MEASURING BENEFITS AND THE ECONOMIC VALUE OF WATER IN RECREATION ON HIGH COUNTRY RESERVATIONS

by

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Completion Report

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ABSTRACT

This report analyzed the public benefits from expanding recreation opportunities at high mountain reservoirs located in the Front Range of Colorado. Until recently, more than 100 reservoirs with 3,500 surface acres were closed to public use, representing 40 percent of the total surface area of reservoirs at 6,000 to 11,000 feet elevation. A representative sample of 200 persons were interviewed at 14 study sites. Respondents reported willingness to pay contingent on changes in congestion and water level. Benefit functions were adjusted for the effects of crowding, reservoir water drawdown, characteristics of participants, type of recreation facilities present, and costs of management. Policy implications were discussed with emphasis on application of the information to water management decisions.

Benefits from expanding recreation opportunities at high mountain reservoirs which until recently were closed, would accrue to all individuals who have access to high mountain reservoirs, because of the reduced congestion which would result at substitute sites. Providing access to one-third more undeveloped and semi-developed reservoirs would increase individual recreation benefits by an average of $3-$6 per user day. However, the same cannot be said for fully developed reservoirs, where expansion of recreation opportunities is not critical in the short run.

In an illustrative case study of a semi-developed high mountain reservoir, marginal benefit per acre foot was $1.80 per day with water drawdown ranging from 25 to 100 percent of maximum water level. On this basis, leaving more water in high mountain reservoirs for an additional 15 to 20 days during August would increase marginal benefits by approximately $30 per acre foot. This would equal the combined marginal benefits of drawdown for use in river recreation and irrigation reported in a previous study.

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SUMMARY

The purpose of this study was to develop and apply a procedure to measure the public benefits from expanding recreation opportunities at high mountain reservoirs located on the Front Range of Colorado. Economic benefit functions show the effects of crowding, reservoir water level, characteristics of participants, type of recreation facilities developed, and costs of management.

Agencies involved in reservoir management are interested in improved measures of the economic benefits of recreation development alternatives to compare with costs. The study will contribute to assessment of the economic feasibility of providing recreation opportunities at more than 100 high mountain reservoirs along the Front Range of Colorado which until recently were closed to public recreation use. With 3,500 surface acres, they represent a substantial potential recreation resource, 40 percent of the total surface area of reservoirs at 6,000 to 11,000 feet elevation on the Front Range of Colorado. Some level of recreation use may be compatible with water storage for irrigation, energy and industrial development, and domestic water supply.

A representative sample of 200 persons were interviewed at 14 high mountain reservoirs during the summer, 1978. Study sites were selected to represent three types of recreation opportunity at reservoirs with undeveloped, semi-developed, and fully developed recreation facilities. Willingness to pay questions were designed to measure consumer surplus which is the area under the demand curve above the cost of outdoor recreation. Trip cost was selected as a realistic payment vehicle. Payment of trip cost is familiar to all individuals who participate in outdoor recreation and has been applied successfully in other recreation benefit studies. Respondents reported willingness to pay contingent on changes in congestion and water level. The stepwise multiple

regression procedure was utilized to develop net benefit functions adjusted for congestion. Benefit functions shifted with reservoir water drawdown from 90 percent of bankful on the day of interview.

Individuals visiting semi-developed high mountain reservoirs who encountered no other persons within 150 feet reported average benefits of about $20 per day. With otherwise identical conditions, benefits declined to zero when 30 other persons were encountered per day. As long as the gains from additional visitors exceeded the loss due to congestion cost, total benefits increased. Beyond some point, congestion costs exceeded the gain experienced by additional visitors and total benefit diminished. For semi-developed reservoirs, this occurred in the neighborhood of 11 persons encountered per day, about one-third fewer than currently. For undeveloped reservoirs without vehicle access, optimum capacity was five persons encountered per day, one-third fewer than currently. For fully developed reservoirs, optimum capacity was 16 persons encountered per day, one-sixth more than currently, indicating excess capacity was present.

This report has shown that research procedures which measure the effects of congestion improve the resulting estimate of recreation benefits. Without adjusting for congestion, the average recreation benefit of semi-developed reservoirs would have been reported as $7 which would represent a $3 or 30 percent under-estimate of the $10 average benefit at optimum capacity. Benefits of undeveloped reservoirs which provide a unique wilderness experience also would have been under-estimated as $14 per day or $3-$6 less than the $17-$20 at optimum capacity. However, the benefits of fully developed reservoirs would have been over-estimated as $15 per day or $2-$3 more than the $12-$13 at optimum capacity.

These results have important implications for estimation of benefits from expanding recreation opportunities at high mountain reservoirs which until recently were closed. Benefits would accrue to all individuals who have access to high mountain reservoirs because of the reduced congestion which would result at substitute sites. Providing access to one-third more undeveloped and semi-developed reservoirs would increase individual recreation benefits by an average of \$3-\$6 per user day. However, the same cannot be said for fully developed reservoirs, where expansion of recreation opportunities is not critical in the short run. Once capacity is reached, the value of future expansion of recreation opportunities at fully developed as well as lesser developed reservoirs would be average benefits which range from \$10 to \$20 per user day.

Reservoir water drawdown would have a substantial effect on estimation of total benefits at optimum capacity. Regression analysis showed that with otherwise identical conditions, individual demand for recreation use would fall by 0.64 days for each 10 percentage point drawdown of water level in semi-developed reservoirs. Thus, water drawdown to 70 percent of reservoir capacity would reduce average recreation benefit to \$8 per user day and optimum encounters to 8 persons per day. Water drawdown to 35 percent of reservoir capacity would decrease benefit to \$4 per user day and optimum encounters to 4 persons per day.

Results were applied to water valuation problems when recreation use is complementary and when it is competitive with other uses. Once capacity of the high mountain reservoir system in a region has been reached, the appropriate measure of the value of recreation as a complementary part of a multiple purpose reservoir development project is the total benefit from the recreation opportunity provided. When recreation becomes competitive with other uses, the appropriate measure of value becomes the marginal benefit of the recreation opportunity provided. In an illustrative case study of a semi-developed high mountain reservoir, marginal benefit per acre foot was \$1.80 per day with water drawdown ranging from 25 to 100 percent of maximum water level. On this basis, leaving more water in high mountain reservoirs for an additional 15 to 20 days during August would increase marginal recreation benefits by approximately $30 per acre foot. This would equal the combined marginal benefits from usage for river recreation and irrigation reported in a previous study.

Benefits from high mountain reservoir recreation would vary to the extent that site specific conditions differ from those considered here. Nonetheless, the information should be of considerable value to water managers who are faced with serious problems in administering the use of basin resources. The contingent valuation approach was successful in meeting the objective of valuing the public benefits from expanding recreation opportunities at high mountain reservoirs. The findings represent a conservative estimate of possible total benefits of water in high mountain reservoirs. There may be long-run ecological benefits which are not included in recreation values.

MEASURING BENEFITS AND THE ECONOMIC VALUE OF WATER IN RECREATION ON HIGH COUNTRY RESERVOIRS*

Richard G. Walsh, Robert Aukerman, and Robert Milton**

INTRODUCTION

The purpose of this report is to analyze the public benefits from expanding recreation opportunities at high mountain reservoirs located on the Front Range of Colorado. Economic benefit functions are adjusted for the effects of several important variables, including: crowding, reservoir water drawdown, characteristics of participants, types of recreation facilities developed, and costs of management. Such information contributes to an assessment of the economic feasibility of providing recreation opportunities at more than 100 high mountain reservoirs along the Front Range of Colorado which until recently were <u>closed</u> to public recreation use. With 3,500 surface acres, they represent a substantial potential recreation resource, 40 percent of the total surface area of reservoirs at 6,000 to 11,000 feet elevation on the Front Range of Colorado. Some level of recreation use may be compatible with water storage for irrigation, energy and industrial development, and domestic water supply. The agencies involved in reservoir management are interested in improved measures of the economic benefits of alternative levels of recreation development in order to compare them with costs.

The primary contribution of this study to the economic literature on economic benefits is to apply a procedure for estimating the effects of congestion. Most studies of economic benefits of reservoir recreation in the past have dealt with uncongested sites or have assumed that no congestion effects exist. Recently, it has been shown that the resulting estimates of benefits may be biased if there is excess demand or congestion present [Fisher and Krutilla, 1972; Freeman, 1979]. Conceptually, congestion is an external cost perceived as a deterioration in the quality of the recreation experience. Thus, recreation benefits are expected to be a decreasing function of the number of persons encountered per day. Net benefits from recreation use of a reservoir are maximized when the gain to the marginal user equals the marginal loss his presence imposes on other users. Given relevant technological and institutional constraints, water resources are allocated efficiently when the net benefits resulting from all uses are maximized. A particular water resource policy is preferred on efficiency grounds when the excess of total benefit over total cost exceeds that which would result from alternative policies. Comparable measurement of the benefit and cost from alternative uses of water in high mountain reservoirs would be more nearly approached by estimation of recreation benefit at optimum capacity [Krutilla and Fisher, 1975].

The objectives of the study were:

(1) To evaluate public benefits from recreation activities at high mountain reservoirs in Colorado;

(2) To measure the relationships between recreation benefits and (a) site characteristics of high mountain reservoirs, (b) type of recreation activity, and (c) characteristics of recreationists;

(3) To assess how recreation benefits are altered by other conjunctive uses of high mountain reservoirs;

(4) To assess the potential benefits and costs of expanding recreation opportunities at high mountain reservoirs in Colorado.

