to the highest marginal value, the appropriate doctrine sacrifices economic efficiency to assure the legal security of senior right owners. Burness and Quirk[16] showed that 1) an equal sharing of water produces a larger social output than an allocation following the appropriation doctrine, and 2) the appropriation doctrine in combination with a competitive market for water rights produces an efficient water allocation. Following the Coasian tradition the market outcome should also be neutral with respect to the initial rights structure.

Instream flow reallocations between irrigators and recreationists defy simple market solutions. The appropriation doctrine is a property rule that works well only if interested parties can meet before any interference. Water rights markets enabling parties to meet in the market place rather than face to face lower transactions costs, thus encourage efficient water exchanges. Colorado has a somewhat efficient market exchange system for transactions between two irrigators, but even the market doesn't help resource allocation under a property rule when many individuals have an interest in prospective transfer. The public good characteristics of instream flow for recreation forces the water managers to consider changes in both the economic and legal allocation institutions.

How can Colorado appropriately allocate stream flow for both irrigation and recreation? One legal alternative is to place a high priority on a minimum flow recreation right. This changes the appropriation doctrine property rule to an inalienable right. During water shortages or periods with low flow, recreation would have priority over irrigation users that must stop diverting as the instream flow falls

---

[16] H. S. Burness and J. P. Quirk, "Appropriative Water Rights and the Efficient Allocation of Resources," American Economic Review (March 1979), pp. 25-37.

toward the statutory minimum. Undoubtedly, a statutory minimum can protect recreation and aesthetic interests, but in Colorado the solution is politically infeasible and, at times, inefficient. A statutory minimum flow level would require a constitutional change in the existing appropriation system. The costs of this change probably outweigh the benefits. A statutory minimum also limits future exchange possibilities. Without provision for exchange the inalienable minimum flow right places an infinite value of instream flows for recreation. Referring back to Tables 5-1 and 5-2, instream recreation has value but not close to infinity. When drought conditions prevail, marginal benefit for crop irrigation for all flow levels exceed marginal benefits for recreation. Assuming away any irreversibility problems, economic efficiency indicates that stream flow should satisfy irrigation needs.

Rather than establish a statutory minimum flow, the Colorado legislature passed Senate Bill 97 giving Colorado's Water Conservation Board power to apply for instream flow rights "sufficient to preserve the natural environment to a reasonable degree."[17] Applying for a junior water right on a stream already overappropriated might seem useless except for the no injury provision inherent the appropriation doctrine. The existing right owner cannot change his water right location or use, if that change injures other junior or senior water rights. Even as an extremely junior right owner, the Conservation Board can object to water exchanges that may injure its recreation instream flow use. Specifically, the Board could block water transfers that change a downstream diversion point to an upstream diversion point.

---

[17]Nelson, Horak, and Lewis, op. cit., pp. 14-18.

For example, the Board could have used Senate Bill 97 to protect minimum flow in the Ricardo Creek, originating in the Sangre de Cristo Mountains.[18] The creek provides stream flow for the Colorado Fuel and Iron Company (CF&I), and a home to a rare Rio Grande River Cutthroat trout. CF&I planned to move the diversion point up high in the mountains. The Board having a junior right could have prevented the transfer, since the change in the diversion point would drastically injure the State's junior water right.

State fish and wildlife supporters find Senate Bill 97 very attractive. Conservation agencies can directly protect instream flows without needing to purchase the water. The only cost is the application fee to appropriate stream flow.

Senate Bill 97 and the no injury proviso was effective in the Ricardo Creek example, but the same provision may limit other efficient water transfers. One strategy increasing instream flow for recreation in the Poudre River requires changing the current timing of irrigation reservoir storage. Currently, operators of some high mountain reservoirs begin storing water for next year's crop production in the fall, while plains reservoirs store in the spring. Tables 5-1 and 5-2 showed that in September, marginal fishing instream benefit exceeds either September's irrigation benefits, or next year's average irrigation marginal value. Ignoring transmission losses, the State could store fall stream runoff in reservoirs downstream from recreation sites and some spring runoff in high mountain reservoirs. Total water storage for crop irrigation would remain the same and only the timing and location would change. But, the same no-injury provision protecting the State's

[18] Ibid., p. 15.

junior right to Ricardo Creek instream flow prevents any exchange between reservoirs, if the transfer injures any other water right owners.

Even though Colorado's appropriation doctrine permits water transfers, the no-injury provision limits many market exchanges.[19] Forcing potential water uses, wanting to purchase water rights, to first prove that the transfer will not injure other users, explicitly increases the exchange transaction costs. Unless the marginal benefit of water in the new use exceeds the marginal benefits in the old use plus the transaction costs the exchange will not take place. Property rules become even more restrictive, higher transaction costs, when the exchange involves recreation activities that have numerous interested participants.

Given the property rule governing water use, the most promising strategy involves purchasing or leasing instream flow water rights. This strategy, directly providing instream flow for recreation and aesthetic purposes, has a major cost constraint. In 1977, the Colorado Division of Wildlife budgeted $500,000 to purchase flow rights, that same year, they spent $18,000 for 1 cfs in Boulder Creek--water is expensive.[20] Leasing, in some situations, might be one alternative. The State can, however, defray part of the acquisition costs by selling or leasing its water right to uses down stream from the major recreation sites where the instream flow value is small.

---

[19]C. Dirck Ditwiler, "Water Problems and Property Rights-An Economic Perspective," Natural Resources Journal (October 1975), pp. 663-670.

[20]Nelson, Horak, and Lewis, op. cit., p. 44.

The Pareto optimal model showed that an efficient stream flow allocation exists if the marginal benefits of instream flow for fishing recreation equals the marginal benefits in crop production. Krutilla's dynamic model altered this conclusion to account for natural resource irreversibilities. But, economics alone cannot solve the instream flow allocation problem. Economists must remember that their models are only an abstraction of reality. Two-party competition models may not completely describe a world having large transactions costs, public goods, unequal income distributions, and different property institutions. Instream flow allocation outcomes where consumption uses must bid away flows from producers are different from the outcome where irrigators must buy water from recreationists. Appropriate prescriptive economics models should look at the economic and legal interrelationships.

Without complete economic and social welfare specifications, there is no optimal instream flow optimal solution. Instead, each recommendation will have advantages and disadvantages according to different social objectives. Certain legal-economic solution will favor production activities, others will favor consumers, and still others will be neutral. However, a legal-economic analysis should aid resource decision making by explicit identification of all the interdependencies and tradeoffs.

# CHAPTER 6

# SUMMARY AND CONCLUSIONS

## Summary

The Problem - In Colorado, economic and legal systems allocating water encouraged farmers, industries, and cities to acquire then develop stream flow to the extent that on many rivers those uses may legally divert most, if not all, water flow from the river. Until recently this strategy was beneficial; water resources for stream recreation activities were readily available compared to water sources for withdrawal uses. Diverting water from the river transferred water having a small value in recreation at the margin into withdrawal uses having a large marginal value.

Today, major economic conflicts are arising between withdrawal and instream flow water use. Many individuals demanding more recreation and amenity goods are willing to pay for water reallocations away from traditional uses. Increases in mobility, leisure time, and income cause water recreation, especially free-flowing stream activities, to assume a greater importance to the State's economy and the general population's welfare. Properly controlled instream flows can produce a quality recreation experience that provides direct utility to recreationists and indirect income support to Colorado's major tourist industry. Thus, instream water resources now have economic benefits large enough to justify minimum flow management strategies.

But, how can Colorado's water resource managers allocate limited water supplies between all possible users? Economic theory of optimal resource allocation supplies one framework to resolve conflicts where water use in one capacity precludes its use in another. The theory calls for a stream flow allocation between competing users that produces the greatest net social benefit. Since stream runoff becomes available each year at zero cost (excluding reservoir storage), resource managers should reallocate stream flow until the net marginal return is the same for alternative uses.[1] Young and Gray provide detailed information on the marginal value of water for withdrawal.[2] But, water managers still lack defensible instream flow benefit estimations.

