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# An Economic Evaluation of Benefits and Costs of Maintaining Instream Flows

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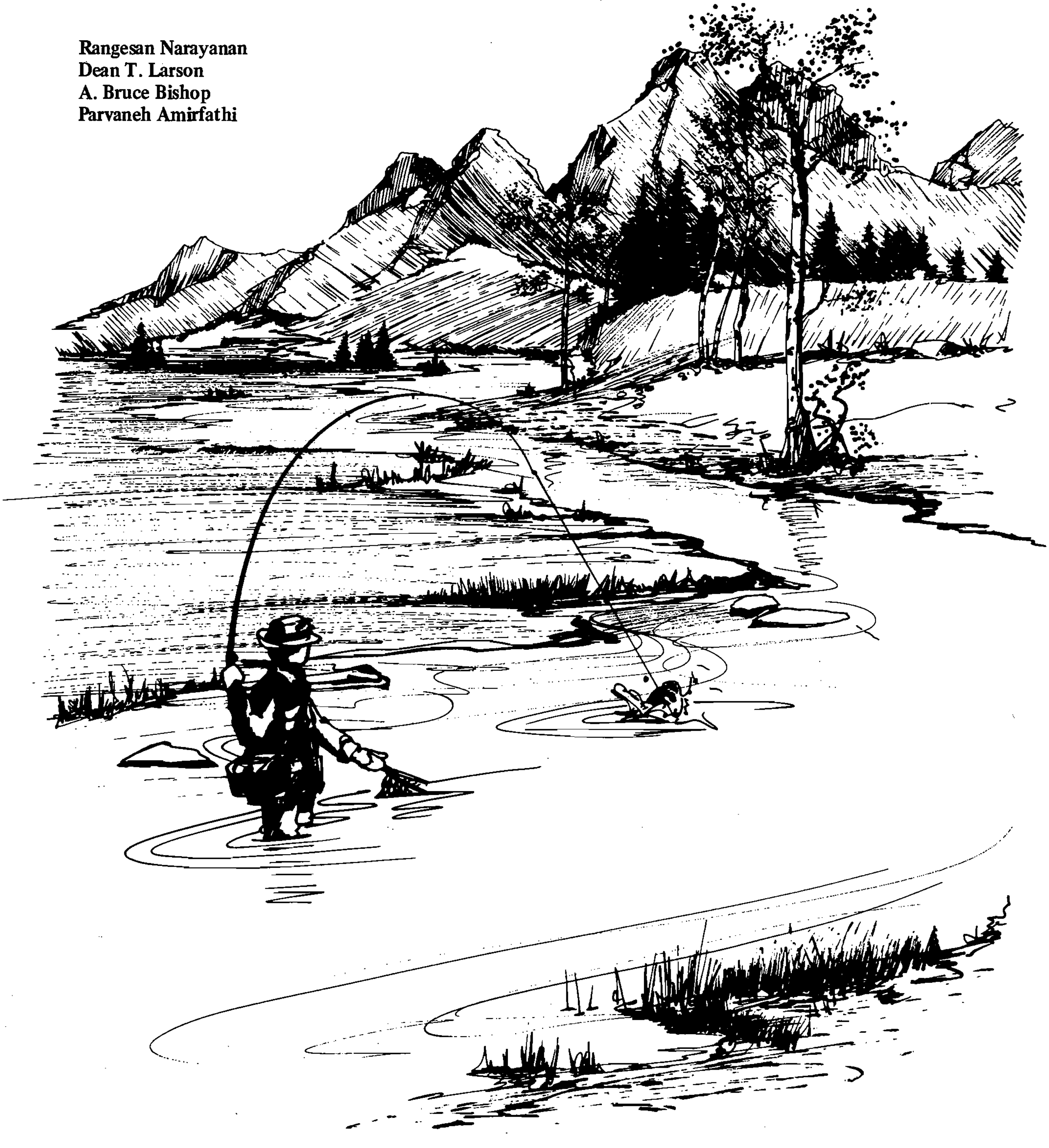

Utah Water Research Laboratory
Utah State University
Logan, Utah 84322

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# AN ECONOMIC EVALUATION OF BENEFITS AND COSTS OF MAINTAINING INSTREAM FLOWS

by

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and
Parvaneh Amirfathi

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# ABSTRACT

Instream flows enhance recreation, hydropower, fish and wildlife maintenance, and riverine ecosystems. Each use has water requirements that vary over time in unique patterns. The determination of the overall instream requirement at any given time must be considered in competition with the demand for municipal and agricultural uses. Two obstacles to integrating instream uses into the appropriation system of water law are difficulty in satisfying the legal requirements of an appropriation for a public use and the fact that instream flow uses are considered more "environmental" than "economic" in character. The extreme options for allocating flow between these user groups are to give them the most junior rights under appropriative water law and provide instream flows to a desired average, and to give instream flows top priority. Neither extreme is reasonable; the first sometimes allocates no water at all for instream flow in dry years and the second inflicts unnecessarily large burden in terms of benefits foregone on agriculture. A compromise is to reserve some instream flow with senior rights. A stochastic linear programming model was used to estimate the expected benefits foregone to agriculture users. The models provided a framework for maximizing benefits and were applied to various flow levels. A case study application to the Blacksmith Fork of the Little Bear River was based on the instream values being predominantly recreational with benefit estimates based on user surveys and travel costs. Agricultural losses increased as more senior rights were taken, but the method for providing instream flows made less difference for large targeted flows. The results provide a basis for optimizing instream flow levels, but further methodological development is needed.

# ACKNOWLEDGMENTS

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# CHAPTER I

# INTRODUCTION

## The Instream Flow Controversy

Many beneficial uses of streams and adjacent riverine lands are enhanced by instream flows. Examples include recreation, hydropower, navigation, waste transport and assimilation, fish and wildlife maintenance and preservation of riverine ecosystems. The amount of flow that is "necessary" to provide an instream value is referred to as an instream flow requirement. Requirements vary among uses and over time for a given use, but the same flow can normally satisfy all the requirements. Consequently the largest requirement is used to determine the flow at any particular time.

These instream uses, however, conflict with uses requiring diversion to offstream locations for domestic use, production of food and fiber, and industrial processing. In the arid west, the institutions that govern water use have principally developed to serve offstream uses, resulting in flow depletions that impair instream uses on many streams. With demands for offstream water use certain to increase with growth, the pressure on instream values will intensify.

The prospects of further streamflow depletions and consequent loss of instream flow benefits have prompted proposals for instream flow protection. Most western states have enacted legislation in the last several years aimed at improving the legal standing of instream flow uses (Tarlock 1978). Thus the instream flow controversy now centers not on whether instream flow values are worthy of protection, but on the proper approach for providing opportunities to protect instream values in the body of western water law.

The competition between diversion and instream use is particularly intense in arid climates and during drought periods. Nationwide, the demand for offstream water use has been increasing and is expected to continue to increase (Water Resources Council 1978), intensifying the competition for water between instream and offstream purposes. Diversions have been accomplished through an institutionalized system for water development operating within an appropriative system of water law. Many individuals and groups are increasingly concerned over declining instream flows and the consequent impairment of widely distributed instream flow benefits, particularly those related to lost recreation activities and potential threats to the aquatic system.

## Instream Uses and Western Water Law

The appropriation doctrine that has evolved politically to govern the allocation of water among uses in the arid west (Hutchins 1971) grants exclusive rights to divert specific amounts of water to specific beneficial uses and to transfer rights to others as possible without impairing existing rights. Priorities among right holders under the appropriation doctrine are on a "first-in-time is first-in-right" basis. Because of the freedom provided for market transfer of water rights, proponents contend that in the promotion of economic development and in the efficient use of the resource, an appropriative system is superior to its main alternative, the riparian system (Trelease 1977).

In contrast to the exclusive rights given for diversions, the traditional view has been that there can be no exclusive right to water freely flowing in the stream. The water right can only be perfected by establishing physical control over the quantity of required water and actually applying it to a specific beneficial use. Consequently, the appropriation doctrine as a whole has not been hospitable to instream values, except for hydroelectricity generation, which has been accommodated because the system to control the flow driving the turbines is equivalent to a diversion.

Historically, the failure of the political system to provide rights for instream uses might be explained by the sufficiency of the stream flow. However, increasing demand for water for offstream development and increasing public interest in instream flow values are intensifying the conflict. Since instream flows produce benefits worthy of protection, the challenge is how to provide a balanced allocation of water between the two, diversions and instream uses, given their divergent methods of use (diversions being private and instream uses being public goods) and demand characteristics (diversions providing large benefits to individual users and instream values being widely dispersed over a large population).

Advocates of stronger instream flows protection find several obstacles to providing for instream uses within the appropriative system. The first is the difficulty of satisfying the requirements of an appropriation for instream uses. The elements of a valid appropriation have been taken to consist of 1) a notice of intent to appropriate; 2) an actual diversion, reducing the water to possession; and 3) an application to a beneficial use (Tarlock 1978). To overcome this barrier, new options are being developed politically. Colorado and Montana, for example, have special statutory provisions for instream appropriation (Bagley et al. 1983). Other states place the burden on the state agency responsible for water rights administration. Both options for protecting flows are being refined with experience (Dewsnup and Jensen 1977, Bagley et al. 1983).