This report presents the empirical results and conclusions of the project. The following section discusses the characteristics of the study areas and differences in the recreation opportunities provided. Section three discusses the theory of a congestion adjusted benefit function. Shifts in the benefit function would result from drawdown of water level associated with other conjunctive uses of water in high mountain reservoirs. Section four discusses the study design in which respondents reported willingness to pay contingent upon changes in congestion and water level. Section five presents the empirical results with respect to benefits and costs. Finally, policy implications are discussed, with emphasis on application of the information provided by the study to water management decisions.

The following publications and manuscripts were prepared as a result of this project:

Walsh, Richard G., Robert Aukerman, and Dean Rud, Economic Value of Benefits from Recreation at High Mountain Reservoirs, Technical Report No. 14, Colorado Water Resources Research Institute, Colorado State University, Fort Collins, January 1979.

Walsh, Richard G. and Robert Milton, "Congestion Adjusted Recreation Benefits from Water in High Mountain Reservoirs," Draft submitted for journal publication, 1980.

Walsh, Richard G., "Estimating the Recreation Value of Water in Reservoirs Compared to Instream Flow," Colorado Water Resources Research Institute Conference, Colorado State University, Fort Collins, April 9, 1980.

Milton, Robert, "The Benefits and Costs of Increasing Public Access to Mountain Reservoirs," Masters thesis, Department of Economics, Colorado State University, Fort Collins, April 1980.

Worley, Christopher G., "An Integrated Fisherman Typology: With Implications for Maintaining Environmental and Recreation Quality," Master of Science thesis, Colorado State University, Fort Collins, December 1980.

STUDY AREAS

The study sites are located at elevations of 6,000 to 11,000 feet in the Front Range of the Rocky Mountains, Colorado, an area with increasingly congested recreation resources. Figure 1 shows the location of the 14 sites which represent an 18.7 percent sample of the nearly 9,000 surface acres of high mountain reservoirs located in the Front Range of Colorado. Most of these reservoirs were constructed early in the past century, primarily by irrigation companies and municipalities to capture the spring snow melt and release water during the dry summer months.

As the quantity of water in a reservoir is drawn down, there is a loss of surface acreage and shrinkage of the shoreline perimeter of the surface. See Appendix Tables 6 to 11. Denuded and mud flats may be exposed with water drawdown. Yearly stocking may be necessary to maintain a fishery in reservoirs with no provision for a minimum pool. Drawdown must be carefully timed to maintain a wild trout population. After trout have spawned in shallow water with a gravel bottom, a drawdown would destroy eggs left in gravel above the water line. Other changes may occur with drawdown which also lower the quality of recreation experience. This tends to reduce the number of persons willing to use the reservoir for water-based recreation activities, and their willingness to pay for the experience. Thus, total recreation benefits are expected to decrease with the loss in volume of water available.

Opportunities for recreation use of high mountain reservoirs normally are provided from a combination of labor, capital, land and scenic resources as well as water [Young and Gray, 1972]. The related inputs may provide such facilities as: access roads and trails, parking areas, observation points,

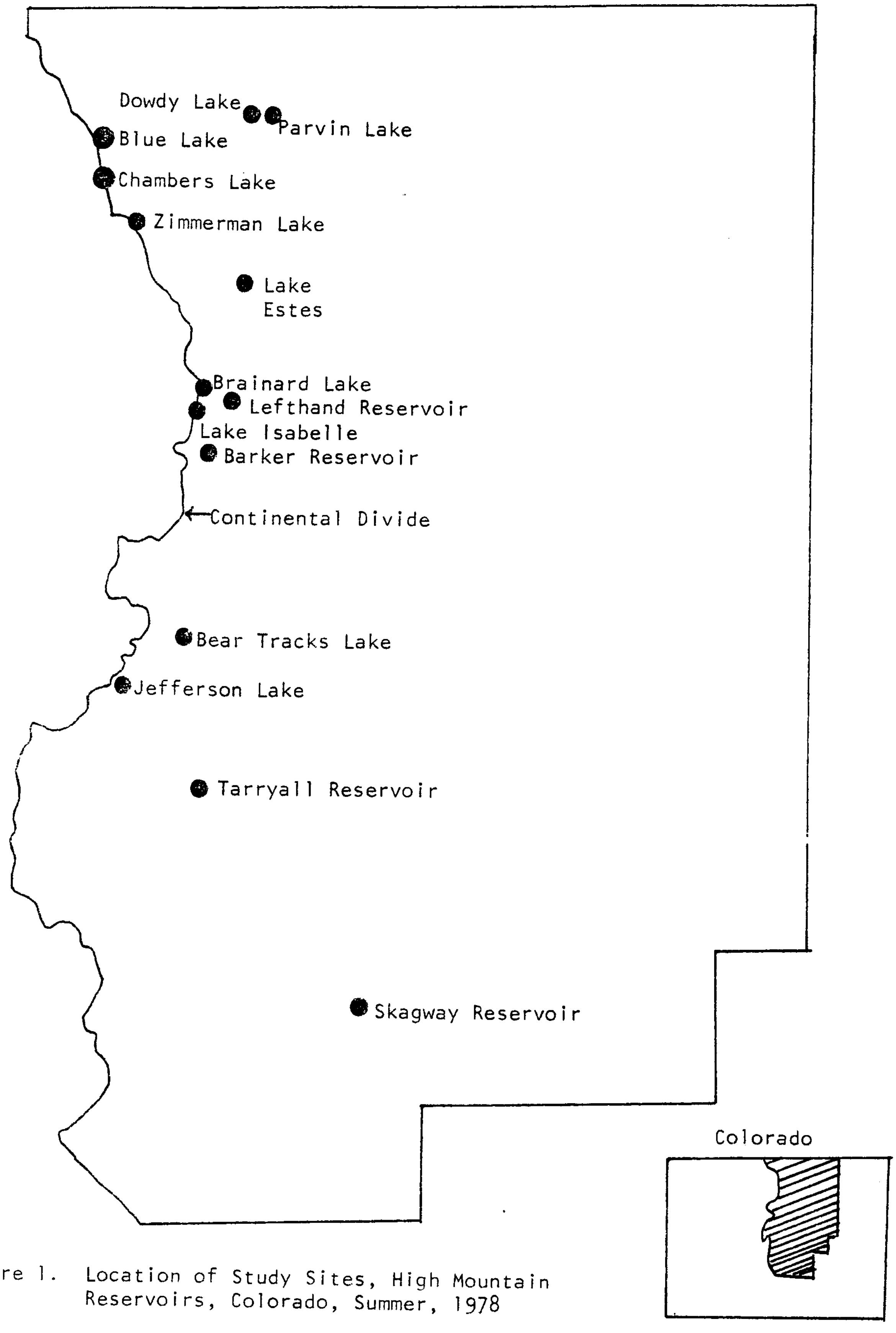


Figure 1. Location of Study Sites, High Mountain Reservoirs, Colorado, Summer, 1978

picnic and camp sites, water and sanitation equipment, landscaping, and occasionally, boat launching and docking facilities. Other expenses include operation, maintenance, cleanup, and public safety. The costs required to develop, operate, and maintain recreation facilities at a high mountain reservoir can be deducted from recreation benefits in order to obtain the recreation value of the natural resources of a site, the water, land, and scenic attributes. Costs of recreation use are especially important when investigating possible water reallocation to recreation.

The study sites were selected to obtain a representative sample of three distinct types of reservoir recreation opportunities [Aukerman, Springer, and Judge, 1977]: (1) Undeveloped -- five reservoirs had no recreation facilities and were accessible by foot and horse trail only. The reservoirs were small with 15 to 36 surface acres and storage capacity of about 150 to 600 acre feet. (2) Semi-developed -- three reservoirs had minimal recreation facilities such as pit toilets, trash cans, picnic tables, and flattened camping areas. They were accessible by unmaintained dirt roads which were unsuited for vehicles with camper trailers. The reservoirs were somewhat larger with 64 to 115 surface acres and storage capacity of 900 to 1,700 acre feet. (3) Developed -- six reservoirs had extensive recreation facilities development including those listed above plus drinking water and campgrounds suitable for camper trailers. Access was provided by paved or well maintained gravel roads. The reservoirs were larger with 115 to 380 surface acres and storage capacity of 3,000 to 13,000 acre feet [Walsh, Aukerman, and Rud, 1979].

High mountain reservoirs offer the majority of two million residents of Colorado's Front Range metropolitan areas an opportunity to engage in water-based recreation activities within 1 to 3 hours drive of their residence.

Severely cold surface water temperatures constrain water-based recreation to non-contact activities such as fishing and camping. The primary recreation activity during the summer of 1978 was fishing, which accounted for two-thirds of total time at semi-developed and developed reservoirs, but only one-third of total time at undeveloped walk-in reservoirs where backpacking and hiking were also important. Camping was the second most important activity at all reservoirs, accounting for nearly 20 percent of total time. Boating was less than 2 percent and swimming less than 1 percent of total time.

THEORETICAL APPROACH

Congestion of a reservoir recreation site occurs when individual users encounter increasing numbers of other users. This reduces individual satisfaction from the experience of engaging in reservoir recreation. Therefore, willingness to pay diminishes and the consumer surplus measure of individual benefit falls. The presence of congestion at a high mountain reservoir has implications for measurement of the effects of drawdown of reservoir water level on recreation benefits. In this section, a simple model is developed to analyze the effects of congestion on estimation of recreation benefits of reservoir use at optimum capacity. The model is then adapted to show how the drawdown of water level in a reservoir shifts the congestion adjusted total benefit function and the estimation of optimum capacity.