Economists usually rely on the private market system to reveal appropriate marginal values. However, most water allocations occur outside the market place. Even if society wanted the market to allocate instream flows and stream-based recreation activities, the collective goods characteristic of instream water resources would hinder normal market transactions. Increased instream flow to one recreationist means more flow for all participants. Private producers can't package and sell just one flow unit to a single consumer. Even if they could, since the marginal cost of providing water to an additional recreationist up to the congestion point is zero, society benefits from public provision.

In the absence of market prices, conventional economic observation of consumer behavior will not lead to instream flow value estimates. Instead, the researcher alters existing methods or creates new models to impute synthetic economic values to instream flow water resources.

---

[1] Hirshleifer, DeHaven, and Milliman, op. cit., p. 38.

[2] Young and Gray, op. cit.

Since water resource managers usually make decisions between incremental additions or subtractions to existing flow levels, the correct economic guide is marginal net benefits--equal to the maximum amount a recreationist would pay to have the flow change, rather than do without.

First attempts valuing non-market water uses focused on the benefits associated with a specific recreation activity and/or recreation site. Even though these studies revealed the social worth of certain recreation experiences, they sidestepped Colorado's instream flow problem. Water resource planners need information concerning water's marginal value as an input into a recreation activity, not the value of the experience itself. Policies involving changes in the existing water allocation require objective estimates about the marginal value of additional instream flows in a recreation experience.

The Study Area - Withdrawal and instream users compete for water on all Colorado's rivers, but the conflicts are especially evident on the Cache la Poudre River in northeastern Colorado. The Poudre River Canyon is an extremely popular recreation area. During spring and early summer when the stream runoff is high, the river provides excellent white water rapids for kayakers and rafters. For those who like to fish, the Poudre River combines temperature, turbidity, and flow attributes to produce an excellent Rainbow and Brown trout fishery. In addition, over 100,000 recreationists visited the canyon to enjoy the picturesque mountain environment.

But, farmers have diverted stream flow from the Poudre River for irrigation since 1864. The State, over the past 100 years, decreed water rights to farmers and cities in excess of 4,000 cfs. Since the average summer flow seldom exceeds 700 cfs, farmers can literally eliminate any instream recreation activity. Only since 1976 has Colorado attempted to manage water flows for recreation.

Objectives - Individuals responsible for recreation management have long known that water-based recreation has a large economic value, and have wanted to maintain a minimum instream flow level. But, they lacked enough specific information on water's marginal value in recreational activities to defend any management strategy. This research focuses, first, on the economic valuation of instream flows for recreation purposes. The resulting estimates of economic benefits, designed to be comparable and commensurate with values in withdrawal uses, reflect the recreationist's willingness to pay for incremental increases in the stream flow level. The second objective is to identify the economic and legal components necessary to evaluate alternative water storage investments or minimum instream flow management strategies. Economic solutions may lead to inappropriate conclusions, unless the analyst considers the legal institutions governing water allocations.

Procedure - A contingent valuation approach directly estimates the recreationist's willingness to pay for instream flow quantity changes.[3] The technique creates a hypothetical water market that confronts the recreationist with an array of instream quantities, and records the recreationist's maximum payment for each specific quantity change, rather than do without. The procedure measures instream flow's net contribution to the recreation activity and not the total value of the experience itself. Since it focuses on incremental changes in the

[3] Randall and Brookshire, op. cit.

stream flow level, it provides surrogate dollar values water resource planners can compare with water value in withdrawal use.

The model assumes that willingness to pay is inversely related to an instream flow quantity index and other economic variables:

$$WTP^c = g(F_j, Y, T, S_k).$$

The variable, $WTP^c$, representing the household's willingness to pay to obtain some increase in the stream flow level, estimates the Hicksian compensating surplus. The variable, $F_j$, represents the cubic feet per second water flow at the observation site. The variable, T, models each individuals' recreation tastes and preferences. And the variable, $S_k$, represents differences in the depth, velocity, aesthetic quality, and fishing quality at each observation site. An ordinary least-squares approach estimated the statistical parameters.

This research used an iterative bidding game similar to the one by Randall, _et al_. on aesthetic improvements in the Four Corners Region (southwestern United States) to obtain contingent instream flow benefits.[4] The survey approach included:

1. color photographs of eight different instream flow rates at four different sites in the Poudre River Canyon,

2. detailed fishery and hydrologic data at each flow level and site combination,

3. two well-defined hypothetical situations (an entrance fee and a sales tax payment vehicle), and

4. a series of iterative bidding game questions where the respondent indicated his maximum payment to obtain the instream flow quantity change.

---

[4]Randall, Ives, and Eastman, op. cit.

To collect the willingness to pay and other economic information, this research surveyed 134 households using the Poudre River for stream recreation activities during summer 1978. The sample included 49 fishermen (fly, lure, or bait), 45 shoreline recreationists (those participating in camping, hiking, viewing, and other non-contact stream activities), and 40 white water enthusiasts (kayakers, rafters, and tubers). We estimated a benefit function for each activity. The reader should be cautious about shoreline results due to the heterogeneous nature of that group.

To assure a representative and random sample, the interviewer sampled random days during each month at different sites in the Canyon. Even though the survey often took nearly an hour to complete, the acceptance rate was over 80 percent. Fishermen and shoreline recreationists were the easiest to interview and the most receptive, only 19 and 7 percent refusing to be interviewed. However, kayakers and rafters often objected to the process, 38 percent refusing the interview. Although a personal interview technique is costly, the interviewer can eliminate many misunderstandings about the hypothetical bidding game process, making the extra precision worth the extra costs.

## Conclusions

The objective of this research is to present the economic factors associated with setting minimum flow regulations on Colorado streams. Five major conclusions flow from that objective.

1. ORDINARY LEAST SQUARES ESTIMATES OF THE TOTAL INSTREAM FLOW BID FUNCTION FOR FISHING, SHORELINE, AND WHITE WATER ACTIVITIES .

For instream flow increases, economic theory suggests that the total willingness to pay should increase at an increasing rate, continue to increase at a decreasing rate up to some peak, then, finally, decrease. This relationship modeled the bid functions for fishing and shoreline activities. A quadratic regression equation, including the variables Flow and $(\text{Flow})^2$, seemed to perform best. White water recreationist models didn't follow the pattern; total willingness to pay increased over all instream flow quantity increases. The best white water statistical equation modeled a linear total bid function.

According to the statistic, $\bar{R}^2$, all statistical equations fit the cross section data reasonably well. Fishing entrance fee and sales tax models explained 41 and 43 percent of the variation in household willingness-to-pay responses. Shoreline entrance fee and sales tax models explained 52 and 50 percent of the bid variation. And, the $\bar{R}^2$ for white water entrance fee and shoreline models was .52 and .66, respectively. Note, model comparison by $\bar{R}^2$ is not strictly appropriate, since the regression equations include different independent variables.

Instream flow quantity variables are the principle determinant of fishing and white water willingness-to-pay responses. According to statistical t-ratio tests, variables, Flow and $(\text{Flow})^2$ are significant (t-ratios equal to 3.58 and 5.78 in the entrance fee fishing model). They also explain 20 and 21 percent of household fishing bid variations. Flow, alone, is highly significant in the white water model (t-ratios equal to 21.68 and 15.05 in the entrance fee and sales tax models), and it explains 38 and 53 percent of the bid variation. Even though Flow and $(\text{Flow})^2$ were significant (t-ratios equal to 2.18 and

2.61) in the shoreline user models, they could explain only 3 and 6 percent of the bid variation. Tables 4-2 through 4-7 summarize the statistical parameter estimated for flow and the other important economic variables.