The second major obstacle to integrating instream uses into the appropriative system is the public good nature of instream uses. Instream values have an inherently public character in that the full value to society cannot be realized by assigning instream flow to exclusive or private use.

State statutes that, explicitly or indirectly, protect instream flows are usually justified by the public trust doctrine. While this "special consideration" has achieved some protection for instream uses, it does not really provide balanced management of the resource because it does not treat instream and offstream uses on an equal basis. Furthermore, the approach is inflexible in two ways. It is difficult at best to secure instream flows on heavily appropriated streams. Once rights are obtained, the administrative arrangements make it unlikely that instream reservations will be reduced if further analyses show that less water would do the job.

Rather than integrate instream with offstream uses, a special status separates them. Decisions on water allocations for diversion are evaluated by one standard (beneficial use), while decisions on allocations to instream uses are evaluated by another (environmental preservation).

On streams already heavily appropriated, protecting minimum flows under the public trust, although theoretically possible, does not appear to be a practical alternative. The paradigm of instream flow protection under the public trust is to withdraw flows from the appropriative arena, not to join it as an equal participant. Just as it is difficult to obtain instream flow protection on appropriated streams, so it is difficult to reduce instream reservations once made, if priorities should change. A government agency charged with preserving and enhancing aquatic habitat and outdoor recreation opportunities is unlikely to facilitate transfers of water to other uses, regardless of their value.

A third problem is that the determination of instream flow needs has not been tied to the economic demand that drives the appropriative system. Rather, they have been tied to a requirements approach that defines stream flow regimes in terms of some qualitative instream use criteria, usually the flow required to support a population of some aquatic organism(s) at critical life stages. These criteria are used to set minimum levels of instream flows and implemented through strategies that prevent new appropriations or changes in existing uses that might deplete the stream.

## Decision Procedures for Instream Flow Allocations

The overriding objective of institutions for water resource management should be to encourage patterns of water use that produce the greatest benefits to society. In the long run, instream use allocation procedures shall be integrated with allocations to uses traditionally regarded as beneficial, and related to collective preferences as well as biological criteria. In a setting of competing uses, relative values are implied by every allocation decision that approves one use and excludes the alternatives. The democratic tradition requires that such decisions be made by a process reflective of the preferences of those interested.

Determining the best way to incorporate preferences is not simple. Some sort of voting arrangement is one possibility. But the determination of the supply of instream flows by a majority vote can lead to inconsistent results, and no guarantee that the alternative providing the greatest social welfare will be chosen (Arrow 1973, Riker 1961). Representative voting does not guarantee better results. Only under stringent assumptions (Luce and Raiffa 1959) would legislative action determine the level of instream flows best for social welfare. In view of these problems, a market approach may appear to be the more attractive allocation mechanism. While there may be greater potential for private participation in instream flow protection than has been generally recognized, social welfare will not be maximized in a market arrangement where transactions do not incorporate all the costs and benefits of the activity (Heller and Starrett 1976). Benefits arising from instream flows appear to be among those difficult to completely capture in market transactions.

The manner in which instream and offstream use allocations are related, and provisions to change allocations in response to changing priorities will be determined through the established policy making process. Whether instream values are exclusively protected by the state, or state protection and private appropriation are combined, rational allocation decisions require information on the relative benefits of instream flows and the costs of alternative methods for obtaining them. The exact determination of the allocation, then, could be based on benefit-cost analysis.

In the long run, instream use allocations must be integrated with the diversions traditionally regarded as beneficial. Whether instream values are exclusively protected by state, or state protection and private appropriation are combined, rational allocation decisions require information on the relative benefits of instream flows and the costs of various proposed methods for obtaining needed flow. The democratic process could be gainfully used to formulate guidelines as to how instream flows may be accorded equal status to offstream uses and to provide flexible mechanisms by which water allocations could take into account the benefits from nonmarket outputs of instream flows. Allocations within those guidelines, however, must be based on benefit-cost analysis.

## Report Objective and Content

In order to determine an appropriate level of instream flows, methodologies are needed for estimating the benefits of instream flows relative to offstream water uses. Chapter II presents a methodology for economic analysis to determine the benefits of instream flow. It is then developed (Chapters III and IV) to estimate the potential foregone benefits to offstream uses as a result of increasing instream flows, taking into account the stochastic nature of stream flow. Then Chapters V through VIII attempt to balance instream flow with diversion benefits to maximize the total value of water in use.

# CHAPTER II

# ECONOMIC APPROACH TO INSTREAM FLOW MAINTENANCE

Instream flow is essential to many beneficial activities within the stream channel. This instream flow input has, in economic terms, "public good" characteristics. For a given level of instream flow, many different instream uses can take place without any one use excluding one or more other uses. Whereas conflicts among instream uses may occur, competition for water (of a given quality) among the uses does not occur since only one level of instream flow is possible at any given time. The offstream uses, on the other hand, directly compete for the total water supply.

The demand for water for an instream use can be derived using market data or survey methods (Freeman 1979). Household production theory (Becker 1965) has been used to derive these demands, and questionnaires and interviews have been used to evaluate demands for fishing, white water boating, and stream-side activities (Daubert et al. 1979). Other important instream flow benefit studies were done by Daubert et al. (1979) and Walsh et al. (1980). Since only one level of instream flow can prevail at any given time, the aggregate demand can be derived by vertical summation of the derived demands. In Figure 1(a), the demands for two instream uses are represented by curves $D_1$ and $D_2$. The vertical sum $D_i$ of these demands is the aggregate demand for instream flows.

In Figure 1(b), $D_o$ represents the demand for water for offstream uses. The horizontal sum of $D_o$ and $D_i$ is the aggregate demand D for water. A horizontal summation is used here because the same water cannot satisfy both uses.

The supply curve S represents the minimum cost of providing various quantities of water. If the water supply is fixed, then S will be a vertical line. Otherwise, minimum cost combinations of such alternatives as water importation, reservoir construction or enlargement, or groundwater pumping for flow augmentation would be used to derive S. The intersection of S and D at $E_1$ represents the benefit maximizing allocation. The optimal level of instream flow is $W_i$ and equally enjoyed by $W_1$ and $W_2$ as shown in Figure 1(a). The optimal offstream water use $W_o$ is shown in Figure 1(b).

Another way of approaching this allocation is that the optimal instream flows are determined by the intersection of the demand curve for instream flows $D_i$ and a curve expressing the marginal opportunity cost of water taken from offstream uses S'. This is shown as point $E_2$ in Figure 1(c). The marginal opportunity cost curve is obtained by plotting a residual supply curve for water as represented by the horizontal differences between S and $D_o$. The benefit maximizing condition, therefore, is that the sum of marginal benefits for instream uses should be equal to the marginal benefit of each offstream use, which in turn should be equal to the marginal cost of water.

It is also useful to conceptualize the balances between instream and offstream use in the context of a stream channel that transports water to downstream users. This transport function

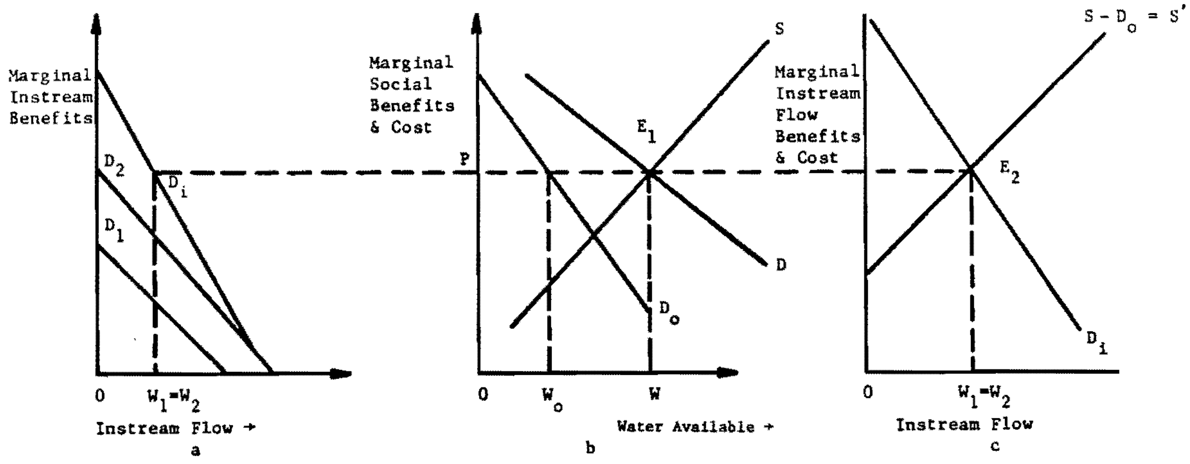

Figure 1. Optimal allocation of water.

provides instream flow in the intermediate reaches. The amount of flow depends on the distribution in time and space of diversions and return flows along the stream. If, in any given stream reach, the normal flow is large enough to satisfy all instream uses, the marginal benefit of additional instream flow is zero. Otherwise, flow augmentation to supply instream requirements may be desirable.