An empirical technique for determining the effect of crowding on benefits at a recreation site was developed by Fisher and Krutilla [1972] and applied to wilderness [Cicchetti and Smith, 1973 and 1976] and beach users [McConnell, 1977].[1/] The general procedure is firmly based in the economic theory of consumer demand. Congestion is viewed as one of a number of quality attributes of the recreation site, and enters an individual's utility function as a separate variable. Users are asked to report their maximum willingness to pay with varying numbers of persons encountered per day. Other important demographic information is recorded. A statistical benefit function is specified of the form:

Benefit = f(congestion, income, substitution, days, travel distance, tastes, etc.)

The effects of all other variables are controlled, and an average benefit function is derived in which congestion has a significant negative effect on individual benefit per day.

Figure 2 shows individual benefit per visitor day to be a declining function of number of persons encountered while engaged in recreation activity. The vertical intercept is the amount an individual would be willing to pay if he were the sole user of the reservoir, that is, if the reservoir were uncongested. The horizontal intercept shows the maximum number of users who will eventually choose to participate, if use rates are unrestricted, since an individual user will participate so long as his benefit per day is positive. However, each additional user imposes losses in benefit on all previous users. The gain in benefit enjoyed by additional individuals is represented by the columns. The loss to existing individual users is represented by the rows. Assume that individual benefit per day declines by $1 for each additional person encountered at a recreation site. To find the economic optimum, locate the point where the loss in benefit to existing users from added congestion just equals the benefit gained by the additional user. The gain in benefit enjoyed by the sixth user is $5 represented by the shaded column. At that point, the loss to five existing users is also $5 represented by the shaded row. Thus, the optimum number of encounters is six.[2/] It can be seen that four users would be too few because at that point the loss to existing users would be $3 compared to a gain by the additional user of $7 benefit. Likewise, it can be seen that seven users would be too many because at that point the loss to existing users of $6 would exceed the gain of $4 in benefit to the additional user.

The marginal user considers only his private cost of congestion, namely, the cost imposed upon him by existing users. By ignoring his imposition of congestion cost on existing users, there is created a divergence between pri-

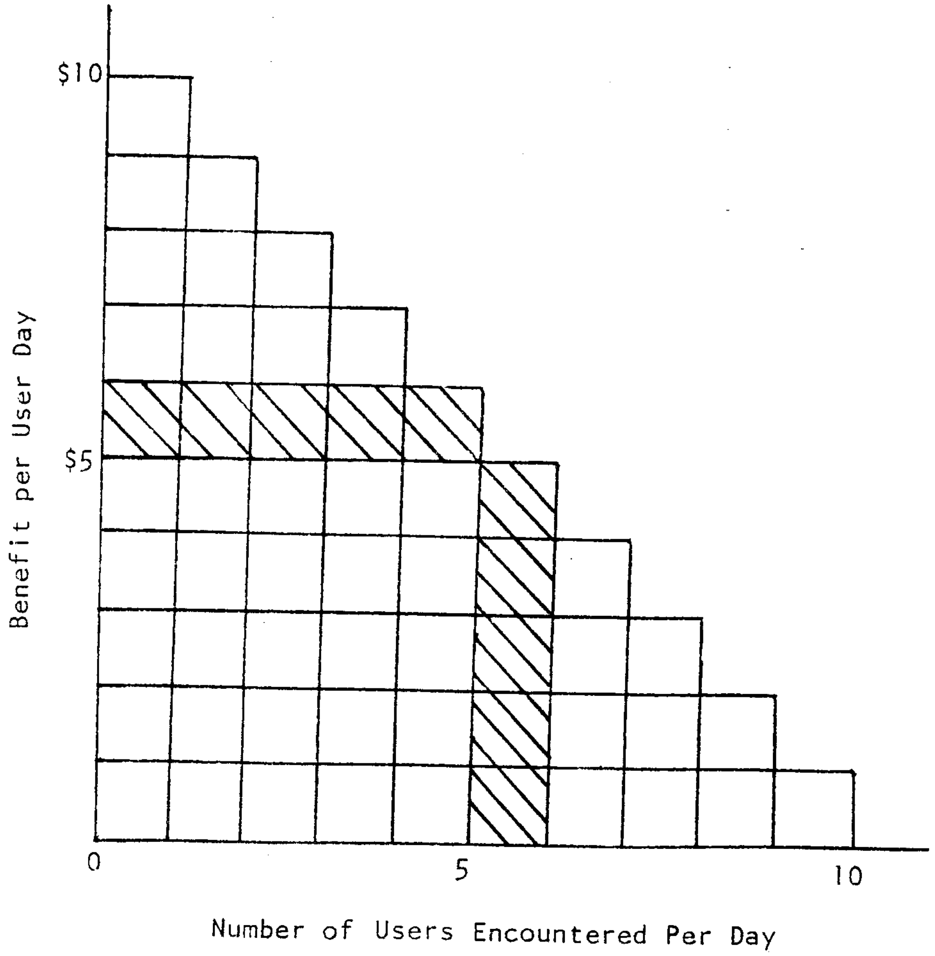


Figure 2. Effect of Crowding on Benefit per User Day and Optimum Capacity of a Recreation Resource.

vate and social costs of congestion. As is generally the case in the theory of externalities, this divergence between social and private costs results in over-use of the resource. The economic optimum level of resource use occurs where incremental benefit just equals incremental congestion cost.

That this is so can be easily shown by formal economic analysis. A total benefit function is derived, multiplying the number of users by individual benefits per user day at each level of congestion. Marginal benefit is simply the change in total benefit divided by the change in number of users. Total benefit functions are shown as the top portion of Figure 3 with marginal benefit as the lower portion. As long as the gain from admitting additional users exceeds the loss due to congestion costs, total benefit will increase. Beyond a point where congestion cost equals the gain experienced by the additional recreationist, total benefit diminishes with further admission. If there are no added costs of reservoir management or environmental degradation, optimum use occurs where total benefits are maximized and marginal benefits are zero.

Figure 3 shows a family of total benefit and marginal benefit curves depicting several threshold levels of water drawdown in high mountain reservoirs.[3/] The largest total and marginal benefit functions shown are expected when reservoir water level is bankful. Below it are a family of total and marginal benefit curves depicting the expected effect of reservoir water drawdown. These are based on a shift coefficient derived from a demand function which contains water level as an independent variable.[4/] Each drawdown of water level is expected to result in a lower carrying capacity and thus lower total benefit of recreation use.

When there are no costs other than those associated with congestion, opti-

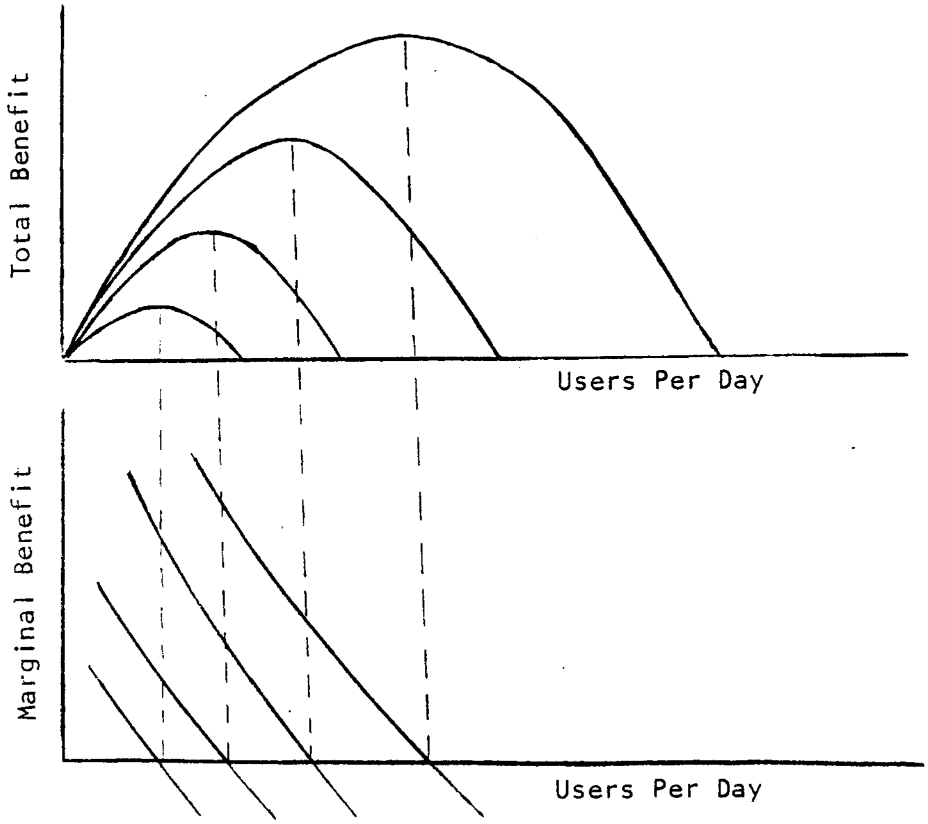


Figure 3. Effect of Reservoir Water Drawdown on Congestion Adjusted Total and Marginal Benefit Functions.

mum capacity will be at the point at which the total benefit is maximized and marginal benefit is zero for each level of water drawdown. With the introduction of added costs of reservoir management and environmental degradation, adjustments in optimum capacity will occur. Accordingly, it is desirable to distinguish these costs from the disutilities associated with congestion. We could do so in Figure 3 by introducing a separate marginal cost function (not shown) representing the change in these costs as intensity of use increases. If such costs should occur before the maximum total benefit is reached, marginal costs would intersect the marginal benefit schedule short of the congestion adjusted optimum level. Thus, added costs of reservoir management and environmental degradation would become a constraint, and a perpendicular dropped from the intersection of the marginal cost and marginal benefit functions to the horizontal axis would indicate a new optimum carrying capacity.