2. AGGREGATE INSTREAM FLOW MARGINAL VALUES

Before water managers can make formal water policy decisions concerning incremental instream flow changes, they need specific information about marginal instream values rather than the total value. The necessary aggregate marginal schedules exhibited rational economic behavior (see page 72 for the aggregation procedures). The fishing instream flow marginal benefit function slopes downward to the right. Each unit flow increase has a value less than the previous one. If the Poudre River's flow is small (50 cfs) fishing marginal instream value is relatively large ($26.38/cfs and $36.59/cfs for the entrance fee and sales tax games). The marginal value falls to zero as instream flows approach 500 cfs. This economic point corresponds closely with the physical fishery model showing that an optimal stream flow for catching trout in the Poudre River occurs at approximately 500 cfs (see Table 4-8). Fishermen, without complex fishing and hydrologic models know which flow level provides the best fishing. Beyond 500 cfs the quality of the Poudre River fishery decreases. The economic values confirm that result, as fishermen would not pay for instream flow additions past 500 cfs.

Like the fishing marginal function, shoreline marginal values decrease as flow quantities increase, turning negative when the Poudre River flow exceeds 700 cfs. But, the starting magnitude is much smaller and the rate of decrease continues over higher flow rates. As long as the Poudre River isn't dry or over bank full, the shoreline recreationist is relatively indifferent between alternative instream flow levels. Because the variance around the bids is so great, none of the marginal values are statistically different from zero (see Table 4-9).

White water marginal functions are slightly different. Total willingness to pay increases at a constant rate over all instream flow quantity changes in the photographs. Thus, the first derivative (marginal benefit) is a constant. Each instream flow cfs increase is worth $9.55 and $14.40 in the entrance fee and sales tax game, respectively. Had the survey been able to include photographs showing the Poudre River at extremely high flow rates, producing a river that is dangerous to kayak, the resulting white water marginal benefit function would have resembled the other two functions (see Table 4-10).

Some analysts criticize bidding game approaches because of the inherent hypothetical market structure. Indeed, respondents may not reveal their true preferences for instream flows. Peter Bohm suggested that, since any hypothetical situation may result in bias, the research design should include at least two different willingness-to-pay games.[5] If individuals are going to give false responses, one game should encourage understatement, the other overstatement of true preferences. The interval between the two benefit functions will be small or large depending on how strongly individuals respond to the specific incentives built into each question design.

The bids for all recreation activities were statistically different for each repayment obligation. Sales tax marginal benefit values

[5]Bohm, "Estimating Access Values," op. cit.

always exceeded entrance fee marginal benefits. The entrance game forcing recreationists to pay their stated valuation may encourage understatement. Some users may believe the State will provide more flow regardless of the willingness-to-pay responses. The sales tax game might provide incentives for overstatement, since the payment is not related to the amount of use. Generally, recreationists using the Poudre River have an incentive to overstate their valuations in order to increase the instream flow at the expense of the general public. This logic does assume that users have mean valuations that exceed society's mean valuation. This study produced sales tax responses approximately $10.00 greater for fishing activities, approximately $4.00 greater for shoreline activities, and approximately $5.00 greater for white water activities at each instream flow rate.

## 3. OPTIMAL INSTREAM FLOW RESOURCES ALLOCATION BETWEEN FISHING AND IRRIGATION ACTIVITIES

The static economic theory of optimal resource allocation shows the conditions for an efficient instream flow allocation. To fulfill the efficiency condition, water resource managers should allocate instream flows into supplementary and complementary activities until further reallocation causes the activities to compete for more instream flow. Once competitive, he should allocate stream flow between uses so that the marginal return from each use is equal.

During May, June, and July fishing and irrigation are complementary outputs. Because the average Poudre River stream flow exceeds 450 cfs (775, 1,542, and 703 cfs, respectively), increased irrigation diversions will increase crop output and increase fishing social benefits by at least $4.26/af, $2.19/af, and $12.81/af (see Table 4-8).

In October, fishing and irrigation become supplementary outputs. Leaving water in the River increases fishing benefits by $6.79/af (average flow in October is 124 cfs), without reducing any crop output that same season. Pareto efficiency calls for increased irrigation diversion in early summer and no diversion after September.

As fishing and irrigation become competitive in September, instream flow water allocation decision becomes more difficult; reallocating flow increases one output at the expense of the other. Current September allocation may be inefficient. Since the average stream flow is only 105 cfs, the marginal return to fishing activities, $10.54/af, exceeds the marginal return for crop irrigation, $7.22/af. To maximize net social benefits, the Poudre River instream flow should be 200 cfs where marginal returns in both uses are approximately equal (7.68/af for fishing and $7.27/af in crop production).

One possible solution involves changing the timing of irrigation water storage in high mountain and plains reservoirs. Many irrigation companies begin filling high mountain reservoirs in the fall and wait until next spring to fill reservoirs on the plains.[6] Changing the storage timing between high mountain and plains reservoirs turns a competitive relationship into a complementary one. Fishing benefits increase by $10/af in the fall as more water runs downstream into plains reservoirs, and benefits increase in the spring as high mountain storage reduces early summer instream flow. The change in storage timing substantially increases total benefits. In September, the additional flow increases recreation benefits by $330/day or approximately $10,000. In October, total benefits increase by $11,000. This water

[6]Aukerman, Springer, and Judge, op. cit.

right storage timing exchange increases social fishing benefits without decreasing water for irrigation. (Note, all seepage and evaporation losses must be accounted for.)

4. FUTURE INSTREAM FLOW VALUES

Static economic analysis is correct, only if today's water allocation doesn't effect future instream flow quantities or future consumption benefits. Generally, irrigation diversions in the Poudre River don't involve intertemporal problems. But, water for instream recreation might change future consumption behavior.[7] More instream flows improve the Poudre River's fishers, and makes fishing activities more accessible. After seeing how much enjoyment fishermen have, shoreliners might take up fishing. Instream flow maintenance for fishing, also, provides an opportunity to increase fishing skills. Both improved fishing skill, and recreation shifts from shoreline to fishing activities, increase instream flow benefits. Resource managers should consider these possible future instream flow benefit increases in their reallocation decisions.

Intertemporal decisions involving irreversible changes in the environment are even more complex. For example, the decision to construct a storage reservoir on the Poudre River results in a permanent benefit loss from free-flowing stream recreation. Krutilla and Fisher have shown that when development benefits grow more slowly than preservation benefits, the decision to preserve is optimal.[8] Assuming no congestion, recreation fishing benefits are growing at 8 percent/year

---

[7]Cicchetti, Seneca, and Davidson, op. cit.

[8]Krutilla and Fisher, op. cit.

in real terms (see Table 5-3). The decision to construct a reservoir must account for this growth rate.

5. LEGAL AND ECONOMIC INTERRELATIONSHIPS

R. H. Coase presented an analysis implying that economic negotiations between irrigators and fishermen will generate optimal instream flow allocations regardless of the property right ownership.[9] However, the instream allocation problem violates the Coasian assumptions. Since instream flow for fishing is a public good; numerous fishermen have an interest in the allocation. The transactions costs to collect all the fishermen preferences, alone, prevents Coasian neutrality. In addition, the fisherman may have non-unique benefit functions. Property rights that force the fisherman to buy water rights from irrigators impose an income constraint on their willingness to pay. If fishermen own the rights to instream flow, each would have a recreation price to sell (willingness to accept compensation) that income doesn't constrain.

The legal institution allocating Colorado's stream flow resources is the appropriation doctrine. This allocation system distributes water according to beneficial use and priority. If appropriations on a stream exceed water supplies, then the application data determines how much water the right owner will receive. Senior appropriators having the earliest application dates divert water first, followed by junior appropriators having later application dates.