The flow at any point on a stream is determined ideally by marginal tradeoffs between upstream and downstream values in use. As illustrated in Figure 2, the marginal benefits of downstream uses (on the left vertical axis) for various amounts of water (measured from 0 to the right) are shown by $D_d$. The total quantity of water available is fixed and represented by the length 00'. $D_u$ indicates the marginal benefits for upstream uses (on the right vertical axis) of various amounts of water use (measured from point 0' to the left). If water rights are freely transferable, $OI_o$ and $I_oO'$ represent the water rights held by downstream and upstream users, respectively. Therefore, the resulting instream flow will be $OI_o$ as determined by the amount of water passed through the stream channel to meet downstream rights.

If the aggregate demand for instream flows is $D_i$, then the combined marginal benefits can be represented by $D_d + D_i$, the vertical sum $D_d$ and $D_i$ at each flow level. The intersection of $D_d + D_i$ and $D_u$ at B represents the benefit maximizing point, and OI* is the optimal instream flow. Instream flows should be increased by $I_oI^*$ to maximize the benefits to society.

Determination of an optimal level of instream flow for any given stream reach is difficult in practice. First, the variation in the quantity of water available from year to year is an important consideration. While the techniques of cost-benefit analysis under uncertainty developed by Hirshleifer (1966) and Arrow and Lind (1970) can be

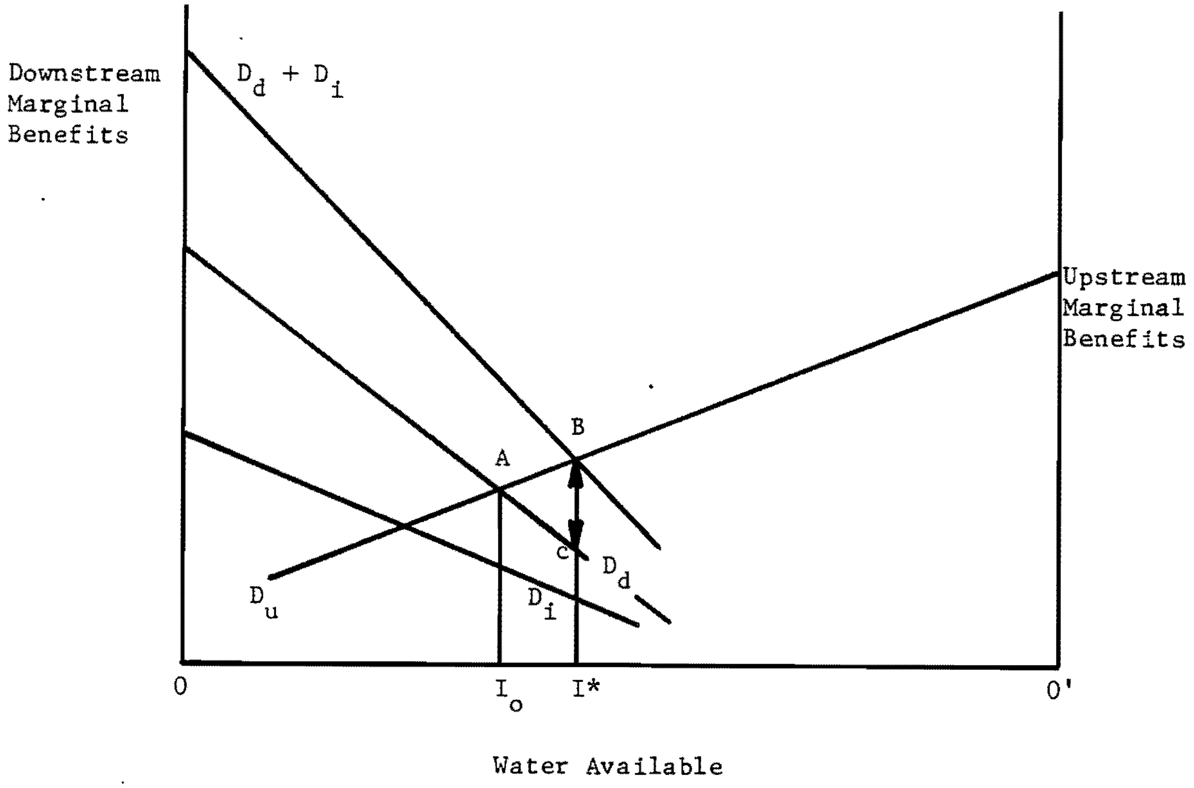

Figure 2. Optimal instream flow determination.

applied, they require additional information on the attitudes toward risk of affected individuals. Furthermore, the computational effort is increased manyfold. However, the stochastic nature of stream flows should be recognized in planning instream flow provisions due to the enormous variation in value with the dependability of water supplies.

A second factor limiting our ability to optimize instream flow provision is that estimates of instream flow demands are limited by sparse site specific data and the high cost of obtaining such data. Also, there are theoretical controversies in estimating benefits and no generally accepted empirical framework to do so.

Without quantitative information on instream flow benefits and individual attitudes toward risk, the stochastic nature of water availability cannot be incorporated satisfactorily within a cost-benefit framework. However, some provision for the stochastic nature of flows is necessary to represent the structure of appropriative water rights which accounts for the uncertainty of supply by ordering rights according to seniority. Traditionally, instream flow planning has had a tendency either to displace senior rights by setting a base flow to be maintained or to reserve less than what is needed because diversions have priority in times of shortage depending on the political power of the conflicting groups.

The first option is favorable to instream values and recognizes these values to have priority over other uses. The second option, however, ignores the instream values by providing the most junior rights. Both these options take different extreme positions and neither are likely to be economically efficient. In addition, the first option is likely to be infeasible in that the desired base instream flow may not be available under times of water shortage.

Neither of these options explicitly recognize the value of the seniority of water rights. The two options, however, would yield the same solution if the streamflow is deterministic. If the streamflow is constant every year (at its average value), then the marginal cost of maintaining a base level instream flow is the opportunity cost of that water in the offstream use. No distinction needs to be made between junior and senior rights. When streamflow is a random variable, no longer could a desired level of instream flow be maintained (unless the desired flow is less than the minimum value of the streamflow). The "instream flow requirement" criterion used in the deterministic approach must be replaced. It is proposed in this study that instead of a desired level of "instream flow requirement," a desired level of "expected instream flow requirement" be made a criterion. The expected instream flow is the statistical average of instream flows over a long period. In one year, the instream flow could be low, but in another year, it could be high. The expected value of these flows in the statistical sense could be required to meet a desired level.

Information on the expected cost of offstream benefits foregone to meet various desired expected instream flows could be useful for planning purposes. Moreover, this approach is compatible with the appropriation doctrine and it recognizes the values of water rights of different seniority.

To illustrate this concept, assume two possible realizations of the streamflow $Q_1$ and $Q_2$ ($Q_2 > Q_1$) with probability of occurrence $\pi_1$ and $\pi_2$ respectively. Let $A_1$ and $A_2$ be the amount of water diverted for offstream use. Assume that there are no return flows. The problem is to find the values of $A_1$ and $A_2$. If the benefit function for offstream use is given by $B(A)$ where $A$ is the water diverted for offstream use, the expected benefit is $\pi_1\ B(A_1) + \pi_2\ B(A_2)$. If $Q_1$ is the streamflow $Q_1 - A_1$ would be the instream flow below the diversion point. Similarly if $Q_2$ is the streamflow, then $Q_2 - A_2$ would be the instream flow below the diversion point. Therefore the expected instream flow is given by $\pi_1(Q_1 - A_1) + \pi_2(Q_2 - A_2)$. Suppose that the desired expected instream flow is $I^*$, then $A_1$ and $A_2$ could be chosen by maximizing $\pi_1\ B(A_1) + \pi_2\ B(A_2)$ subject to the constraint $\pi_1(Q_1 - A_1) + \pi_2(Q_2 - A_2) \geq I^*$. The solution to this problem gives the expected benefit-maximizing decision rules (the value of A conditional upon the realization of streamflow). In terms of water right structure, the offstream use holds $A_1$ units of senior water right and $A_2 - A_1$ units of junior water rights (assuming $A_2 \geq A_1$). The instream use will have $Q_1 - A_1$ units of senior water rights and $Q_2 - A_2 - Q_1 + A_1$ units of junior water rights. The complexity of the solution procedure increases as different months and many streamflow events are introduced. Comparison of solutions for alternate strategies for maintaining instream flows could be examined within this framework.

By following this approach, a general stochastic linear programming model was used to estimate the expected costs of alternative methods to maintain instream flows from foregone value of agricultural products by assuming a direct conflict between offstream agricultural use and the maintenance of instream flows. Alternatively, the approach could be expanded to include conflicts with other water uses as well as additional water management alternatives such as reservoir construction, modification of reservoir operating rules, groundwater pumping, and interbasin transfers that can be accommodated within the model framework.

# CHAPTER III

## DESCRIPTION OF STUDY AREA AND MODEL APPLICATION

Two streams, Blacksmith Fork and Little Bear River located in the southwest portion of Cache County in northern Utah, were selected for a case study (Figure 3). The Little Bear, draining an area of 339 square miles, flows roughly south to northwest to its confluence with the Bear River. The Blacksmith Fork, draining 267 square miles, flows west to join the Logan River which later flows into the Bear River. The headwaters of both rivers originate in the Wasatch mountains. Annual discharge volumes vary considerably from year to year with the amount of snowpack.