STUDY DESIGN

The basic economic data for this study were obtained from interviews with a representative sample of 200 recreation visitors at 14 high mountain reservoirs on the Front Range of Colorado during the summer of 1978. Following Knetsch and Davis [1966], the method of valuation was total direct trip costs. Respondents were asked to report the direct out-of-pocket costs of the trip. This was followed by a question which asked respondents to report the maximum amount they would be willing to pay rather than do without the recreation experience. Willingness to pay was defined as the maximum increase in total trip expenses[5/] above which the individual would decide not to participate, given the level of congestion and water drawdown on the day of interview. The direct costs actually paid were then subtracted from maximum willingness to pay so that the resulting value was a consumer surplus measure of benefit from high mountain reservoir recreation.

Subsequently, respondents were asked to report changes in the maximum amount they were willing to pay contingent upon changes in congestion and drawdown of water level. Individuals estimated the change in reported willingness to pay with congestion at five threshold levels: with no other person encountered, with 25 percent, 50 percent, 75 percent, and the maximum number of persons encountered above which they would discontinue the recreation activity. Individuals also estimated the change in reported willingness to participate at the site with a full reservoir and water drawdown to four threshold levels: 75 percent, 50 percent, 25 percent, and zero percent of maximum bankful. Maximum water level was obvious from clearly observed water lines resulting from maximum bankful conditions in the past.

The approach was first applied by Davis in a 1963 study of the consumer surplus benefit of recreation activities in the Maine woods. He asked recreationists how much additional cost they would pay before deciding to discontinue the activities at the study site. The procedure has been successfully applied to value recreation resources in the Maine woods [Knetsch and Davis, 1966], a water basin in British Columbia [Meyer, 1974], water quality in Colorado [Walsh, Greenley, Young, McKean, and Prato, 1978], fishing in Washington State [Mathews and Brown, 1970], the Western Flyway [Hammack and Brown, 1974], wildlife in the Southeastern region [Horvath, 1974], and air quality in New Mexico [Randall, Ives, and Eastman, 1974] and at the Glen Canyon National Recreation Area [Brookshire, Ives, and Schultze, 1976].

The U.S. Water Resources Council [1979] recently recommended this contingent valuation approach to water-based recreation benefit estimation. The Council recommended two types of contingent valuation procedures: the iterative bidding game, and the open-ended direct question. The preferred format for large water projects is an iterative bidding procedure in which respondents answer "yes" or "no" to questions asking if they are willing to pay a stated amount of money to obtain decreased congestion. The value is increased by random amounts until the highest amount that the respondent is willing to pay is identified. The Council recommended this technique on the basis that it has been applied effectively in several surveys [Knetsch and Davis, 1966; Randall, Ives, and Eastman, 1974; Brookshire, Ives, and Schultze, 1976; and Walsh, Greenley, Young, McKean, and Prato, 1978].

The second procedure is a noniterative technique in which the respondent is asked either to select his maximum willingness to pay from a list of stated values or to report his maximum willingness to pay. In this study, respondents were asked the open-ended direct question which the Council recommends for valuation of recreation on small water projects such as high mountain reservoirs: What is the maximum amount of money the respondent would pay to obtain decreased congestion levels? The Council suggests that at present, insufficient evidence has been accumulated through research to conclude that noniterative bidding questions are as reliable as iterative bidding questions. However, preliminary results of a number of studies suggest that the noniterative technique can provide results comparable to the iterative techniques [Mathews and Brown, 1970; Hammack and Brown, 1974; Walsh, Ericson, McKean, and Young, 1978].

Benefit functions are estimated for all members of a representative sample and extrapolated to the population using the reservoir site. The purpose of the approach is to estimate the changes in consumer surplus benefits which would result from changes in the quality of resources used at a recreation site. It is important to note that the resulting congestion adjusted benefit function is not a demand curve; it is a direct measure of the change in benefits represented by shifts in the demand curve resulting from increased congestion [Bradford, 1970].

The contingent valuation approach appears to be gaining broad acceptance. It is generally recognized that the method requires careful wording of questions and well-defined situations with which the respondent is familiar. In several of the studies cited above more than one approach was used. No one method has emerged superior in all cases, and there is need for further research to test the effectiveness of alternative willingness to pay formats.

ANALYSIS OF RESULTS

The benefit functions developed in the analysis are shown in Table 1. The proportion of the variation in benefit per day explained by the independent variables included in the three equations ranged from 0.31 to 0.53. All parameters were significantly different from zero at the 5 percent level. The estimated benefit function for semi-developed high mountain reservoirs is shown in Figure 4, where individual benefit per day is measured along the vertical axis with number of persons encountered measured along the horizontal axis.[6]

Ordinary least squares statistical methods were used to estimate the coefficients and the constant for the model. Then the model was simplified to show the relationship between the two variables of interest. All variables other than the dependent variable, number of persons encountered, were set at their means and added to the constant.[7] This may be illustrated by the following regression function which was obtained for semi-developed high mountain reservoirs:

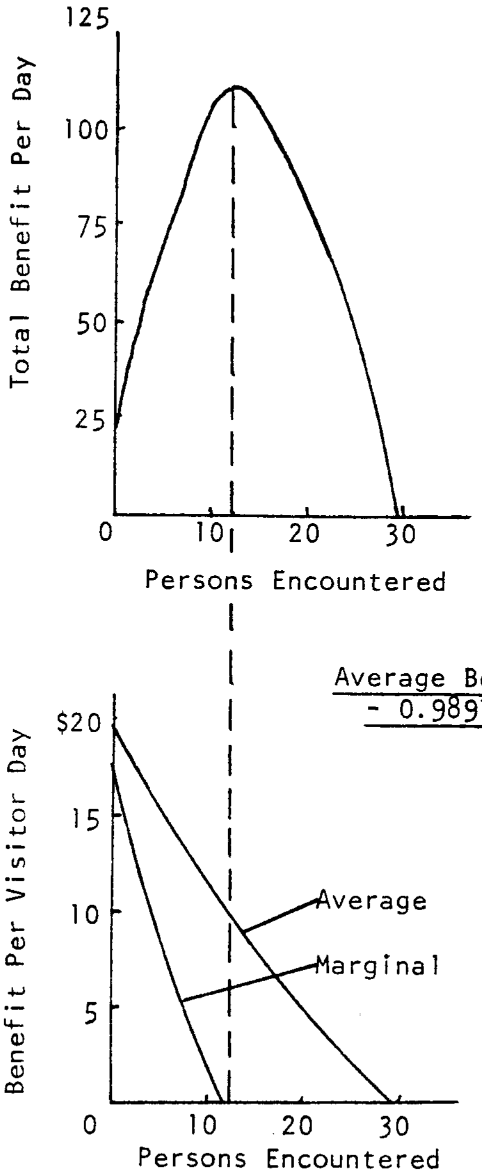
$$\text{Average benefit} = 19.56 - 0.9897\ \text{Persons} + 0.0106\ \text{Persons}^2$$

This indicates that an average visitor who encounters no other persons within 150 feet can be expected to have benefits of about $20 per day. With otherwise identical conditions, the benefits decline by approximately 80-90 cents per day for each additional person encountered while visiting a high mountain reservoir. Visitors who encounter an average of 16 other persons as reported on the day interviewed, would have average benefits of about $7 per day. Those who encounter 30 other persons per day would receive virtually no benefits and would be expected to discontinue recreation activity at these reservoirs.

Table 1. Ordinary Least Square Equation Estimates of the Effect of Crowding on Net Benefit Per Day of Recreation Activities at 14 High Mountain Reservoirs, Colorado, 1978.[a/]

Variable	High Mountain Reservoirs		
	Small, Undeveloped	Medium, Semi-developed	Large, Developed
Constant	-13.6729	9.3158	2.2800
Crowding, persons	-2.7155 (-3.19)	-0.9897 (-5.46)	-0.8642 (-7.92)
Crowding Squared	0.0379 (2.62)	0.0106 (3.96)	0.0656 (4.59)
Benefits Per Day of This Trip, Dollars	1.2054 (6.94)	0.6874 (10.27)	1.1618 (21.96)
Persons Encountered at Reservoir Today		0.3025 (2.37)	0.2020 (3.20)
Distance from Home, Miles			0.0089 (2.80)
Days at This Site on This Trip		-0.6814 (-2.08)	
Size of City, 4 Point Scale			1.6758 (2.24)
Sex of Respondent Male = 1	23.4314 (1.97)		
Adjusted R^2	.31	.42	.53
F	15.91	32.51	100.71
Observations	127	231	537

a. Number in parenthesis below each coefficient represents student t-ratios for the null hypothesis. All variables are significant at the 95 percent confidence level.



$$\underline{\text{Average Benefit} = 19.56 - 0.9897\ \text{Persons} + 0.0106\ \text{Persons}^2}$$

Figure 4. Total, Average, and Marginal Benefit Per Day of Fishing at Semi-Developed High Mountain Reservoirs, Colorado, 1978.

The total benefit function takes the same standard textbook form as the total revenue function based on price times quantity; in this case, it is average benefit times number of encounters plus one, the observer. As long as the gain from additional visitors exceeds the loss due to congestion cost, total benefit increases. Beyond some point, congestion cost exceeds the gain experienced by additional visitors and total benefit diminishes. For semi-developed reservoirs, this occurs in the neighborhood of 11.3 persons encountered per day. Total benefits are maximized where the cost of incremental congestion equals the benefit of incremental use, hence the marginal benefit function at that point is zero.