The appropriation doctrine establishes a full property rule. Fishermen, wanting higher instream flow levels can either pursuade irrigation companies, who have rights to virtually all the Poudre River

[9]Coase, op. cit.

stream flow, to divert less or they can purchase water rights. Property rules combined with economic markets function efficiently if interested parties can meet before the transaction. Colorado has a quasi-market exchange systems between irrigators, but the market doesn't aid allocations between recreationists and irrigators where numerous individuals have an interest in the public goods aspect of instream flows. Without different property right rules or some other economic mechanism to transfer water rights to uses having the highest water return, allocations according to the doctrine of appropriation sacrifice economic efficiency and equity to assure legal security for senior water right owners.

## BIBLIOGRAPHY


Ajzen, I. and M. Fishbein, "Attitude-Behavior Relationships: A Theoretical Perspective and Review of Empirical Research," Psychological Bulletin 84 (1977), pp. 888-918.

Aukerman, Robert, William T. Springer, and James F. Judge, Inventory of Colorado's Front Range Mountain Reservoirs, Colorado State University Environmental Resources Center, Information Series No. 23, May 1977.

Bohm, Peter, "Estimating Access Values," Public Economics and the Quality of Life, Resources For The Future (Washington, D.C.: Johns Hopkins University Press, 1977), pp. 181-195.

Bohm, Peter, "Estimating Demand for Public Goods: An Experiment," European Economic Review (March 1972), pp. 111-130.

Bovee, Ken D. and Tim Cochnauer, Development and Evaluation of Weighted Criteria - Probability of Use Curves for Instream Flow Assessment: Fisheries, Cooperative Instream Flow Service Group, Fort Collins, Colorado (December 1977).

Bradford, D. F., "Benefit-Cost Analysis and Demand Curves for Public Goods," Kyklos 23 (1970).

Bromley, Daniel W., "Property Rules, Liability Rules, and Environmental Economics," Journal of Economic Issues (March 1978).

Brookshire, David S., Berry C. Ives, and William D. Schulze, "The Valuation of Aesthetic Preferences," Journal of Environmental Economics and Management (1976).

Brown, W. O., F. H. Nawas, and J. B. Stevens, The Oregon Big Game Resource: An Economic Valuation, Oregon Agr. Exp. Station (1973).

Burness, H. S. and J. P. Quirk, "Appropriative Water Rights and the Efficient Allocation of Resources," American Economic Review (March 1979), pp. 25-37.

Calabresi, Guido and Douglas Melamed, "Property Rules, Liability Rules, and Inalienability: One View of the Cathedral," Harvard Law Review (April 1972), pp. 1089-1128.

Carlson, James W., District Ranger, Arapahoe and Roosevelt National Forests, Fort Collins, Colorado (September 1978).

Cicchetti, Charles J., J. S. Seneca, and P. Davidson, The Demand and Supply of Outdoor Recreation: An Econometric Analysis, Bureau of Economics Research, Rutgers, New Brunswick, New Jersey, 1969.

Cicchetti, Charles J. and V. Kerry Smith, The Costs of Congestion (Cambridge, Mass.: Ballinger Publishing Co., 1976).

Clawson, M., Methods of Measuring the Demand For and Value Of Outdoor Recreation (Washington, D.C.: Resources For The Future, 1959), Reprint No. 10.

Coase, R. H., "The Problem of Social Cost," Journal of Law and Economics (October 1960), pp. 1-44.

Daubert, John, "Conjunctive Ground and Surface Water Allocation: The Economics of a Quasi-Market Solution," M.S. Thesis, Colorado State University, Fort Collins, Colorado, Fall 1978.

Davis, R. K., "The Value of Big Game Hunting in a Private Forest," Proceedings XXIX American Wildlife Conference (1964).

Ditwiler, C. Dirck, "Water Problems and Property Rights-An Economic Perspective," Natural Resources Journal (October 1975), pp. 663-670.

Freeman, A. M., "A Survey of the Techniques for Measuring the Benefits of Water Quality Improvement," Cost-Benefit Analysis and Water Pollution Policy, edited by H. M. Peskin and E. P. Seskin (Washington, D.C.: The Urban Institute, 1975).

Gum, R. L. and W. F. Martin, "Problems and Solutions in Estimating the Demand For and Value of Rural Outdoor Recreation," American Journal of Agricultural Economics, Vol. 57, No. 4 (1975), pp. 558-566.

Hall, R., "The Specification of Technology with Several Kinds of Output," Journal of Political Economy, Vol. 81 (1973), pp. 387-398.

Hammack, Judd and Gardner Brown, Waterfowl and Wetlands: Toward Bioeconomic Analysis, Resources For The Future (Baltimore: Johns Hopkins University Press, 1974).

Harberger, A. C., "Three Basic Postulates for Applied Welfare Economics: An Interpretive Essay," Journal of Economic Literature (September 1971).

Henderson, J. M. and R. E. Quant, Microeconomic Theory, 2nd Edition (New York: McGraw-Hill, 1971).

Herfindahl, Orris C. and Allen V. Kneese, Economic Theory of Natural Resources (Columbus, Ohio: Charles E. Merrill Publishing Co., 1974).

Hicks, J. R., "The Four Consumers' Surpluses," Review of Economic Studies, Vol. 11 (Winter 1943).

Hirshleifer, J., J. C. DeHaven and J. W. Milliman, Water Supply (Chicago: University of Chicago Press, 1960).

Hyra, Ronald, Methods of Assessing Instream Flows for Recreation, Instream Flow Information Paper No. 6, Cooperative Instream Flow Service Group, Fort Collins, Colorado, June 1978.

Johnston, J., Econometric Methods (New York: McGraw-Hill, 1972).

Kmenta, Jan, Elements of Econometrics (New York: Macmillan Publishing Co., 1971).

Knetsch, J. L., "Outdoor Recreation Demands and Benefits," Land Economics, Vol. 39, No. 4 (1963), pp. 387-396.

Knetsch, Jack L. and Robert K. Davis, "Comparisons of Methods for Recreation Evaluation," Water Research (Baltimore: Johns Hopkins Press, 1966), p. 129.

Krutilla, John V. and Anthony C. Fisher, The Economics of Natural Environments, Resources For The Future (Baltimore: Johns Hopkins University Press, 1975).

Kurz, Mordecai, "Experimental Approach to the Determination of the Demand for Public Goods," Journal of Public Economics 3 (1974), pp. 329-348.

Lancaster, K. J., Consumer Demand: A New Approach (New York: Columbia University Press, 1971).

Langford, William and D. J. Cocheba, The Wildlife Valuation Problem: A Critical Review of Economic Approaches, Canada Wildlife Service, Occasional Paper No. 37 (1977).

Lucas, Robert C., "Bias in Estimating Recreationist's Length of Stay from Sample Interviews," Journal of Forestry (December 1963), pp. 912-914.

Maass, A. and R. L. Anderson, ...And the Desert Shall Rejoice: Conflict, Growth, and Justice in Arid Environments (Cambridge, Mass.: MIT Press, 1978).

Mäler, Karl-Göran, "A Method of Estimating Social Benefits from Pollution Control," Swedish Journal of Economics (1971).

Martin, William E., J. Craig Tinney, and Russell L. Gum, "A Welfare Economic Analysis of Potential Competition Between Hunting and Cattle Ranching," Western Journal of Agricultural Economics, Vol. 3, No. 2 (December 1978), pp. 87-97.

McInerney, John, "The Simple Analytics of Natural Resource Economics," Journal of Agricultural Economics (January 1976), pp. 31-52.

Mendenhall, W., L. Ott, and R. L. Scheaffer, Elementary Survey Sampling (Belmont, Calif.: Duxbury Press, 1971), p. 61.