About 15 percent of the Little Bear drainage and 63 percent of the Blacksmith Fork drainage lie in either the Cache National Forest or state lands. Downstream, approximately 32,000 acres in the Little Bear drainage and 2,000 acres in the Blacksmith Fork drainage are irrigated. Irrigation constitutes by far the largest use of water. Minor uses include municipal, culinary, and hydroelectric water. Both rivers support excellent brown trout fisheries.

Both streams, but particularly Blacksmith Fork, are dewatered over some lower reaches during the middle and late summer of years with below normal flows. Such dewatering occurred in the summer of 1981, resulting in the loss of a large number of fish. A proposal by the City of Hyrum to rehabilitate its power plant on the Blacksmith could dewater another stretch above the canyon mouth by diverting the flow into a pipe for conveyance to a downstream generation site. Consequently, this area, which is already experiencing conflicts between water use for irrigated-agriculture and instream flows for fish habitat, presents a good situation for demonstrating model application.

A stochastic linear programming model (Wagner 1975) is developed in this study to analyze alternative instream flow strategies. Annual water availability is assumed to be a discrete random variable that can take any one of eight levels. Each level is assumed to be an independent event with an associated probability. The monthly flows are calculated as fixed portions of the annual total. This is accomplished by calculating the ratio of the sum monthly gaged flows for all sample points (34 years) to the sum of the total for all months over the same 34 year period. Under the assumption of perfect correlation between monthly flows and seasonal total flow (the season consists of the months from May-September), this procedure yields the maximum likelihood estimator of the fraction of the annual flow that would be measured in a given month. A histogram is then constructed to determine a discrete density for the 5 month flow period. Eight flow events beginning with 10,000 AF up to 170,000 AF at an interval of 20,000 AF are used and the respective probabilities are estimated. Using the monthly fractions, the streamflow estimates for various months and the respective probabilities are calculated (Table 1).

In general, instream flow strategies are the manner in which determined instream flow requirements are reserved. This desired level of flow in the context of random water availability

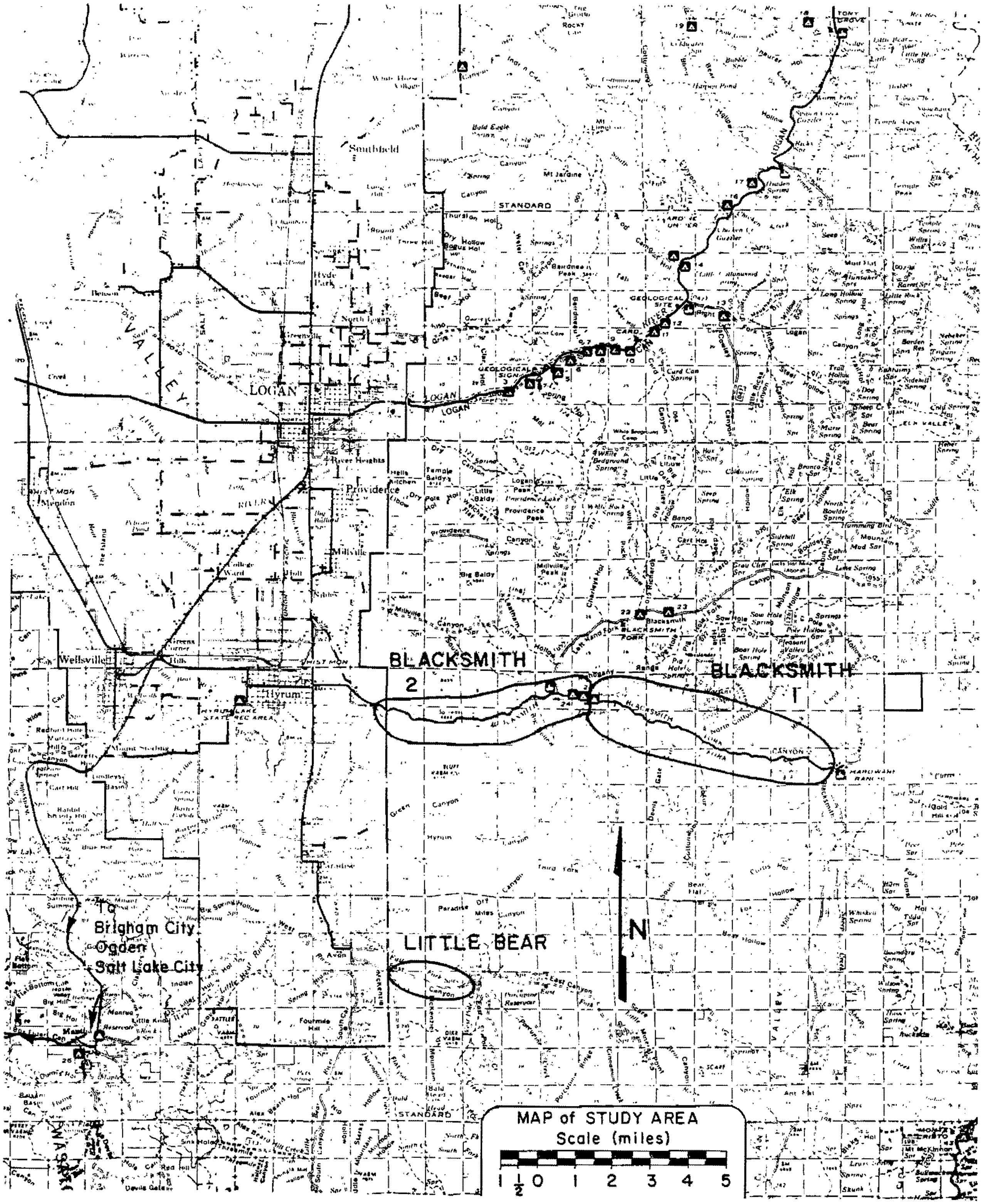

Figure 3. Blacksmith Fork and Little Bear River are sites for case study.

Table 1. Stream flow volumes at different probabilities of occurrence in acre/feet.

| State k | Probability of Occurrence | Months (t) May | June | July | Aug. | Sept. | Seasonal Total |
|---|---|---|---|---|---|---|---|
| 1 | 0.029 | 9,000 | 4,200 | 2,600 | 2,200 | 2,000 | 20,000 |
| 2 | 0.1176 | 18,000 | 8,400 | 5,200 | 4,400 | 4,000 | 40,000 |
| 3 | 0.1764 | 27,000 | 12,600 | 7,800 | 6,600 | 6,000 | 60,000 |
| 4 | 0.3235 | 36,000 | 16,800 | 10,400 | 8,800 | 8,000 | 80,000 |
| 5 | 0.1470 | 45,000 | 21,000 | 13,000 | 11,000 | 10,000 | 100,000 |
| 6 | 0.1470 | 54,000 | 25,200 | 15,600 | 13,200 | 12,000 | 120,000 |
| 7 | 0.029 | 63,000 | 29,400 | 18,200 | 15,400 | 14,000 | 140,000 |
| 8 | 0.029 | 72,000 | 33,600 | 20,800 | 17,600 | 16,000 | 160,000 |

should be defined in terms of expected instream flow requirement.

The alternatives examined are three basic strategies for meeting this requirement under two conditions of water rights transferability. The basic strategies are:

1. The expected instream flow strategy (EIF)* determines the combination of junior and senior rights needed to maintain the desired level of expected instream flow at least cost in terms of expected agricultural output foregone.

2. The minimum flow strategy (IF) meets the desired level of expected flows by reserving the required amount of the most senior rights.

3. The critical flow strategy (CF) combines the previous two, using IF to guarantee a base flow to prevent any irreversible damages (attain maximum protection up to a critical flow level), and EIF to obtain the remainder of the desired expected instream flow.

Under water rights condition 1, transfers from agriculture to instream uses are restricted to permanent conversions; under condition 2, temporary or short term transfers are freely permitted. These conditions correspond to programs of long term water rights acquisition and of annual administrative allocations, respectively. While three methods and two conditions may seem to combine into six alternatives, only five (EIF 1, EIF 2, IF, CF 1, CF 2) are real because transferability is not applicable to IF.

In formulating the model, let $P_{jr}$ represent the net revenue (value-added) per acre of jth crop produced on the rth class of land. Irrigated land is classified into three classes based on productivity levels. The values of $P_{jr}$ for six major crops are shown in Table 2. $Z_{jr}^k$ is the number of acres of rth class of land devoted to the production of jth crop when water availability k occurs with an associated probability $\pi^k$. The expected returns to irrigated agriculture are thus:

$$\sum_k \sum_j \sum_r P_{jr} \pi^k Z_{jr}^k \quad . \; . \; . \; . \; . \; (1)$$

The problem is to maximize these returns subject to the following

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*The meaning of the expected instream flow strategy and the expected instream flow requirement must be carefully distinguished. The strategy is denoted by EIF throughout the report.

constraints. The amount of irrigated land is restricted to be less than the available acres $L_r^*$ in each land class for every event k.

$$\sum_j Z_{jr}^k \le L_r^* \qquad r=1,2,3; \qquad k=1,2,\ldots 8 \quad . \quad . \ (2)$$

The amount of water $A_t^k$ used for irrigation in month t and probability state k is defined by the equation:

$$\sum_r \sum_j w_{jt} Z_{jr}^k - A_t^k = 0 \qquad t=1,2,\ldots 5; \qquad k=1,2,\ldots 8 \quad . \quad . \ (3)$$

where $w_{jt}$ represents the consumptive use requirement for crop j in month t (Table 3). Six crop rotational constraints are used in the model (Keith et al. 1978). A general representation of these equations is given by:

$$\sum_r \sum_j V_{jr}^i Z_{jr}^k \gtrless 0 \qquad i=1,2,\ldots 6; \qquad k=1,2,\ldots 8 \quad . \quad . \ (4)$$

where the $V_{jr}^i$ represents the portions of various crop acreages required for good crop rotation.