If there were no costs for reservoir recreation other than those associated with congestion, the optimum capacity would be at the point where total benefits are maximized and marginal benefits are zero. With the introduction of costs of recreation development and management to prevent degradation in water quality, optimum capacity would shift to the left. For developed high mountain reservoirs, these costs have been estimated by the Forest Service as approximately $2.50 per visitor day. If costs were as much as $2.50 for semi-developed reservoirs, optimum visitor capacity would decline from 11.3 to 10.6 encounters per day. This would be the point where marginal benefit equals marginal cost. At this level of congestion, average benefit from reservoir recreation would rise only slightly from $9.73 to $10.26.

APPLICATIONS

This paper has shown that research procedures which measure the effects of congestion improve the resulting estimation of recreation benefits from high mountain reservoirs. More meaningful comparison of the alternative uses of water in reservoirs is possible if the total benefits from each are estimated at optimum capacity. Table 2 shows that if congestion effects had been ignored, the average recreation benefits of semi-developed reservoirs would have been reported as \$7 per day and total benefits would have been underestimated. This was the average consumer surplus estimated on the basis of values reported by participants interviewed during the summer, 1978. This would represent a \$3 or 30 percent under-estimate of average benefits at optimum capacity calculated as approximately \$10 per day. While both of these estimates fall within an acceptable range, the \$10 value lends support to the U.S. Water Resources [1979] unit day standard ranging from \$3-\$13 benefit per day, with the higher end of the range assigned to the more unique experiences that undeveloped and semi-developed high mountain reservoirs provide.[8/]

Benefits from recreation at undeveloped high mountain reservoirs without vehicle access were affected more by congestion than those with fully developed recreation facilities. The former provided a unique wilderness experience and individual benefits were higher. At optimum capacity, average benefits of reservoirs with trail access were calculated as \$17-\$20 per day, which was \$3-\$6 per day higher than the \$14 reported by respondents during the summer, 1978, with congestion and excess demand evident. Benefits from recreation at high mountain reservoirs with fully developed recreation facilities such as campgrounds were calculated as \$12-\$13 per day at optimum

Table 2. Effects of Congestion and Agency Costs on Carrying Capacity and Individual Benefits Per Day from Recreation Activities at 14 High Mountain Reservoirs, Colorado, 1978.

Variable	High Mountain Reservoirs		
	Small, Undeveloped	Medium, Semi-developed	Large, Developed
Persons Encountered Per Day			
Reported by respondents	8.0	16.0	14.2
At optimum capacity with congestion costs	6.5	11.3	18.0
At optimum capacity with agency costs of $2.50[a]	5.4	10.6	16.2
Average Benefits Per Day			
Reported by respondents	$13.72	$ 6.99	$14.80
At optimum capacity with congestion costs	$17.01	$ 9.73	$12.32
At optimum capacity with agency costs of $2.50[a]	$19.50	$10.26	$13.47
Range of difference	$3.29-$5.78	$3.29-$3.82	$1.33-$2.48

a. Agency costs of $2.50 per user day was a reasonable average for several case studies in 1978 [Milton, 1980]. Marginal costs could be as low as $1.00 per user day, depending on level of development and rate of use. There is a need for further research on the cost of providing recreation opportunities.

capacity. This was \$2-\$3 lower than the \$15 reported by respondents during the summer, 1978, who reported less than optimum resource use.

This paper has demonstrated an empirical basis for estimating optimum capacity of recreation at high mountain reservoirs, as conceived by Fisher and Krutilla [1972] nearly a decade ago. For semi-developed reservoirs, the optimum number of encounters per day was calculated as 10.6 persons within 150 feet, about one-third fewer than currently.[9/] This is the level of use where marginal benefits would equal marginal costs estimated as \$2.50 per day for recreation development and management to prevent environmental degradation. For reservoirs with fully developed recreation facilities, the number of encounters at optimum capacity was calculated as 16.2 persons per day. This was about 14 percent more than currently.

The optimum capacity of undeveloped high mountain reservoirs without vehicle access was about one-half the capacity of semi-developed reservoirs and one-third the capacity of reservoirs with fully developed recreation facilities. The number of encounters at optimum capacity was calculated as 5.4 persons per day for undeveloped reservoirs. This was about one-third fewer than the average number of persons encountered by respondents during the summer, 1978. This suggests that visitors to high mountain reservoirs with trail access prefer a wilderness type of experience while there. Optimum number of encounters per day of 5.4 persons is about equal to the proposed standard for solitude in primitive areas and wilderness of 2-3 parties of one or more persons each [Stankey, 1973; USDA, 1980].

These results have important implications for estimation of benefits from expanding recreation opportunities at high mountain reservoirs which until recently were closed. Incremental benefits would accrue to recreation users of currently accessible reservoirs because of the reduced congestion which would result [Milton, 1980]. For a discussion of conditions under which these benefits would occur, see Freeman [1979] and Cesario [1980]. Providing non-vehicle access to one-third more undeveloped reservoirs would increase existing recreation benefits by \$3-\$6 per visitor day, because of reduced congestion at existing undeveloped reservoirs. Providing vehicle access to one-third more semi-developed reservoirs would increase existing recreation benefits by \$3-\$4 per visitor day because of reduced congestion at existing semi-developed reservoirs. However, the same cannot be said for fully developed reservoirs. These findings suggest that opportunities for recreation use should be increased by providing access to undeveloped and semi-developed high mountain reservoirs, while in the short run, expansion of opportunities for fully developed reservoir recreation is less critical. Once capacity is reached, however, future expansion of recreation opportunities at fully developed as well as lesser developed reservoirs would be valued at the higher levels shown in Table 2 as average benefits of \$10 to \$20 per user day of high mountain reservoir recreation.

These estimates of congestion adjusted benefits from recreation use of high mountain reservoirs assumed average water drawdown to 90 percent of maximum reservoir water level. This was the average drawdown estimated by respondents on the days interviewed during the summer, 1978. Actual drawdown during the recreation months of July, August, and September may greatly exceed this level. Figure 5 shows a family of total benefit and marginal benefit curves depicting several threshold levels of water drawdown. These shifts are based on regression results which showed that individual demand would fall by 0.64 days for each 10 percentage point drawdown of water level at semi-developed reservoirs

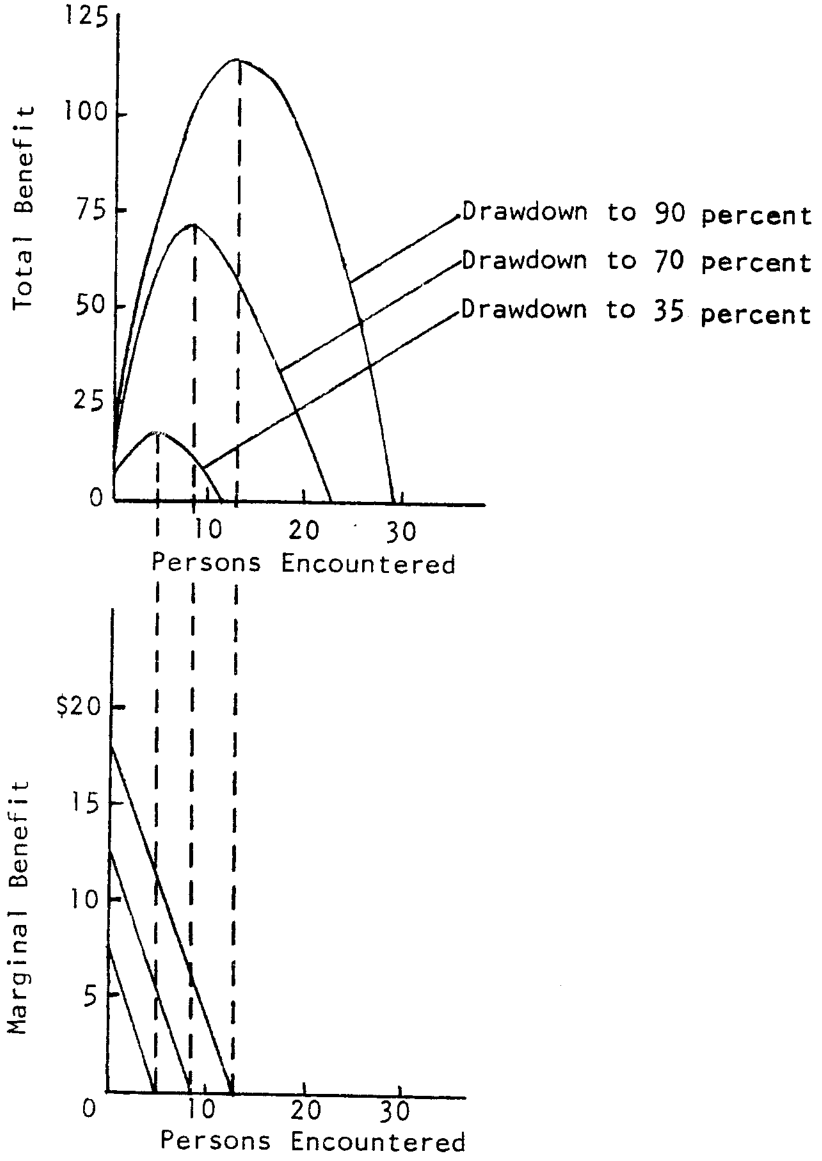


Figure 5. Water Drawdown Shifts Total and Marginal Recreation Benefits Per Day at Semi-Developed High Mountain Reservoirs, Colorado, 1978.

from a maximum of 6.4 days annual use with water level at maximum reservoir capacity. As can be seen, reservoir water drawdown has a substantial effect on total benefits at optimum capacity.