Michael, R. T. and G. S. Becker, "On the New Theory of Consumer Behavior," Swedish Journal of Economics (Fall 1973).

Michalson, E. L., "An Attempt to Quantify the Esthetics of Wild and Scenic Rivers in Idaho," River Recreation Management and Research Symposium, USDA, Forest Service, January 1977.

Milhous, Robert R. and Ken D. Bovee, Theoretical Considerations Necessary for Predicting Discharge, Stage, and Velocity from Measurements of Natural Streams for Instream Flow Assessments, Cooperative Instream Flow Service Group, U.S. Department of Interior, Fort Collins, Colorado (December 1977).

Mishan, E. J., "The Economics of Disamenity," Natural Resources Journal (January 1974), pp. 55-86.

Nelson, Wayne, Gerry Horak, and Martin Lewis, "Instream Flow Strategies for Colorado," Fish and Wildlife Service, U.S. Department of the Interior, FWS/OBS-78/37 (May 1978), p. 12.

Neutz, John, District Water Commissioner, Fort Collins, Colorado, personal interview. (March 1979)

Pindyck, Robert S. and Daniel L. Rubinfeld, Econometric Models and Economic Forecasts (New York: McGraw-Hill, 1976), pp. 103-106.

Pollak, R. A. and M. L. Wachter, "The Relevance of the Household Production Function and Its Implications for the Allocation of Time," Journal of Political Economy, No. 83 (April 1975), p. 258.

Randall, Alan and David S. Brookshire, "Public Policy, Public Goods and Contingent Valuation Mechanisms," Staff Paper 68, University of Kentucky, Lexington, Kentucky, June 1978.

Randall, Alan, Berry Ives, and Clyde Eastman, "Bidding Games for Valuation of Aesthetic Environmental Improvements," Journal of Environmental Economics and Management (1974).

Randall, A. and J. Stoll, "Consumer's Surplus in Commodity Space," Working Paper, Department of Agricultural Economics, University of Kentucky, Lexington, Kentucky, 1978.

Recreational Information Management System, USDA, Forest Service, Fort Collins, Colorado, personal communication (1978).

Samuelson, P. A., "The Pure Theory of Public Expenditure," Review of Economics and Statistics, Vol. 36, No. 4 (November 1954).

Seckler, David W., "On the Uses and Abuses of Economic Science in Evaluating Public Outdoor Recreation," Land Economics (November 1966), pp. 485-494.

Sinden, J. A., "An Utility Approach to the Valuation of Recreation and Aesthetic Experiences," American Journal of Agricultural Economics, Vol. 56, No. 1 (February 1974).

Smith, Adam, Wealth of Nations (New York: Modern Library, 1937).

Smith, Robert J., "Problems of Interpreting Recreation Benefits from a Recreation Demand Curve," Recreation, Economics and Analysis, G. A. C. Searle (ed.) (New York: Longman Group Hd., 1975), p. 73.

Stevens, J. B., "Recreation Benefits from Water Pollution Control," Water Resources Research (Spring 1966), pp. 167-181.

Tideman, Nicolaus, "The Efficient Provision of Public Goods," Public Prices for Public Products (Washington, D.C.: The Urban Institute, 1972).

U.S. Department of Interior, Hydrology Branch of the Division of Project Investigations, Bureau of Reclamation, Guide for Applications of the Water Surface Profile Computer Program, Denver, Colorado (December 1968).

U.S. Department of Agriculture, Economics, Statistics, and Cooperatives Service, State Farm Income Statistics Supplement Bulletin to No. 609 (September 1978), p. 18.

Walsh, Richard G., Ray K. Ericson, and Daniel J. Arosteguy, An Empirical Application of a Model for Estimating the Recreational Value of Instream Flow, Draft Completion Report No. A-036-COLO (October 1978).

Walsh, Richard G., Douglas A. Greenley, Robert A. Young, John R. McKean, and Anthony A. Prato, Option Values, Preservation Values and Recreational Benefits of Improved Water Quality, U.S. Environmental Protection Agency, January 1978.

Willig, R. D., "Consumer's Surplus Without Apology," The American Economic Review (September 1976), p. 589.

Winch, D. M., Analytical Welfare Economics (London: Penguin, 1971).

Young, R. A. and S. L. Gray, Economic Value of Water: Concepts and Empirical Estimates, Final Report to the National Water Commission, Report No. NWC-SBS-72-047, March 1972.

# APPENDIX A

## MINIMUM FLOW OPINION SURVEY

Department of Economics
Colorado State University
Fort Collins, Colorado 80523

Good Morning/Afternoon. I'm collecting information concerning the importance of minimum water flows in the Poudre River. Minimum flow regulations may have significant impacts on the current uses of the Poudre River. For example, requiring a specific level of water would enhance stream recreation but might reduce the water available for crop irrigation during the growing season. This research examines some of the trade-offs between farm, municipal, and recreational uses of stream flow. With these objectives in mind, I would like to ask you a few questions to see how you value various water quantities in the Poudre River.

1. When using the Poudre River for your recreational purposes, which activity do you enjoy most? Please rank recreation activities in order of your preference.

   ________ Fishing ________ Rafting and kayaking

   ________ Shoreline activities (picnicking, camping, hiking, viewing, etc.)

2. How many days in the last 12 months would you estimate that you participated in your most preferred activity in the Poudre River Canyon?

   _____1-3 _____4-6 _____7-9 _____10-12 _____13-15

   _____16-18 _____19-21 _____22-24 _____25-27 _____28-30

   _____Over 30

3. How many years have you been traveling into the Poudre Canyon to participate in ________ activities? ________ years

   I have some additional questions which will help determine your value (in dollar terms) of different water flows in the River. The photographs I have show how the Poudre River looks with various stream flows. Each flow level provides a somewhat different ________ experience.

4. Would you please look at these four sets of photographs at different sites of the Poudre River and rank the sites in order of your preference:
   1st__________ 2nd__________ 3rd__________ 4th__________

5. Would you please use the photographs to rank the different flow levels at site _____ in order of your preference: 1st_____ 2nd_____ 3rd_____ 4th_____ 5th_____

   I noticed that the type of stream recreation you prefer is __________. Suppose that you were going to use the Poudre River to __________ for _____ day(s) of annual use. Assume also that a local governmental agency collected an annual district recreational sales tax to finance the provision of different stream flows for your __________ enjoyment. This annual tax is the only way to finance the program. All area residents and visitors to the Poudre River recreation district would pay the annual sales tax. This sales tax will permit use for all members of your household going __________ for _____ day(s) of annual use.

6. How do you expect to pay for the added cost?

   __________ 1 - I expect my income to increase (by how much _____%)

   __________ 2 - I will work extra hours (no. of additional hours __________)

   __________ 3 - I will purchase less of other goods

   __________ 4 - I will save less

   __________ 5 - Other (explain)

7. Would you be willing to add _____% increase to present sales taxes, if that resulted in stream flow increases from those in picture 1 to those in picture 2?

8. (If any bid = zero, choose one.) Did you answer zero because:

   __________
   1. You do not receive any benefits from additional water flows; therefore, you see no reason for the extra sales tax.
   2. Sales taxes are already too high.
   3. Other.

   I would like to play a somewhat different bidding game with you. Assume that to gain access to the Poudre River Canyon to __________ for _____ day(s) of annual use all users must pay a daily entrance fee. All of this daily fee would be used to provide the best stream flow for your __________ enjoyment. This daily fee is the only way of financing the various water quantities in the photographs. All users will pay the same fee as you do. This fee will permit use for all members of your household going __________ for _____ day(s) of annual use. Also, assume that participation in

_________ at any other river canyon would require payment of an entrance fee.

9. Would you please rank the photographs of different flow levels at site _____ in order of your preference. 1st_____ 2nd_____ 3rd_____ 4th_____ 5th_____

10. If the entrance fee cost $_____/day would you pay the fee so the members of your household could travel up the Poudre River Canyon to _________ for _____ day(s) of annual use, if that amount resulted in an increase in water flow in picture 1 to those in picture 2?