Table 2. Net revenues per acre for different crops and land classes ($P_{jr}$).

| Land Class | Crop | | | | | |
|---|---|---|---|---|---|---|
| | Alfalfa Full | Alfalfa Partial | Barley | Corn Grain | Beets | Nurse Crop |
| Class 1 | 107.49 | 82.13 | 106.68 | 156.63 | 72.44 | 64.21 |
| Class 2 | 86.83 | 68.29 | 89.75 | 120.22 | 48.47 | 50.98 |
| Class 3 | 67.81 | 62.38 | 74.96 | 77.32 | 43.85 | 39.98 |

Table 3. Water requirements for crops per acre in acre-inches ($w_{jt}$).

| Month | Crop | | | | | |
|---|---|---|---|---|---|---|
| | Alfalfa Full | Alfalfa Partial | Barley | Corn Grain | Beets | Nurse Crop |
| May | 3.828 | 3.190 | 1.772 | 1.311 | 1.240 | 1.772 |
| June | 5.727 | 4.713 | 7.805 | 3.801 | 3.345 | 7.805 |
| July | 7.598 | 6.228 | 7.665 | 7.392 | 7.528 | 7.665 |
| August | 6.416 | 5.508 | 1.513 | 6.235 | 7.566 | 1.513 |
| September | 3.644 | 3.197 | 0.930 | 2.417 | 4.239 | 0.930 |
| Total | 27.212 | 22.836 | 19.685 | 21.156 | 23.913 | 19.685 |

The water supply constraint,

$$I_t^k + A_t^k = Q_t^k \qquad t = 1,2,\ldots 5; \quad k = 1,2,\ldots 8 \quad . \quad . \quad (5)$$

restricts the sum of the amounts of water used in irrigated agriculture $A_t^k$ and the instream flows $I_t^k$ to be equal to the water availability $Q_t^k$ in month t and state k. The distribution of values of $Q_t^k$ are shown in Table 1. The expected instream flow requirement is imposed by the constraint

$$\sum_k \pi^k I_t^k \geq \bar{I}_t^* \qquad t = 1,2,\ldots 5 \quad . \quad . \quad (6)$$

where $\bar{I}_t^*$ is the desired expected instream flow level. The values of $\bar{I}_t^*$ examined in this analysis correspond to 40 percent, 50 percent, 60 percent, and 70 percent of average flows as shown in the first column of Table 4. To restrict water right transfers between irrigation and instream flows, the following constraints are included.

$$A_t^{k+1} - A_t^k \geq 0 \qquad k = 1,2,\ldots 7; \quad t = 1,2,\ldots 5$$

$$I_t^{k+1} - I_t^k \geq 0 \qquad k = 1,2,\ldots 7; \quad t = 1,2,\ldots 5 \quad . \quad . \quad (7)$$

$A_t^{k+1}$ represents the irrigation water use corresponding to event $Q_t^{k+1}$. Since there are eight flow events $Q_t^k$ selected for analysis, water rights are grouped into eight levels of seniority. The difference between $A_t^{k+1}$ and $A_t^k$, therefore, can be interpreted as the water right of (k+1)th seniority. For

Table 4. Minimum instream flow requirements in acre-feet ($I_t^*$).

| Expected Instream Flow (Percent of Average) | Time<br>May | <br>June | <br>July | <br>August | <br>September |
|---|---|---|---|---|---|
| (40%)<br>4,667 | 4,667 | 4,681 | 4,729 | 4,790 | 4,852 |
| (50%)<br>5,834 | 5,834 | 5,882 | 6,034 | 6,158 | 6,283 |
| (60%)<br>7,000 | 7,000 | 7,084 | 7,401 | 7,772 | 8,003 |
| (70%)<br>8,167 | 8,167 | 8,285 | 9,029 | 10,127 | 12,850 |

example, $A_t^1$ is the amount of most senior water rights, $A_t^2 - A_t^1$ represents the amount of the water right having the next lower priority and $A_t^8 - A_t^7$ represents the most junior water rights in the stream. Equation 7 assumes that water rights of different seniority are maintained nonnegative. In the absence of Equation 7, $A_t^{k+1} - A_t^k$ could be negative. This means that if $Q_t^{k+1}$ is observed to be the stream flow, $A_t^{k+1}$ is the optimally required agricultural water use. This will require selling some of the water rights. For example, in the previous year the flow event was 80,000 AF. Corresponding optimal value of $A_t^k$ is 20,000 AF. If in the current year the flow is 100,000 AF and the value of $A_t^k$ is 15,000 AF. This means 5,000 AF of water rights will have to be sold. Without constraint (7), sale or purchase of water rights would be required on an annual basis.

Strategy EIF 1 is given by the stipulation of constraint (7), in which the model does not allow transfer of water rights between irrigated agriculture and instream flows because the constraint fixes the allocation between them for any flow event. Specifically, the variables in constraint (7) can be regarded as first stage decision variables in a two stage stochastic linear programming model with the cropping pattern regarded as the second stage decision variable. Strategy EIF 2 is obtained if constraint (7) is not imposed, in which the model implies that water rights can be transferred between agriculture and instream flows after observing the event $Q_t^k$. The model is solved with and without constraint (7) for various levels of expected instream flow requirements. While the first solution (EIF 1) may yield a lower value of the objective (1), the second solution (EIF 2) may impose large transaction costs due to the necessity for transferring water rights.

In addition, minimum flow requirements are imposed by stipulating

$$I_t^k \geq \bar{I}_t^k \qquad t = 1,2,\ldots 5; \quad k = 1,2,\ldots 8 \quad . \quad . \ (8)$$

These constraints are used in two ways. First, by implicitly finding $\bar{I}_t^k$ such that the expected value of $\min(Q_t^k, \bar{I}_t^k) = \bar{I}_t^*$, the minimum instream flow reservation consistent with the expected instream flow requirements can be determined. These minimum requirements by month are shown in Table 3 under columns 2-6. Then, constraint (8) is imposed so that $I_t^k \geq \min(Q_t^k, \bar{I}_t^k)$. By imposing (8), the decrease in the objective function value corresponding to minimum instream flow strategy (IF) is determined.

Second, critical instantaneous flows may be required to prevent irreversible damages, since simple EIF requirements could allow zero flows. Critical flows $I_t^c$ were set at 20 percent of average flows by stipulating in Equation 8, $I_t^k \geq \min(Q_t^k, I_t^c)$. The critical flow strategy is used with and without Equation 7 for conditions 1 and 2, to give results for strategies CF 1 and CF 2, respectively.

## CHAPTER IV

## ANALYSIS OF RESULTS

Net benefit maximizing solutions for the five strategies were obtained for providing instream flows equal to 40 percent, 50 percent, 60 percent, and 70 percent of the average flows. For comparison purposes, a base solution without requiring any instream flows (by setting $\bar{I}_t^* = 0$ and deleting Equations 7 and 8) is obtained. This solution indicates how the available water could be allocated among various agricultural activities. This allocation of water for various flow events indicates the maximum value of agricultural returns. Multiplied by the probability of each flow event, and adding the results, the expected value of agricultural returns could be obtained without requiring instream flows. The values of the objective function for all solutions corresponding to the five strategies were subtracted from the base solution value to arrive at the cost of instream flow maintenance for the five strategies. These costs are shown in Table 5. The water allocations are shown in Tables 6 through 10.

It is interesting to note that while the differences in cost with (EIF 1 and CF 1) and without (EIF 2 and CF 2) the transferability constraint (7) are negligible (Table 5), the corresponding (EIF 1, CF 2) patterns of water allocation for the two conditions are quite different. Although the implementation of decision rules without constraining short term transfers would be ideally preferable, it would be costly in terms of the water right transaction costs.