Table 3 shows the effect of drawdown in the water level on benefit maximizing use levels of a typical semi-developed reservoir. Table 4 shows the same information for a smaller undeveloped reservoir and Table 5 a larger fully developed reservoir. Simmons and Lord [1978] defined the relationship between instream flow and optimum recreation use as a "capacity constraint curve." This is shown for reservoirs as column four of the tables. The data indicate that reservoir capacity constraint curves are linear, decreasing at a constant rate over the entire range of drawdown in water level. However, capacity constraint curves would be curvilinear with respect to drawdown in acre feet of water storage volume. This is because water volume declines at an increasing and then decreasing rate with respect to drawdown of water level. Recreation capacity of a reservoir is primarily determined not by water volume but by the amount of usable shoreline and surface water area, which decline at about the same rate as water level. Actual use of a reservoir may be more or less than the optimum carrying capacity levels shown, however, non-optimum use would result in a loss of total benefits. Optimum total benefits associated with each threshold level of drawdown in water level are shown as column six of the tables. Marginal benefits per acre foot of water storage volume are shown as column seven of the tables.

These results can be applied to water valuation problems when recreation use is complementary and when it is competitive with other uses. Young and Gray [1972] reviewed the concept of the economic value of water and problems in its empirical measurement and concluded that recreation uses of water are

Table 3. Effect of Drawdown on Congestion Adjusted Recreation Benefits from Water in Semi-Developed High Mountain Reservoirs, Colorado, 1978.

Percent of Maximum Water Level[a]	Storage Volume, Acre Feet[b]	Optimum Encounters Per Day[c]	Optimum Users Per Day[d]	Optimum Net Benefits Per User Day	Total Net Benefits Per Day	Marginal Net Benefits Per Acre Foot Per Day[e]
0	0	0	0	0	0	
5	21.3	0.59	7.49	$0.57	$4.26	$0.20
10	42.6	1.18	14.98	1.14	17.07	0.60
15	63.9	1.76	22.35	1.71	38.21	0.99
20	85.2	2.35	29.84	2.28	68.03	1.40
25	106.5	2.94	37.33	2.85	106.39	1.80
30	132.7	3.53	44.83	3.42	153.31	1.80
35	163.5	4.11	52.19	3.99	208.23	1.80
40	199.2	4.70	59.69	4.56	272.18	1.80
45	239.5	5.29	67.18	5.13	344.63	1.80
50	284.6	5.88	74.67	5.70	425.61	1.80
55	334.5	6.46	82.04	6.27	514.39	1.80
60	389.2	7.05	89.53	6.84	612.38	1.80
65	448.5	7.64	97.02	7.41	718.91	1.80
70	512.7	8.23	104.52	7.98	834.06	1.80
75	581.4	8.81	111.88	8.55	956.57	1.80
80	655.2	9.40	119.38	9.12	1,088.74	1.80
85	733.5	9.99	126.87	9.69	1,229.37	1.80
90	816.7	10.58	134.36	10.26	1,378.53	1.80
95	904.5	11.16	141.73	10.83	1,534.95	1.80
100	1,000.0	11.75	149.23	11.40	1,701.22	1.80

a. Percent of maximum water level observable as the high water line, usually equal to design capacity.

b. Maximum volume, Dowdy Lake, Colorado. Drawdown of storage volume at five percent thresholds of water level was based on water engineering estimates from blueprints of bottom contours for eight high mountain reservoirs.

c. Within 150 feet of respondents.

d. Optimum number of encounters times a constant 12.3. See Note 2.

e. Rounded.

Table 4. Effect of Drawdown on Congestion Adjusted Recreation Benefits from Water in Undeveloped High Mountain Reservoirs, Colorado, 1978.

Percent of Maximum Water Level[a]	Storage Volume, Acre Feet[b]	Optimum Encounters Per Day[c]	Optimum Users Per Day[d]	Optimum Net Benefits Per User Day	Total Net Benefits Per Day	Marginal Net Benefits Per Acre Foot Per Day[e]
0	0	0	0	0	0	
5	12.7	0.30	3.42	$1.08	$3.69	$0.29
10	25.5	0.60	6.85	2.17	14.87	0.87
15	38.3	0.90	10.28	3.25	33.41	1.44
20	51.1	1.20	13.71	4.33	59.36	2.02
25	63.9	1.50	17.14	5.42	92.89	2.60
30	79.6	1.80	20.57	6.50	133.70	2.60
35	98.1	2.10	24.00	7.58	181.92	2.60
40	119.5	2.40	27.43	8.67	237.81	2.60
45	143.7	2.70	30.86	9.75	300.88	2.60
50	170.7	3.00	34.29	10.84	371.70	2.60
55	200.7	3.30	37.71	11.92	449.50	2.60
60	233.5	3.60	41.14	13.00	534.82	2.60
65	269.1	3.90	44.57	14.09	627.99	2.60
70	307.7	4.20	48.00	15.17	728.16	2.60
75	348.8	4.50	51.43	16.25	835.73	2.60
80	393.1	4.80	54.86	17.34	951.27	2.60
85	440.1	5.10	58.29	18.42	1,073.70	2.60
90	490.0	5.40	61.72	19.50	1,203.54	2.60
95	542.7	5.70	65.15	20.50	1,335.57	2.60
100	600.0	6.00	68.58	21.67	1,486.12	2.60

a. Percent of maximum water level observable as the high water line, usually equal to design capacity.

b. Maximum volume, Isabelle Lake, Colorado. Drawdown of storage volume at five percent thresholds of water level were based on water engineering estimates from blueprints of bottom contours for eight high mountain reservoirs.

c. Within 150 feet of respondents.

d. Optimum number of encounters times a constant 12.3, less 10 percent, an adjustment for the smallness of the reservoir. See Note 2.

e. Rounded.

Table 5. Effect of Drawdown on Congestion Adjusted Recreation Benefits from Water in Fully Developed High Mountain Reservoirs, Colorado, 1978.

Percent of Maximum Water Level[a]	Storage Volume, Acre Feet[b]	Optimum Encounters Per Day[c]	Optimum Users Per Day[d]	Optimum Net Benefits Per User Day	Total Net Benefits Per Day	Marginal Net Benefits Per Acre Foot Per Day[e]
0	0	0	0	0	0	
5	63.9	0.90	12.57	$0.75	$9.42	$0.13
10	127.8	1.80	25.14	1.50	37.71	0.40
15	191.7	2.70	37.71	2.25	84.84	0.67
20	255.6	3.60	50.29	2.99	150.36	0.93
25	319.5	4.50	62.86	3.74	235.09	1.20
30	398.1	5.40	75.43	4.49	338.68	1.20
35	490.5	6.30	88.01	5.24	461.17	1.20
40	597.6	7.20	100.58	5.99	602.47	1.20
45	718.5	8.10	113.15	6.74	762.63	1.20
50	853.8	9.00	125.73	7.49	941.71	1.20
55	1,003.5	9.90	138.30	8.23	1,138.20	1.20
60	1,167.6	10.80	150.87	8.98	1,354.81	1.20
65	1,345.5	11.70	163.44	9.73	1,590.27	1.20
70	1,538.1	12.60	176.02	10.48	1,844.68	1.20
75	1,744.2	13.50	188.59	11.23	2,117.86	1.20
80	1,965.6	14.40	201.16	11.98	2,409.89	1.20
85	2,200.5	15.30	213.74	12.72	2,718.77	1.20
90	2,450.1	16.20	226.31	13.47	3,048.39	1.20
95	2,713.5	17.10	238.88	14.22	3,396.87	1.20
100	3,000.0	18.00	251.46	14.97	3,764.35	1.20

a. Percent of maximum water level, observable as the high water line, usually equal to design capacity.

b. Maximum volume, Skagway Reservoir, Colorado. Drawdown of storage volume at five percent thresholds of water level was based on water engineering estimates from blueprints of bottom contours for eight high mountain reservoirs.

c. Within 150 feet of respondents.

d. Optimum number of encounters times a constant 12.3, plus 10 percent, an adjustment for the larger size of reservoir. See Note 2.

e. Rounded.

most often complementary to other uses. Water stored for irrigation, mining, industrial, or municipal purposes often can be used for recreation purposes without diminishing its value in alternative uses. Once capacity of the high mountain reservoir system in a region has been reached, the appropriate measure of the value of recreation as a complementary part of a multiple purpose water development project is the total benefit from the recreation opportunity provided. Thus, the annual benefits of providing optimal public access to a multiple purpose semi-developed reservoir with storage volume of 1,000 acre feet drawn down to 90 percent of capacity would be $10 per user day or $165,400 per year.[10/] This is equivalent to an annual yield of $203 per acre foot of water stored. Capitalized at 10 percent interest in perpetuity, this would represent an investment value of $1.65 million, which is equivalent to $2,000 per acre foot. If development plans provide that reservoir water level will be systematically drawn down to 35 percent of maximum water level during the summer months, recreation benefits would fall to $4 per user day or $25,000 per year. This is equivalent to an annual yield of $153 per acre foot of water stored. Capitalized at 10 percent interest in perpetuity, this would represent an investment value of $250,000 which is equivalent to $1,500 per acre foot. If development plans provide for non-vehicle access to a reservoir with storage volume of 600 acre feet, these benefit estimates would decrease by 3.1 percent. If plans provide for public access to a fully developed reservoir with storage volume of 3,000 acre feet, these benefit estimates would increase by 1.21 times.