11. (If any bid = zero, choose one.) Did you answer zero because:

_________

1. You do not receive any benefits from additional water flows.
2. You believe that it is unfair to charge access to public property.
3. Other.

(Play entrance fee bidding game for third site.)

12. Would you please rank the photographs of different flow levels at site _____ in order of your preference? 1st_____ 2nd_____ 3rd_____ 4th_____ 5th_____

13. Play Entry Fee Bidding Game.

14. Show individual his bid matrices. Would you like to change any bids? _________(If there are substantial differences between the sales tax bids and the entrance fees, ask why.)

_________ 1 - You do not like the idea of an entrance fee to a public canyon.

_________ 2 - You do not like the idea of increasing sales taxes.

_________ 3 - You prefer some sites over others.

_________ 4 - Other.

15. Respondents

Sex _____ Age _____ Employment _____ Employer _____

Employment

1. Professional
2. Business owner/mgr.
3. Skilled foreman
4. Salesman, buyer
5. Office worker
6. Unskilled
7. Housewife
8. Retired
9. Student
10. Other

Employer

1. Mfg.
2. Const.
3. Retail
4. Financial
5. Health services
6. Education
7. Public adm.
8. Agr.
9. Unemployed
10. Other

16. Do you live in the Fort Collins area? _____
(If yes) How long have you lived in this area? _____years
(If no) Where do you live __________ city For how many years? ___

17. How would you classify your previous residence?

    1. very large city (100,000+)
    2. medium-size city (25,000-100,000)
    3. small city (5,000-25,000)
    4. rural area or town (non-farm)
    5. farm
    6. have always lived at current residence

18. How many individuals do you have living in your home? _____

19. How many of the individuals living at home in Question 15 would participate in __________ with you? no. _____

20. Please circle the highest level of schooling you completed

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Elementary | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| High school or vocational school | 9 | 10 | 11 | 12 | | | | |
| College or technical school | 13 | 14 | 15 | 16 | | | | |
| Graduate training | 17 | 18 | 19 | 20 | 21 | 22 | | |

21. If you don't object, could you indicate which of the following brackets your family incomes fall into before taxes:

    1. under 3,000
    2. 3,000-4,999
    3. 4,999-6,999
    4. 7,000-9,999
    5. 10,000-14,999
    6. 15,000-19,999
    7. 20,000-24,999
    8. 25,000-25,999
    9. over 30,000

## APPENDIX B

## HYDROLOGIC SIMULATION

The purpose of the water surface profile computer program is to predict the depths and velocities at a stream cross section, given various discharge rates. There are several possible approaches: Manning's equation, stage-discharge relationships, and combinations of both. Each differ primarily with respect to the number of discharge measurements the researcher needs to calibrate the hydrologic simulation program. This thesis used the single discharge measurement calibration method required by the Manning's equation approach. Since it requires only one field survey, there are considerable cost and time savings. The cost savings do, however, cause a decrease in accuracy. Since the reason behind predicting river profiles is to provide the respondent with additional, but approximate, information about the river at each site and not for legal use to set minimum flows, the cost savings dominated the accuracy considerations.

At any one river cross section Manning's equation can be written as:[1]

$$Q = \frac{1.49}{n} S_e^{1/2} AR^{2/3}$$

---

[1]Robert R. Milhous and Ken D. Bovee, Theoretical Considerations Necessary for Predicting Discharge, Stage, and Velocity from Measurements of Natural Streams for Instream Flow Assessments, Cooperative Instream Flow Service Group, U.S. Department of Interior, Fort Collins, Colorado (December 1977).

where

$Q$ = discharge in CFS

$A$ = cross section area in $ft^2$

$R$ = the hydrologic radius

$S_e$ = energy grade line or slope

$n$ = calibration coefficient of channel roughness.

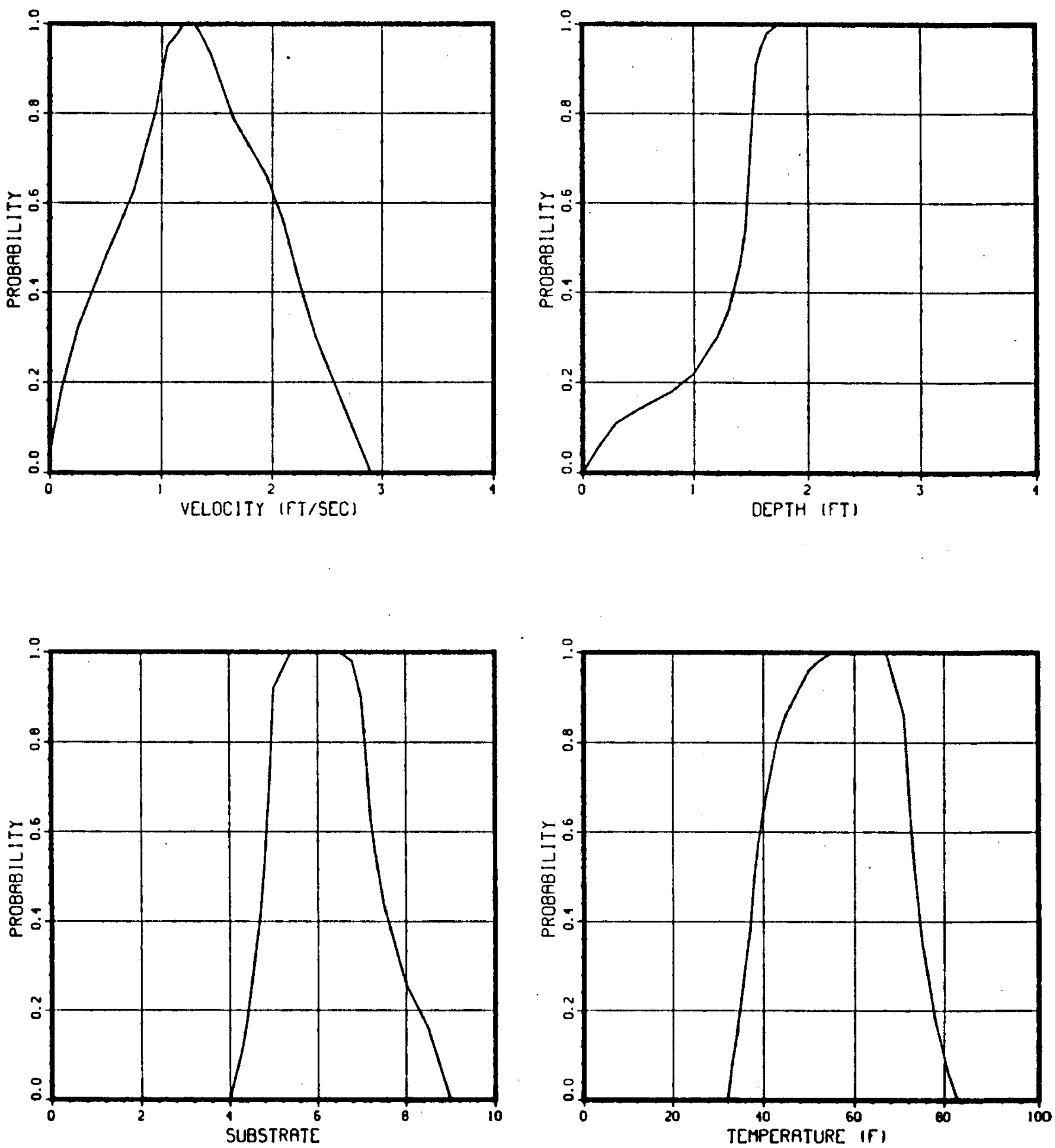
Using only one measurement of discharge, stage, and the proper calibration of n, the water surface profile program can calculate discharge, velocity, and depth at other stages. Note that since n varies with discharge, Manning's equation can predict profiles at stages reasonably close to the calibration stage.