The difference in objective function values between the EIF strategies and the critical flow strategies are not significant. This implies that the instantaneous flows selected as critical can be provided with minimal impacts on agriculture. However, the differences in cost between the minimum flow strategy and other strategies are substantial. However as instream flow requirements are increased from 40 percent to 70 percent of the average flow, the cost differences at first increase and then decrease both in absolute and

Table 5. Expected costs of instream flow maintenance (in dollars).

| Strategies | Expected Instream Flow | | | |
|---|---|---|---|---|
| | 40% | 50% | 60% | 70% |
| EIF1 | 603,653 | 764,760 | 938,858 | 1,397,799 |
| EIF2 | 603,648 | 764,755 | 938,856 | 1,397,796 |
| IF | 625,171 | 829,248 | 1,103,966 | 1,424,417 |
| CF1 | 605,351 | 766,458 | 940,556 | 1,397,799 |
| CF2 | 605,346 | 766,454 | 940,553 | 1,397,796 |

Table 6. Water allocations for expected instream flow (EIF I).

| Expected Flow Requirement | | 40% Flow | | 50% Flow | | 60% Flow | | 70% Flow | |
|---|---|---|---|---|---|---|---|---|---|
| State | Probability | Instream Flow | Agriculture | Instream Flow | Agriculture | Instream Flow | Agriculture | Instream Flow | Agriculture |
| 1 | 0.029 | 11551 | 8448 | 11837 | 8163 | 11837 | 8162 | 20000 | 0 |
| 2 | 0.1176 | 27252 | 12747 | 31695 | 8304 | 31837 | 8162 | 37573 | 2426 |
| 3 | 0.1764 | 38804 | 21195 | 43255 | 16744 | 47871 | 12128 | 57573 | 2426 |
| 4 | 0.3235 | 58804 | 21195 | 62616 | 17383 | 67864 | 12134 | 77573 | 2426 |
| 5 | 0.1470 | 78791 | 21208 | 82603 | 17396 | 87857 | 12142 | 97573 | 2426 |
| 6 | 0.1470 | 98789 | 21210 | 102601 | 17398 | 107855 | 12144 | 117573 | 2426 |
| 7 | 0.029 | 118789 | 21210 | 122601 | 17398 | 127855 | 12144 | 137573 | 2426 |
| 8 | 0.029 | 138789 | 21210 | 142601 | 17398 | 147855 | 12144 | 157573 | 2426 |

Table 7. Water allocations for expected instream flow (EIF IIAF).

| Expected Flow Requirement | | 40% Flow | | 50% Flow | | 60% Flow | | 70% Flow | |
|---|---|---|---|---|---|---|---|---|---|
| State | Probability | Instream Flow | Agriculture | Instream Flow | Agriculture | Instream Flow | Agriculture | Instream Flow | Agriculture |
| 1 | 0.029 | 14211 | 5788 | 11837 | 8162 | 11837 | 8162 | 20000 | 0 |
| 2 | 0.1176 | 34211 | 5788 | 34211 | 5788 | 34211 | 5788 | 35380 | 4619 |
| 3 | 0.1764 | 34655 | 25344 | 48501 | 11498 | 36756 | 23243 | 58217 | 1782 |
| 4 | 0.3235 | 46207 | 33792 | 46207 | 33792 | 66146 | 13853 | 75380 | 4619 |
| 5 | 0.1470 | 94213 | 5786 | 94213 | 5786 | 94213 | 5786 | 100000 | 0 |
| 6 | 0.1470 | 103891 | 16108 | 114211 | 5788 | 114211 | 5788 | 120000 | 0 |
| 7 | 0.029 | 134211 | 5788 | 134211 | 5788 | 134211 | 5788 | 140000 | 0 |
| 8 | 0.029 | 154211 | 5788 | 154211 | 5788 | 154211 | 5788 | 160000 | 0 |

Table 8. Water allocation for minimum flow (IF) in acre-feet.

| Expected Flow Requirement | | 40% Flow | | 50% Flow | | 60% Flow | | 70% Flow | |
|---|---|---|---|---|---|---|---|---|---|
| State | Probability | Instream Flow | Agriculture | Instream Flow | Agriculture | Instream Flow | Agriculture | Instream Flow | Agriculture |
| 1 | 0.029 | 20000 | 0 | 20000 | 0 | 20000 | 0 | 20000 | 0 |
| 2 | 0.1176 | 40000 | 0 | 40000 | 0 | 40000 | 0 | 40000 | 0 |
| 3 | 0.1764 | 50441 | 9558 | 60000 | 0 | 60000 | 0 | 60000 | 0 |
| 4 | 0.3235 | 61572 | 18427 | 66303 | 13696 | 80000 | 0 | 80000 | 0 |
| 5 | 0.1470 | 73126 | 26873 | 77367 | 22632 | 82689 | 17310 | 100000 | 0 |
| 6 | 0.1470 | 84676 | 35323 | 88917 | 31082 | 93550 | 26449 | 120000 | 0 |
| 7 | 0.029 | 96216 | 43783 | 100466 | 39533 | 104911 | 35088 | 116518 | 23481 |
| 8 | 0.029 | 107752 | 52247 | 112001 | 47998 | 116451 | 43548 | 126498 | 33501 |

Table 9. Water allocation for expected flow with critical flow (CFI) in acre-feet.

| Expected Flow Requirement | | 40% Flow | | 50% Flow | | 60% Flow | | 70% Flow | |
|---|---|---|---|---|---|---|---|---|---|
| State | Probability | Instream Flow | Agriculture | Instream Flow | Agriculture | Instream Flow | Agriculture | Instream Flow | Agriculture |
| 1 | 0.029 | 20000 | 0 | 20000 | 0 | 20000 | 0 | 20000 | 0 |
| 2 | 0.1176 | 31551 | 8448 | 31837 | 8162 | 34211 | 5788 | 37573 | 2426 |
| 3 | 0.1764 | 43103 | 16896 | 43472 | 16527 | 47304 | 12695 | 57573 | 2426 |
| 4 | 0.3235 | 56570 | 23429 | 62184 | 17815 | 67249 | 12750 | 77573 | 2426 |
| 5 | 0.1470 | 76557 | 23442 | 82171 | 17828 | 87241 | 12758 | 97573 | 2426 |
| 6 | 0.1470 | 96555 | 23444 | 102169 | 17830 | 107239 | 12760 | 117573 | 2426 |
| 7 | 0.029 | 116555 | 23444 | 122169 | 17830 | 127239 | 12760 | 137573 | 2426 |
| 8 | 0.029 | 136555 | 23444 | 142169 | 17830 | 147239 | 12760 | 157573 | 2426 |

Table 10. Water allocation for expected flow with critical flow (CF II) in acre-feet.

| Expected Flow Requirement | | 40% Flow | | 50% Flow | | 60% Flow | | 70% Flow | |
|---|---|---|---|---|---|---|---|---|---|
| State | Probability | Instream Flow | Agriculture | Instream Flow | Agriculture | Instream Flow | Agriculture | Instream Flow | Agriculture |
| 1 | 0.029 | 20000 | 0 | 20000 | 0 | 20000 | 0 | 20000 | 0 |
| 2 | 0.1176 | 34211 | 5758 | 34211 | 5788 | 34211 | 5788 | 35380 | 4619 |
| 3 | 0.1764 | 34655 | 25344 | 47159 | 12840 | 36756 | 23243 | 58217 | 1782 |
| 4 | 0.3235 | 46207 | 33792 | 50382 | 29617 | 65414 | 14585 | 75380 | 4619 |
| 5 | 0.1470 | 82751 | 17248 | 94213 | 5786 | 94213 | 5786 | 100000 | 0 |
| 6 | 0.1470 | 114241 | 5758 | 114211 | 5788 | 114211 | 5788 | 120000 | 0 |
| 7 | 0.029 | 134241 | 5758 | 134211 | 5788 | 134211 | 5788 | 140000 | 0 |
| 8 | 0.029 | 154241 | 5758 | 154211 | 5788 | 154211 | 5788 | 160000 | 0 |

in relative terms. This is because for lower flow requirements relatively more senior water rights are held by agriculture under the EIF and CF strategies. As instream flow requirements increase, costs increase because more water is withheld from irrigation use. At higher expected instream flow levels, more senior rights are held for instream flows. Therefore, the minimum flow strategy and the expected flow strategies tend to become similar at higher expected instream flow requirements. The maximum differences in costs, however, do not exceed 10 percent among various strategies.

Figure 4 shows irrigated land acreages for the levels of water availability under each of the three alternative strategies for maintaining instream flows at 40 percent, 50 percent, and 60 percent of their average levels. The expected flow and the critical flow strategies give almost flat curves over a wide range of flow levels, indicating a stable situation for maintaining irrigated acreages. However, under the minimum flow strategy, much more land is irrigated at higher flows. This is because at lower stream flows a relatively more "certain" water is reserved for instream purposes. The correspondingly more "uncertain" water is available at higher flows for irrigation purposes. With the expected and critical flow strategies, the junior and senior water rights are more evenly distributed.

In Figure 5, summer recession hydrographs for 80 percent and 30

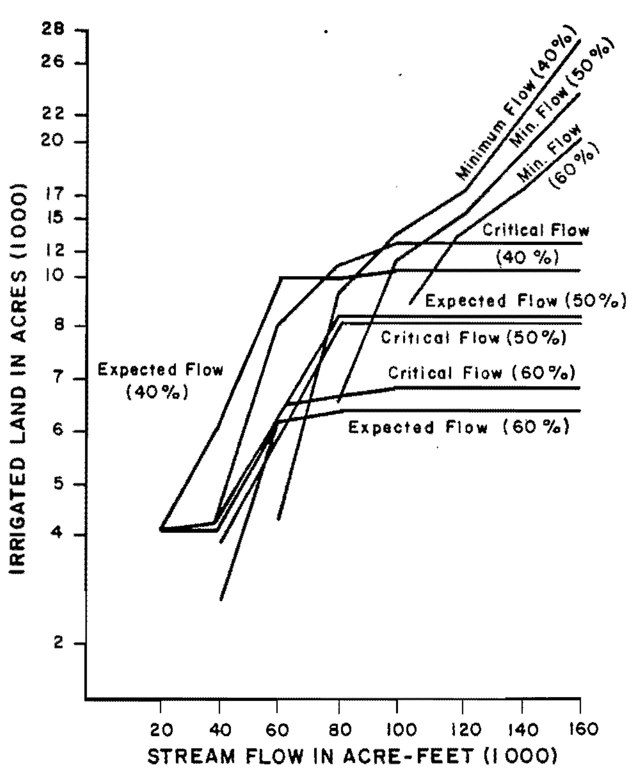

Figure 4. Irrigated land under various strategies.