When recreation becomes competitive with other uses, the appropriate measure of value becomes the marginal benefit of the recreation opportunity provided. Water managers maximize the social benefit from water resources when the marginal benefit from high mountain reservoir recreation equals the marginal benefit from crop irrigation and recreation use of instream flow. Marginal benefit per acre foot of water is the change in total benefit divided by change in acre feet of water storage. Marginal benefit of semi-developed high mountain reservoir recreation averaged about $1.80 per acre foot per day with drawdown in water level from 100 to 25 percent of maximum water level. This was equivalent to $216 per acre foot for the 120-day recreation season. With water drawdown to 20 percent of maximum water level, marginal benefit per acre foot fell to $1.40 per day. With water drawdown to 10 percent of maximum water level, marginal benefit per acre foot decreased to $0.60 per day. By comparison, Table 4 shows marginal benefit of recreation use of a smaller undeveloped high mountain reservoir averaged $2.60 per acre foot per day, with drawdown in water level from 100 to 25 percent of maximum. Table 5 shows marginal benefit of recreation use of a larger fully developed high mountain reservoir averaged $1.20 per acre foot per day with drawdown over the same range. Marginal benefit per acre foot would vary among high mountain reservoirs to the extent that site specific conditions differ from those considered here. Still, information on the marginal benefit of water for recreation use in high mountain reservoirs should be of considerable value to water managers who are faced with serious problems in administering the use of basin resources.

High mountain reservoirs were developed to capture water when it is abundant and release water when it is scarce. Drawdown of water in high mountain reservoirs for irrigation during late July and August is competitive with recreation use. Leaving more water in semi-developed high mountain reservoirs for an additional 16.7 days during August would increase marginal recreation benefits by approximately $30 per acre foot. This would equal the marginal benefits from combined usage for river recreation and irrigation. Daubert and Young [1979] reported the marginal return to crop irrigation in August of a normal year as $15 per acre foot and the marginal benefits to recreation of instream flow in August as an estimated $14.81 per acre foot. By comparison, the equivalent amount of high mountain storage would be 12.5 days for reservoirs without vehicle access and 25 days for reservoirs with fully developed recreation facilities.

One possible solution to the competitive uses of water in the Poudre River Basin involves changing the timing of irrigation water storage in high mountain and plains reservoirs. In the past, many irrigation companies began filling high mountain reservoirs in the fall and waited until the following spring to fill reservoirs on the plains [Aukerman, Springer, and Judge, 1977]. Total benefits could increase if high mountain reservoirs were drawn down to a minimum pool sufficient to sustain fish life in October after the high mountain recreation season. Water could be used to fill reservoirs on the plains and the augmented instream flow would increase river recreation benefits in the fall months. Recreation benefits would increase as the spring run-off fills high mountain storage capacity and reduces early summer (June and early July) instream flow to levels more suitable for trout fishing. Primarily utilizing reservoirs on the plains for irrigation during late July and August could limit the drawdown of high mountain reservoirs during a normal year until October, after the high mountain recreation season.[11/]

The results of this study have important implications for calculation of benefits from providing recreation access to high mountain reservoirs which have been closed to public use. Table 6 shows the benefits from recreation use of 54 high mountain reservoirs with public access calculated as about $10.3 million per year, compared to benefits estimated as $12.4 million from providing public access to an optimum 65 reservoirs on the Front Range of Colorado. These comparisons are based on dollar values reported in 1978, unadjusted for changes in the price level.

Recreation benefits would be nearly $2.2 million per year from providing public access to 11 more high mountain reservoirs. Under conditions of excess demand for recreation use of the 54 reservoirs with public access, the recommended benefit calculation is the incremental surplus which would accrue to recreation users of currently accessible reservoirs because of the reduced congestion which would result with substitution [Cesario, 1980]. This would include providing non-vehicle access to eight more undeveloped reservoirs increasing recreation benefits by $1.4 million per year, as congestion is reduced to optimum levels at existing and newly opened undeveloped reservoirs. Also, providing vehicle access to five more semi-developed reservoirs would increase recreation benefits by nearly $1.2 million per year, as congestion is reduced to optimum levels at existing and newly opened semi-developed reservoirs. However, the same cannot be said for fully developed reservoirs where increasing use to optimum levels would result in shifting two reservoirs with excess recreation facilities to semi-developed status. As a result, optimum total benefits of fully developed reservoirs would be $0.4 million per year less than benefits in 1978. If this calculation of benefits had assumed no congestion associated with reservoir recreation use, the benefit of opening

Table 6. Benefits from Recreation Use of 54 High Mountain Reservoirs with Public Access Compared to Benefits from Providing Access to an Optimum 65 Reservoirs, Front Range, Colorado, 1978.

Variables	High Mountain Reservoirs			
	Undeveloped, Non-Vehicle Access	Semi-Developed, Vehicle Access	Fully Developed, Vehicle Access	Total or Average
Existing reservoirs with public access[a]	25	16	13	54
Benefits per day[b]	$13.72	$6.99	$14.80	$11.49
Users per year[c]	245,258	345,036	303,617	893,911
Benefits per year	$3,364,940	$2,411,802	$4,493,532	$10,270,274
Optimum number of reservoirs with public access	33	21	11	65
Benefits per day	$19.50	$10.26	$13.47	$13.89
Users per year	245,258	345,036	303,617	893,911
Benefits per year	$4,782,531	$3,540,069	$4,089,721	$12,412,321
Change in number of reservoirs with public access	8	5	-2	11
Benefits per day	$5.78	$3.27	-$1.33	$2.43
Users per year	245,258	345,036	303,617	893,911
Benefits per year	$1,417,591	$1,157,698	-$403,811	$2,171,478

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a. From a survey which included 124 of 167 identified high mountain reservoirs with 10-400 surface acres [Aukerman, Springer, and Judge, 1977]. The survey identified 54 reservoirs with public access, containing surface area of 5,348 acres and storage capacity of 199,108 acre feet. A total of 70 reservoirs studied were closed to the public, with surface area of 3,487 acres and storage capacity of 84,207 acre feet. At least 43 additional reservoirs without public access were not studied.

b. Benefits in 1978 dollars, unadjusted for inflation.

c. Based on 25 undeveloped reservoirs with public access times 61.7 optimum users at 90 percent of maximum water level times a factor of 1.325 for congestion in 1978 times the 120-day recreation season. For semi-developed reservoirs, 16 x 134.36 x 1.3375 x 120. For fully developed reservoirs, 13 x 226.31 x 0.86 x 120.

11 reservoirs would have been the entire area under the demand curve above direct cost, or $1.5 million per year, which represents an under-estimate of $0.6 million or 29 percent.[12/]

Once optimum capacity is reached future expansion of recreation opportunities at fully developed as well as lesser developed reservoirs would be valued at higher levels. Under conditions of optimum recreation use of the 65 reservoirs with public access, the recommended benefit calculation would be the entire area under the demand curve above direct cost or an average of $13.89 per user day [Knetsch, 1977; Cesario, 1980]. For example, with a 5 percent annual growth in demand for recreation use of high mountain reservoirs it would be efficient to provide public access to an additional 3-4 reservoirs each year during the next 10 years. This would provide average annual benefits of $190,000 per reservoir, specifically, $145,000 per undeveloped reservoir with non-vehicle access, $168,000 per semi-developed reservoir with vehicle access, and $272,000 per fully developed reservoir. Social gains from providing public access to high mountain reservoirs would be net of capital costs for new construction and operating costs. A particular level of development would be preferred on efficiency grounds when the excess of total benefit over total cost exceeded that which would result from alternative levels of development.

CONCLUSIONS

The contingent valuation approach was successful in meeting the objective of valuing the public benefits from expanding recreation opportunities at high mountain reservoirs. Contingent valuation techniques have been successfully applied to the valuation of air and water quality in the past. The technique appears to be appropriate for valuation of a wide variety of non-market goods including the effects of congestion and reservoir water drawdown. It should be remembered, however, that contingent valuation measures the responses of individuals faced with hypothetical situations. Thus, considerable care must be exercised in the design of questions and the conduct of surveys, to insure the results obtained are as realistic as possible.

In addition to the recreation benefits of water in high mountain reservoirs, there may be long-run ecological benefits that are not included in recreation values. It is impossible now for biologists to predict what these might be, let alone put a dollar value on them and incorporate them into a benefit estimate. For this reason, it seems that present benefit figures represent a conservate estimate of possible total benefits of water in high mountain reservoirs. The inability of economic analysis to place a dollar value on ecological effects should be recognized in making decisions about drawdown of water stored in high mountain reservoirs.

FOOTNOTES

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1. An extension of this technique was presented by Freeman and Haveman [1977] and by Freeman [1979]. In its simplest form, an <u>uncongested</u> demand curve for a recreation site is specified and below it a family of <u>constant</u> congested demand curves. The area between the demand curves represents the loss in consumer utility measured in dollars resulting from increased congestion. From this, a congestion cost function was developed as the difference between the maximum willingness to pay when there are no other users present and when there are an increasing number. Each point on the congestion cost curve represents the most an individual would be willing to pay in order to have congestion reduced to zero. The marginal congestion cost curve equals the congestion cost the marginal user imposes on existing users, plus the congestion cost the existing users impose on the

marginal user. Optimum is defined as the point where this marginal congestion cost curve equals the uncongested willingness to pay curve. This formulation yields a solution similar to the procedure applied in this report.

2. Individuals experience congestion as number of encounters. For management purposes, encounters must be converted to persons present. Insufficient resources were available to do a simulation analysis of the relationship between number of encounters and persons present in the study areas. Shichter and Lucas [1978] reported the results of a simulation analysis of the Desolation Wilderness Area in California, with numerous high mountain reservoirs and lakes. They reported that the relationship was site specific and linear within the relevant range. Information available on the daily recreation use of high mountain reservoirs in Colorado shows that the average number of visitor days is approximately 12.7 times number of encounters within 150 feet of an individual user. It is a simple step to multiply number of encounters per day times this constant to estimate total reservoir users per day.