APPENDIX C

# RAINBOW TROUT

Probability-of-Use Curves

11102 ADULT 78/01/24.




Source: Ken D. Bovee, Probability-of-Use Criteria for the Family Salmonidae, Cooperative Instream Flow Service Group, Fort Collins, Colorado (January 1978).

APPENDIX C
(continued)

Table C-1. Available Weighted Usable Surface Area (WUSA) Per 1000 Feet of the Poudre River for Rainbow and Brown Trout, Site A.

| Quantity of Flow (CFS) | Rainbow Life Stages Juveniles[1] (WUSA in sq. ft.) | Rainbow Life Stages Adults[2] (WUSA in sq. ft.) | Brown Life Stages Juveniles[1] (WUSA in sq. ft.) | Brown Life Stages Adults[2] (WUSA in sq. ft.) |
|---|---|---|---|---|
| 35 | 14770 | 6248 | 31583 | 13626 |
| 58 | 17634 | 9648 | 30844 | 18977 |
| 189 | 14889 | 27449 | 27891 | 24918 |
| 255 | 14844 | 29573 | 26627 | 25761 |
| 984 | 6342 | 32901 | 13921 | 26516 |

[1]Trout between 2" and 8".

[2]Trout over 8".

Table C-2. Available Weighted Usable Surface Area (WUSA) Per 1000 Feet of the Poudre River for Rainbow and Brown Trout, Site B.

| Quantity of Flow (CFS) | Rainbow Life Stages Juveniles[1] (WUSA in sq. ft.) | Rainbow Life Stages Adults[2] (WUSA in sq. ft.) | Brown Life Stages Juveniles[1] (WUSA in sq. ft.) | Brown Life Stages Adults[2] (WUSA in sq. ft.) |
|---|---|---|---|---|
| 35 | 4618 | 5586 | 18226 | 7649 |
| 58 | 7729 | 7355 | 18289 | 10029 |
| 189 | 8550 | 12162 | 13088 | 10751 |
| 255 | 8374 | 11438 | 11366 | 10168 |
| 984 | 5348 | 8471 | 7916 | 8021 |

[1]Trout between 2" and 8".

[2]Trout over 8".

APPENDIX C
(continued)

Table C-3. Available Weighted Usable Surface Area (WUSA) Per 1000 Feet of the Poudre River for Rainbow and Brown Trout, Site C.

| Quantity of Flow (CFS) | Rainbow Life Stages Juveniles[1] | Rainbow Life Stages Adults[2] | Brown Life Stages Juveniles[1] | Brown Life Stages Adults[2] |
|---|---|---|---|---|
| | (WUSA in sq. ft.) | | (WUSA in sq. ft.) | |
| 40 | 2142 | 1426 | 5660 | 0 |
| 189 | 7563 | 4331 | 10124 | 6741 |
| 309 | 6964 | 3870 | 9978 | 6720 |
| 406 | 7411 | 5190 | 9363 | 7891 |
| 840 | 2730 | 8567 | 7527 | 9940 |
| 1166 | 1815 | 6919 | 3520 | 9024 |

[1]Trout between 2" and 8".

[2]Trout over 8".

Table C-4. Available Weighted Usable Surface Area (WUSA) per 1000 Feet of the Poudre River for Rainbow and Brown Trout, Site D.

| Quantity of Flow (CFS) | Rainbow Life Stages Juveniles[1] | Rainbow Life Stages Adults[2] | Brown Life Stages Juveniles[1] | Brown Life Stages Adults[2] |
|---|---|---|---|---|
| | (WUSA in sq. ft.) | | (WUSA in sq. ft.) | |
| 40 | 11215 | 4243 | 14422 | 4729 |
| 189 | 8435 | 13010 | 14260 | 8345 |
| 309 | 5373 | 11728 | 13979 | 9036 |
| 406 | 6793 | 9216 | 13089 | 10730 |
| 840 | 6131 | 7916 | 13035 | 14072 |
| 1166 | 4789 | 9461 | 7434 | 13173 |

[1]Trout between 2" and 8".

[2]Trout over 8".

# APPENDIX D

This appendix presents alternative total willingness-to-pay model formulations. All models included the variables Flow; total activity days in the Poudre River Canyon, activity days in other river canyons, years of experience, and income. Each successive model added other independent taste and preference parameters.

Table D-1. Ordinary Least-Square Equation Estimates of Total Willingness to Pay Entrance Fee, Fishing Activity, 1978.[A]

| Variable | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|---|---|---|---|---|---|
| $\alpha$ | 15.40 (14.38) | -1.31 (1.23) | -.58 (.50) | 2.31 (1.57) | 2.14 (1.55) |
| Flow | 9.21 (16.02) | .21 (11.06) | .16 (9.38) | .14 (8.71) | .1295 (3.55) |
| $(Flow)^2$ | | -.36 E-3 (13.40) | -.37 E-3 (11.92) | -.14 E-3 (7.84) | -.138 E-3 (5.28) |
| $(Flow)^3$ | | - | - | - | - |
| TD | .17 (3.85) | -.64 (14.17) | -.51 (9.98) | 0.33 (8.42) | -.13 (5.97) |
| $(TD)^2$ | | .76 E-2 (11.84) | -.78 E-2 (12.29) | .48 E-2 (10.01) | .21 E-2 (3.21) |
| SUB | -.22 (4.10) | - | - | - | - |
| Year | - | .67 E-1 (3.16) | .49 E-1 (3.27) | .012 (2.98) | .043 (4.85) |
| IN | - | - | - | - | - |
| $(IN)^2$ | - | - | - | - | - |
| AGE | | - | .37 (2.12) | - | - |
| SEX | | | | - | - |
| ED | | - | - | .52 (6.32) | -.71 (4.91) |
| Site(i) | | | .52(2) (2.48) | .84(2) (3.01) | .36(2) (2.50) |
| OC(i) | | | | -1.42(7) (5.21) | -1.37(7) (4.40) |
| | | | | - | -1.28(5) (4.30) |
| | | | | -.68(9) (2.32) | -.52(8) (2.64) |
| EMP(i) | | | | - | .84(1) (4.76) |
| | | | | 1.52(5) (2.84) | 1.14(5) (2.73) |
| | | | | .32(4) (3.42) | .85(4) (4.08) |
| POP(i) | | | | | .56(4) (4.60) |
| $\bar{R}^2$ | .24 | .33 | .34 | .40 | .41 |
| F | 9.48 | 20.27 | 21.48 | 25.62 | 26.98 |

[A]Number in parentheses below each coefficient represents student t-ratios for the null hypothesis.