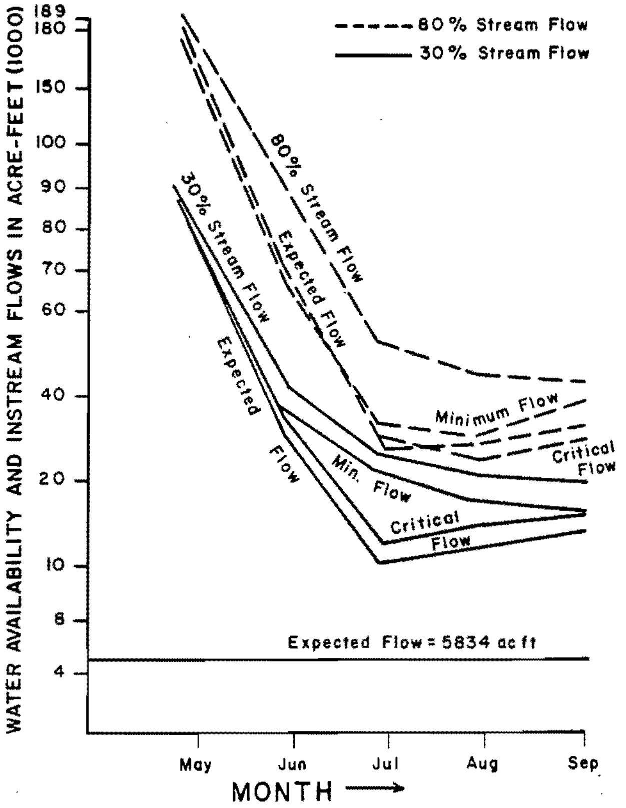

Figure 5. Instream flows under alternative strategies.

percent of the average flows are shown for the irrigation season. The corresponding solutions for instream flow values under expected flow (EIF 1), critical flow (CF 1) and minimum flow (IF) strategies are shown for 50 percent expected instream flow level. Compared to the other two strategies, the higher positioning of the curve for instream flows for the minimum flow strategy clearly indicates that this approach requires a larger amount of senior water rights, thus allowing much less water for agriculture during critical periods.

By using a stochastic linear programming model, the expected cost of maintaining various level of expected instream flows was determined. Due to the difference in the values of junior and senior water rights, using an expected instream flow strategy produces a consistently lower cost as compared to a minimum flow strategy. At higher levels of expected instream flow requirements, the difference in costs between the two strategies narrowed. However, to maintain expected instream flows at 70 percent of average flows, the agricultural sector has to be virtually eliminated.

One disadvantage of the expected instream flow strategy is that it could prescribe zero instream flows during certain water short periods. Therefore, a critical instantaneous flow of 20 percent of average flows to prevent irreversible damages was stipulated. This modification causes no appreciable change in the cost of maintaining expected instream flows.

The irrigated acreage is found to be fairly stable over most ranges of water availability for the simple EIF strategy and the critical flow strategy. Under the minimum flow strategy, larger acreages of land may be irrigated under high stream flow conditions, but irrigated land generally drops to zero under low and medium stream flow conditions.

Based upon these results, the critical flow strategy appears to be a promising criterion for providing instream flows. However, stream-specific costs of alternative expected instream flow requirement levels need to be determined before choosing a desired level of expected instream flow. Furthermore, an estimate of expected instream flow benefits would be useful in choosing the efficient level of expected instream flow requirement. In the following chapters, a methodology for evaluating a benefit function for instream flow is suggested and the results from the application to the case study area are provided.

# CHAPTER V

# ESTIMATION OF INSTREAM FLOW BENEFITS

## Overview of Estimation Techniques

Several benefit components are associated with instream flows. Possibilities include benefits from streamside recreation, instream recreation, power generation, navigation, waste transport and assimilation, aesthetics, and the aquatic ecosystem. However, for a specific stream, only some of these benefits apply. Modification of the stream channel to produce instream flow benefits from other activities would entail costs. If the costs are less than the benefits, the project is beneficial. Such projects, however, are not considered in this study due to the difficulties involved in 1) conceiving alternative designs, 2) considering conflicts among designs, 3) estimating the costs, and 4) estimating potential benefits.

Even after limiting the analysis to present instream benefits, some components are extremely difficult to estimate. For instance, some nonusers would be willing to pay to maintain the streamflow against severe depletions and thus have a preservation demand that is difficult to estimate (Krutilla et al. 1972). Aesthetic benefits accruing to individuals or groups driving along a stream are also difficult to estimate. Where methodology or information is not available to estimate total benefits, estimates that capture at least part of the benefits are still useful for preliminary evaluation of instream flow policies.

In this study, the major goods and services provided by instream flows in the Blacksmith Fork River and the Little Bear River are streamside and instream recreation activities. Therefore, the instream flows could be regarded as largely providing recreation benefits. The major recreation activities are camping, hiking, picnicking, and fishing. Both streams are classified as major trout fishing areas. The area is not easily accessible to out-of-state tourists.

The determination of instream flow benefits requires deriving the demand for instream flows. The demand expresses the maximum amount individuals would be willing to pay for an additional unit of instream flow. There are three methods by which instream flow demands could be determined.

The first and perhaps the easiest method is to ask individuals what they would be willing to pay to avert a defined reduction in streamflows. Methods ranging from simple interviews to sophisticated multiple questionnaires are available to determine an individual's willingness-to-pay (Daubert and Young 1979). Many of these methods have been shown to underestimate marginal willingness-to-pay since consumers have strong incentives to conceal their true preferences (Mäler 1974). Various survey method refinements to elicit true individual preferences have been structured from assumptions of individual rationality and perfect information. How well these methods would work is difficult to assess.

The second method is to estimate the demand for recreation at several sites by using cross-sectional household data (Burt and Brewer 1971, Cicchetti et al. 1976, Cesario 1976, Cesario and Knetch 1976). Differences in estimated demand among sites but not explained by the model are attributed to site quality differences. One variable reflecting site quality could be instream flow. Another is water quality (Saxonhouse 1977). Problems with this approach are that it is hard to quantify site quality variables and that the data needed for various recreation sites are hard to find. However, once equations are established to estimate demands, the effects of simultaneous policy changes for multiple sites are readily evaluated.

A third approach is to collect time-series use data for a site and examine changes in recreation demand as a function of instream flows. This method requires data on flows as well as demand data over a fairly long time period. Structural changes in demand might occur in this long a period and short run data will not be adequate to capture flow variations.

In this study, an attempt is made to estimate instream flow benefits for a single site from a reasonable data base. The method combines the Clawson-Knetch approach for estimating demand for a single site using travel and travel-time costs with information on the effect on visitation rate of reductions in instream flows as obtained by direct survey questions. Therefore, this method is not subject to the same, and hopefully to less, bias than the first approach which elicits information directly on the willingness-to-pay. The demand estimation is simpler than the second approach since it involves only a single site. However, this is a partial equilibrium approach and therefore not amenable to study the effects of changes in policies on multiple sites as is the second approach. Time-series data are not required as in the third approach; and, therefore, a one-season on-site sample is adequate.

## Theoretical Aspects of Instream Flow Benefit Estimation

The basic principle used in this study to estimate instream flow benefits is to relate the benefits to a demand for a private good. If a suitable private good is not available, then the procedure outlined here could not be used.

The basic demand equation assumes that the utility for the ith individual is given by the quasi-concave function

$$u = u\ (Y_0, Y_1, Y_2, W_1, W_2) \quad . \quad . \quad . \quad (9)$$

where $Y_0$ is all the other goods an individual consumes, $Y_1$ is the number of visits to the study area or site 1, $Y_2$ is the number of visits to an alternative recreation site 2 of equal quality, and $W_1$ and $W_2$ are instream flows at 1 and 2. The individual's budget constraint can be given by

$$P_0Y_1 + P_1Y_1 + P_2Y_2 = I \quad . \quad . \quad (10)$$

where $P_0$ is the price of $Y_0$, $P_1$ and $P_2$ are prices for recreating at sites 1 and 2 respectively, and I is the income of the individual. By maximizing utility (Equation 9) subject to available income (Equation 10), demands for $Y_0$, $Y_1$ and $Y_2$ can be derived. The functions are Marshallian demands given by

$$Y_i = Y_i\ (P_0,\ P_1,\ P_2,\ I,\ W_1,\ W_2)$$

$$i = 0,\ 1,\ 2 \quad . \quad . \quad . \quad . \quad . \quad (11)$$

The functions $Y_i$ must satisfy certain restrictions. They are homogeneous of degree zero in prices and income in that the doubling of all prices and income will leave the quantity demanded unchanged. They must also satisfy the "adding-up" restriction imposed by the limitation of available income. Furthermore, the functions should also satisfy the Slutky equations, also known as integrability conditions (implied by Young's theorem that requires the cross second partial derivatives of the expenditure function discussed below to be symmetric to satisfy continuity). The desired functions are given by

$$\frac{\partial Y_i}{\partial I} Y_j + \frac{\partial Y_i}{\partial P_j} = \frac{\partial Y_j}{\partial I} Y_j + \frac{\partial Y_i}{\partial P_i} \quad \text{for all } i, j \quad . \quad .(12)$$

Alternatively, a dual approach may be used to derive the demand functions. This involves minimizing the total expenditure subject to holding utility at a constant level $u^0$.