3. Simmons and Lord [1978] developed a model which shifts the congestion adjusted total and marginal benefit function with changes in instream water flow. With reservoir water drawdown, fewer fishermen can be present without interfering with others because there is less area suitable for fishing.

4. An alternative procedure would be to include the independent variable, willingness to participate, as a shifter in the initial function from which congestion adjusted total and marginal benefit curves were derived. This more efficient approach would yield similar results.

5. Increased trip expense was chosen as a payment vehicle over the alternative entrance fee to avoid protest bids. Respondents experienced zero admission fees to high mountain reservoirs, however, some purchased fishing licenses and camping permits at developed campsites. Trip expenses were familiar to all respondents and were dissociated from resource management and ownership, whose fees may produce adverse reactions.

6. In this analysis, it is assumed that tastes for congestion avoidance are homogeneous. For a discussion of the ramifications of heterogeneous tastes, see Freeman and Haveman [1977].

7. Other variables which shift the congestion adjusted benefit function included: the consumer surplus and level of congestion experienced by respondents, distance traveled, length of stay, size of residential community, and sex. For example, with each additional day per trip, the congestion adjusted benefit function declined by $0.68. The empirical results of this study suggest that income was not associated with willingness to pay to avoid congestion. Thus, non-price rationing of recreation use of high mountain reservoirs may be efficient. For a discussion of the effects of income distribution on equitable pricing to ration use races, see Cory [1979-80].

8. These results suggest that the U.S. Forest Service 1980 Resources Planning Act (RPA) unit day standard of $6.25 benefit from coldwater trout fishing may be an under-estimate. This value was assigned to a 12-hour visitor day. For 6-hour reservoir fishing days, the derived value would be $3.13 which seems low for high mountain reservoirs in Colorado, even with congestion.

9. Reservoir capacity tends to be site specific and varies with conditions such as steepness of bank, amount of marsh, restricted fishing areas, and quality of fishing which may result in periodic changes in the location of fishermen along the shore. See Grubb and Goodwin [1968], Pankey and Johnston [1969], Kalter [1971], and Knetsch [1974]. The 1971 Colorado state capacity standard for reservoir fishing was 100 linear feet of shoreline per fisherman and a turnover of 2 persons per day [Colorado, 1974]. For typical high mountain reservoirs with shoreline of 6,000 to 25,000 feet, this would equal about 60 to 250 fishermen per day. This is reasonably close to our findings with respect to optimum economic capacity with encounters converted to 134 users of semi-developed, 62 users of undeveloped, and 226 users of fully developed reservoirs. See Note 2.

10. With a 120-day reservoir recreation season from May 15 to September 15 at elevations of 6,000 to 11,000 feet. The results of this study have important implications for projection of benefits over a planning period representing the life of a multi-purpose reservoir development project. With a normal growth in number of users from a low base, application of a constant value per visitor day would understate congestion adjusted total benefit during the early years and overstate it during later years of the planning period.

11. The relative drawdown of high mountain and plains reservoirs during late July and August would depend, in part, on the relative recreation benefits of water in each. There is a need to study the recreation and aesthetic benefits of water in reservoirs on the plains, which are unknown. In addition, all seepage and evaporation losses must be accounted for.

12. If the calculation of benefits had assumed no congestion associated with reservoir recreation use, the accepted procedure would have been to estimate the entire area under the demand curve for newly opened sites [Knetsch, 1977]. This would represent the maximum amount users would be willing to pay for use of the new sites, given the other sites are in existence. However, the effect of ignoring congestion effects would be to calculate the benefit of opening 11 undeveloped and semi-developed reservoirs on the Front Range of Colorado as $1.5 million per year, an under-estimate of $0.6 million or 29 percent. No fully developed reservoir facilities would be considered in excess supply.

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Appendix Table 7. Effects of Water Drawdown on Storage Capacity, Surface Area, and Length of Shoreline, Skagway Reservoir, Colorado, 1978.

Water Level		Storage Capacity, Volume		Surface Area		Length of Shoreline	
Gage Height, Feet	Percentage of Maximum	Acre Feet	Percentage of Maximum	Acres	Percent of Maximum	Linear Feet	Percent of Maximum
60[a]	100	3,078	100	115	100	9,400	100
45	75	1,640	54	79	69	6,800	72
30	50	713	23	46	40	4,900	52
15	25	202	7	22	19	2,800	30

a. Maximum design capacity

Appendix Table 8. Effects of Water Drawdown on Storage Capacity, Surface Area, and Length of Shoreline, Estes Reservoir, Colorado, 1978.

Water Level		Storage Capacity, Volume		Surface Area		Length of Shoreline	
Gage Height, Feet[a]	Percentage of Maximum	Acre Feet	Percentage of Maximum	Acres	Percent of Maximum	Linear Feet	Percent of Maximum
50.0	100	3,068	100.0	185.0	100.0	21,504	100.0
37.5	75	920	30.0	99.0	53.5	12,691	59.0
25.0	50	215	7.0	27.0	14.6	9,248	43.0
12.5	25	76	2.5	13.5	7.3	2,336	11.0

a. Maximum observed water level elevation.

Appendix Table 9. Effects of Water Drawdown on Storage Capacity, Surface Area, and Length of Shoreline, Chambers Reservoir, Colorado, 1978.

Water Level		Storage Capacity, Volume		Surface Area		Length of Shoreline	
Gage Height, Feet[a]	Percentage of Maximum	Acre Feet	Percentage of Maximum	Acres	Percent of Maximum	Linear Feet	Percent of Maximum
53.0	100	10,247	100	298	100	16,400	100
40.0	75	6,394	62	260	87	15,200	93
26.5	50	3,556	35	208	70	11,200	68
13.3	25	1,170	11	109	37	8,600	52

a. Maximum design capacity.

Appendix Table 10. Effects of Water Drawdown on Storage Capacity, Surface Area, and Length of Shoreline, Isabelle Reservoir, Colorado, 1978.

Water Level		Storage Capacity, Volume		Surface Area		Length of Shoreline	
Gage Height, Feet[a]	Percentage of Maximum	Acre Feet	Percentage of Maximum	Acres	Percent of Maximum	Linear Feet	Percent of Maximum
28	100	594	100	34	100	7,008	100
21	75	385	65	25	74	5,392	77
14	50	225	38	21	62	4,780	68
7	25	89	15	17	50	4,377	62

a. Designed capacity equals observed capacity.

Appendix Table 11. Effects of Water Drawdown on Storage Capacity, Surface Area, and Length of Shoreline, Tarryall Reservoir, Colorado, 1978.

Water Level		Storage Capacity, Volume		Surface Area		Length of Shoreline	
Gage Height, Feet[a]	Percentage of Maximum	Acre Feet	Percentage of Maximum	Acres	Percent of Maximum	Linear Feet	Percent of Maximum
64	100	13,135	100.0	506	100	26,012	100
48	75	6,818	52.0	312	62	15,960	61
32	50	2,638	20.0	198	39	11,440	44
16	25	469	3.6	75	15	4,068	16

a. Designed capacity equals observed capacity.

Appendix Table 12. Effects of Water Drawdown on Storage Capacity, Surface Area, and Length of Shoreline, Jefferson Reservoir, Colorado, 1978.

Water Level		Storage Capacity, Volume		Surface Area		Length of Shoreline	
Gage Height, Feet[a]	Percentage of Maximum	Acre Feet	Percentage of Maximum	Acres	Percent of Maximum	Linear Feet	Percent of Maximum
58.6	100	6,163	100	140	100	8,844	100
44.0	75	4,230	69	124	89	7,800	88
29.3	50	2,523	41	109	78	6,885	78
14.7	25	1,187	19	84	60	5,624	64

a. Designed capacity equals observed capacity.

DISTANCE TRAVELED, DIRECT COST AND CONSUMER SURPLUS

Appendix Table 13 shows miles traveled, direct cost per trip and per day at the recreation sites, with consumer surplus per day of participation. Consumer benefit cost ratios were calculated with average total willingness to pay as the numerator and direct trip costs as the denominator. Users of undeveloped reservoirs valued the recreation experience relatively more than users of semi-developed and fully developed reservoirs. The consumer benefit cost ratio for undeveloped reservoirs averaged 2.3 compared to 1.7 for semi-developed reservoirs and 1.8 for fully developed reservoirs. Recreation users of undeveloped reservoirs traveled more miles. They traveled an average of 254 miles one-way from their residence to the reservoir sites. Users of semi-developed reservoirs traveled 146 miles and users of fully developed reservoirs 136 miles. Thus, trip cost was higher for undeveloped reservoirs. However, users of undeveloped reservoirs remained more days at the reservoir per trip. As a result, their direct costs per day were not as high as for users of fully developed reservoirs and only slightly higher than for semi-developed reservoirs.

Appendix Table 13. Miles Traveled, Direct Cost Per Trip and Per Day at Site, with Consumer Surplus Per Day of Participation in Recreation at High Mountain Reservoirs, Colorado, 1978.

Recreation Site	Average One-Way Miles Traveled on This Trip	Average Direct Out-of-Pocket Cost for This Trip		Average Consumer Surplus Above Trip Cost Per Day[a]	Average Total Willing-ness to Pay Per Day	Consumer Benefit/ Cost Ratio
		Total Cost of Trip	Cost Per Day			
High Mountain Reservoirs						
Small, Undeveloped	254	$56.35	$14.85	$19.50	$34.35	2.3
Medium, Semi-Developed	146	28.98	14.05	10.26	24.31	1.7
Large, Fully Developed	136	43.98	17.14	13.47	30.61	1.8
Average	163	38.69	15.16	14.41	29.57	2.0

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a. With number of users at optimum capacity and water level at 90 percent of maximum and agency costs of $2.50 per user day.