Table D-2. Ordinary Least-Square Equation Estimates of Total Willingness to Pay Sales Tax Game, Fishing Activity, 1978.[A]

| | Model | | | | |
|---|---|---|---|---|---|
| Variable | 1 | 2 | 3 | 4 | 5 |
| $\alpha$ | 22.08 | -4.82 | .94 | 2.63 | 3.11 |
| | (12.32) | (2.62) | (1.97) | (1.53) | (1.31) |
| Flow | -.89 | .21 | .20 | .18 | .1761 |
| | (12.01) | (9.48) | (6.48) | (3.92) | (4.65) |
| $(Flow)^2$ | | -.42 E-3 | -.23 E-3 | -.16 E-3 | -.1563 E-3 |
| | | (6.84) | (8.94) | (6.23) | (5.78) |
| $(Flow)^3$ | | - | - | - | - |
| TD | .24 | -.29 | -.33 | -.25 | -.18 |
| | (3.42) | (4.32) | (6.32) | (5.78) | (6.79) |
| $(TD)^2$ | | .35 E-2 | .42 E-2 | .37 E-2 | .28 E-2 |
| | | (4.92) | (4.32) | (4.62) | (3.60) |
| SUB | -.89 | - | - | - | - |
| | (3.12) | | | | |
| Year | .41 E-1 | .36 E-1 | .38 E-1 | .33 E-1 | .28 E-1 |
| | (3.98) | (3.42) | (2.62) | (2.72) | (2.15) |
| IN | - | .09 | .17 | .15 | .13 |
| | | (3.05) | (2.87) | (2.32) | (2.09) |
| $(IN)^2$ | | - | - | - | - |
| AGE | | .18 | - | - | - |
| | | (2.53) | | | |
| SEX | | - | - | - | - |
| ED | | - | - | - | - |
| Site(i) | | | -.83(2) | -.93(2) | -.67(2) |
| | | | (4.42) | (2.78) | (3.37) |
| OC(i) | | | | -.85(7) | -.97(7) |
| | | | | (3.35) | (2.35) |
| | | | | .91(3) | .48(3) |
| | | | | (3.31) | (2.56) |
| | | | | -.33(5) | -.35(5) |
| | | | | (3.42) | (3.19) |
| EMP(i) | | | | 1.32(6) | .88(6) |
| | | | | (4.06) | (4.53) |
| | | | | .06(1) | .35(1) |
| | | | | (2.79) | (3.19) |
| POP(i) | | | | | 1.65(2) |
| | | | | | (6.51) |
| | | | | | -.83(1) |
| | | | | | (5.14) |
| $\bar{R}^2$ | .22 | .31 | .34 | .42 | .43 |
| F | 10.43 | 18.42 | 20.12 | 27.32 | 29.01 |

[A]Numbers in parentheses below each coefficient represent student t-ratios for the null hypothesis.

Table D-3. Ordinary Least-Square Equation Estimates of Total Willingness to Pay Entrance Fee Game, Shoreline Activity, 1978.[A]

| Variable | Model 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| α | 10.32 | 4.64 | 7.62 | 2.23 | 1.40 |
| | (8.32) | (3.32) | (1.92) | (2.42) | (.34) |
| Flow | 1.42 E-1 | .43 E-1 | .23 E-1 | .16 E-1 | .1485 E-1 |
| | (2.79) | (2.83) | (2.47) | (2.21) | (2.29) |
| $(Flow)^2$ | | -.18 E-4 | -.16 E-4 | -.11 E-4 | -.1045 E-4 |
| | | (2.18) | (2.52) | (2.35) | (2.18) |
| $(Flow)^3$ | | - | - | - | - |
| TD | -.42 | .18 | .22 | .18 | .20 |
| | (7.82) | (6.42) | (5.47) | (6.01) | (5.30) |
| $(TD)^2$ | | -.14 E-1 | -.52 E-2 | -.67 E-2 | -.97 E-2 |
| | | (5.32) | (3.42) | (2.97) | (2.48) |
| SUB | -.49 E-1 | -.38 E-1 | .41 E-1 | - | - |
| | (4.32) | (2.42) | (3.04) | | |
| Year | -.28 | -.37 | .26 | .17 | -.10 |
| | (6.72) | (7.42) | (6.32) | (6.11) | (6.02) |
| IN | -.32 E-1 | -.92 E-1 | -.97 E-1 | -.72 E-1 | -.86 E-1 |
| | (2.62) | (2.46) | (3.42) | (4.36) | (6.00) |
| $(IN)^2$ | | - | - | - | - |
| AGE | | - | - | .70 E-1 | .66 E-1 |
| | | | | (7.32) | (6.13) |
| SEX | | .82 | 1.02 | - | .32 |
| | | (6.42) | (7.32) | | (3.47) |
| ED | | -.46 | -.53 | -.33 | -.28 |
| | | (4.32) | (6.42) | (7.71) | (6.34) |
| Site(i) | | | | - | - |
| OC(i) | | | | 1.05(4) | .76(4) |
| | | | | (5.78) | (5.34) |
| | | | | .92(7) | 1.91(7) |
| | | | | (4.32) | (6.94) |
| | | | | | 1.81(9) |
| | | | | | (6.32) |
| EMP(i) | | | | .32(1) | -.55(1) |
| | | | | (3.41) | (4.80) |
| | | | | 1.36(5) | .59(5) |
| | | | | (4.12) | (4.92) |
| | | | | | .20(6) |
| | | | | | (2.83) |
| POP(i) | | | | | 1.01(3) |
| | | | | | (3.88) |
| | | | | | .73(2) |
| | | | | | (5.26) |
| $\bar{R}^2$ | .11 | .36 | .37 | .50 | .52 |
| F | 8.82 | 12.42 | 13.04 | 20.01 | 24.68 |

[A]Numbers in parentheses below each coefficient represent the student t-ratios for the null hypothesis.

Table D-4. Ordinary Least-Square Equation Estimates of Total Willingness to Pay Sales Tax Game, Shoreline Activity, 1978.[A]

| Variable | Model 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| α | 7.38 | 2.02 | 2.52 | 2.00 | 1.25 |
| | (7.36) | (1.79) | (3.20) | (5.62) | (4.94) |
| Flow | .88 E-1 | .21 E-1 | .19 E-1 | .18 E-1 | .178 E-1 |
| | (2.38) | (3.36) | (2.42) | (3.32) | (2.61) |
| $(Flow)^2$ | | -.14 E-4 | -.15 E-4 | -.13 E-4 | -1.375 E-4 |
| | | (3.78) | (2.52) | (2.32) | (2.56) |
| $(Flow)^3$ | | - | - | - | - |
| TD | - | .13 | .17 | .19 | .24 |
| | | (6.06) | (7.04) | (6.43) | (5.06) |
| $(TD)^2$ | | -.43 E-2 | -.51 E-2 | -.62 E-2 | -.54 E-2 |
| | | (5.43) | (3.46) | (3.94) | (3.94) |
| SUB | -.16 | - | - | - | - |
| | (5.32) | | | | |
| Year | -.64 E-1 | -.67 | .24 | -.21 | -.19 |
| | (4.88) | (4.71) | (6.42) | (5.78) | (5.23) |
| IN | -.23 E-1 | .52 E-1 | -.77 E-1 | -.83 E-1 | -.75 E-1 |
| | (9.91) | (5.42) | (3.02) | (4.46) | (3.91) |
| $(IN)^2$ | | - | - | - | - |
| AGE | | - | - | - | - |
| SEX | | .14 | .28 | - | - |
| | | (7.25) | (6.92) | | |
| ED | | -.29 | -.43 | - | - |
| | | (5.43) | (4.52) | | |
| Site(i) | | | - | - | - |
| OC(i) | | | | 3.02(7) | 2.51(7) |
| | | | | (9.64) | (8.41) |
| | | | | 1.32(5) | 1.09(5) |
| | | | | (4.43) | (5.25) |
| EMO(i) | | | | -1.22(7) | -1.07(7) |
| | | | | (5.32) | (4.43) |
| | | | | .92(5) | -1.39(1) |
| | | | | (4.62) | (4.45) |
| | | | | | .44(5) |
| | | | | | (4.09) |
| | | | | | .33(6) |
| | | | | | (2.23) |
| POP(i) | | | | | .56(3) |
| | | | | | (2.63) |
| | | | | | .91(2) |
| | | | | | (6.00) |
| $\bar{R}^2$ | .19 | .35 | .36 | .47 | .50 |
| F | 23.36 | 38.37 | 38.52 | 52.06 | 54.21 |

[A]Number in parenthesis below each coefficient represents the student t-ratios for the null hypothesis.