Formally,

$$\text{Min } E = \Sigma P_i Y_i \quad . \; . \; . \; . \; . \; (13)$$

subject to

$$u(Y_1, Y_1, Y_2, W_1, W_2) = u_0 \quad . \; . \; . \; (14)$$

The resulting solutions

$$\hat{Y}_i = \hat{Y}_i \; (P_0, P_1, P_2, W_1, W_2, u_0)$$

$$i = 0, 1, 2 \; . \; . \; . \; . \; . \; (15)$$

are known as Hicksian demand functions. The demand functions in Equation 11 also differ in that they hold money income constant whereas the demands in Equation 14 hold utility constant. Substituting the optimal solution $\hat{Y}_i$ in Equation 13 gives an expenditure function

$$E^* = E^* \; (P_0, P_1, P_2, W_1, W_2, u^0) \quad . \; . \; . \; (16)$$

that provides the minimum cost of achieving utility level $u_0$ for a given set of prices $P_0$, $P_1$ and $P_2$ and instream flows $W_1$ and $W_2$. If instream flows are decreased from $W_1$ and $W_2$ to $W_1{}^1$ and $W_2{}^1$ respectively, then the cost (compensating variation) of keeping the individual at utility level $u_0$ is given by

$$CV = E^*(P_0, P_1, P_2, W_1{}^1, W_2{}^1, u^0) - E^*(P_0, P_1, P_2, W_1, W_2, u^0) \quad . \; . \; . \; (17)$$

The marginal demand price for $W_1$ and $W_2$ could be determined by the first derivatives of the expenditure function, $\partial E^*/\partial W_1$ and $\partial E^*/\partial W_2$ respectively. In order to estimate CV, an expenditure function is needed which can only be obtained if demand systems such as Equation 11 can be estimated. However, by using the concept of weak complementarity, CV for a change in $W_1$ could be derived using one equation from the system defined by Equation 15 under certain reasonable assumptions.

The Hicksian or compensated demand for $Y_1$ is given by (from Equation 15)

$$\hat{Y}_1 = \hat{Y}_1(P_1, W) \quad . \; . \; . \; (18)$$

Since $P_0$, $P_2$, $u^0$ and $W_2$ are constants, the compensating variation is estimated by

$$CV = \int_{P_1}^{\bar{\bar{P}}_1} \hat{Y}_1(\tilde{P}_1, W_1{}^1) d\tilde{P} - \int_{P_1}^{\bar{P}_1} \hat{Y}_1(\tilde{P}_1, W_1) d\tilde{P} \quad . \; . \; .(19)$$

where $\bar{P}_1$ and $\bar{\bar{P}}_1$ are the prices at which $\hat{Y}_1 = 0$ for $W_1$ and $W_1{}^1$ respectively. This can be illustrated graphically. In Figure 6, $\hat{Y}_1$ and $\hat{Y}_1{}^1$ represent the compensated demands for instream flows $W_1$ and $W_1{}^1$ respectively. The initial price for $Y_1$ is $P_1$. The shaded area corresponds to Equation 19.

The area provides a valid measure of recreation benefits when the weak complementarity condition is satisfied. This condition requires that when the demand for recreation is zero, the demand for instream flow is also zero. This is a reasonable requirement since

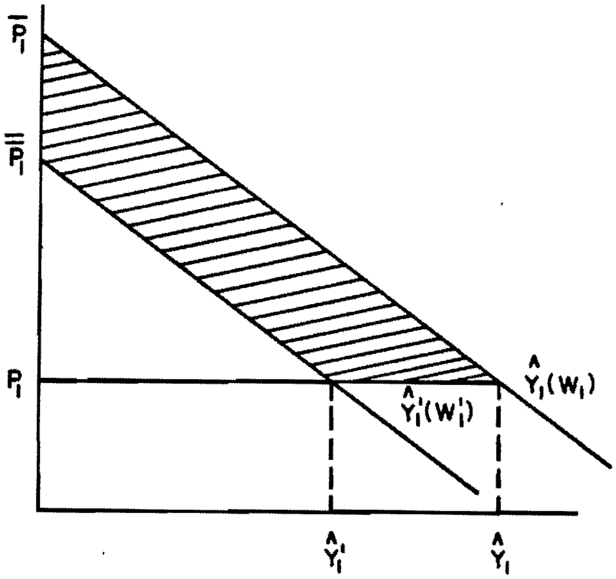

Figure 6. Benefit loss from a reduction in instream flows.

with no visitors, the stream flow could not be expected to provide any recreation benefits. However, if a preservation demand exists, the total benefit will not be zero even if there are no visitors to the site. Existence of such nonuser demands implies that the shaded area in the figure underestimates the true cost of instream flow reduction.

Another condition required for this area to be a valid measure of demand is that prices such as $\bar{P}_1$ and $\bar{\bar{P}}_1$ exist at which $\hat{Y}_1$ and $\hat{Y}_1^1$ become zero. If a consistent aggregation of demand over all individuals for $\hat{Y}_1$ were possible, then this approach could provide a reasonable measure of instream flow benefits. The aggregation condition that is sufficient is that the marginal propensity to consume $Y_1$ be equal for all individuals.

## A Practical Procedure for Instream Flow Benefit Estimation

In common econometric practice, the Marshallian or ordinary demand curves are estimated by statistical procedures for fitting observed market data. Although compensated demand and expenditure functions could be derived from these demands (Houseman 1981), the derivations are complex. An alternative is to use Marshallian demand as an approximation to the compensated demands. If the income elasticity for $Y_1$ is constant over the range of price variation for $Y_1$, then the conditions derived by Willig (1976), under which Marshallian demands could be used as an approximation, will be valid for the analysis outlined earlier (Freeman 1979). These conditions are likely to be satisfied in the case of recreation. The consumer surplus S (defined as the area under the demand $Y_i$) as a fraction of income I should be less than 0.9. That is

$$\left|\frac{S}{I}\right| \leq 0.9$$

However,

$$\frac{|S|}{I} \leq \frac{|\Delta P_1|}{P_1} \; \frac{P_1 Y_1}{I}$$

If the expenditure for recreation at $Y_1$ is 1 percent of the annual income, and even if price changes of 90 times the current price is considered, the condition is met. The other two conditions require that

$$\left|\frac{S}{I}\,\frac{\eta_I{}^U}{2}\right| \leq 0.05$$

and

$$\left|\frac{S}{I}\,\frac{\eta_I{}^L}{2}\right| \leq 0.05$$

where $\eta_I{}^U$ and $\eta_I{}^L$ are maximum and minimum values of income elasticity for $Y_1$. If S/I is even 1 percent, income elasticities up to 10 and −10 will meet the conditions. Under these conditions, the area under an ordinary demand curve approximates CV within 5 percent. Using

Willig's justification and assuming that the income elasticity is constant, the ordinary demand curve for $Y_1$ will be used in this study.

The estimation of ordinary demand for recreation came out of the work by Clawson (1959) and later by Clawson and Knetch (1966). In the absence of market prices, Clawson uses travel costs from various zones of origin to recreation site as price. Based on the relationship between per capita visits from a zone and travel costs, visitation equations are derived. These visitation equations are then used to derive the effect on visits from all zones for various levels of entry prices charged. This traces out the demand for recreation at a given site. Various refinements of this method have been achieved since Clawson's original work in terms of model specifications, measurement, and estimation procedures. Using this travel cost approach, the demand for recreation at site 1 for the present level of instream flow is derived.

The visitation equation used was

$$V_Z = A\ P_Z^{\alpha}\ D_Z^{\beta} \quad . \quad . \quad . \quad (20)$$

where $V_Z$ refers to the visits per capita from zone Z. $P_Z$ is the travel and travel time cost from Z and $D_Z$ is the distance from Z to an alternate site from Z of equal quality (used as a proxy for price) and A is a constant term. To include the effect of stream flow, this visitation equation is modified to

$$V_j^Z = (AP_Z^{\alpha}\ D_Z^{\beta})\ f(w_j) \quad . \quad . \quad . \quad (21)$$

$V_j^Z$ = visitation rate (visits/capita) from zone Z with instream flow of $w_j$

$w_j$ = percent of 1982 flow level ($w_j$ = 0, 10, 25, 33, 50, 67, 75, 100)

$f(w_j)$= a fraction defined by the ratio of visitation rate at flow level of $w_j$ to the visitation rate at 1982 flow level; $f(W_8) = 1$ and $f(W_1) = 0$

$P_Z$ = travel and travel time cost from zone Z

$D_Z$ = distance from zone Z to an alternate site of equal quality

$\alpha$ = percent change in visitation rate (at $w_j$ = 100) to percent change in $P_Z$)

$\beta$ = percent change in visitation rate (at $w_j$ = 100) to percent change in $D_Z$

A = constant

The function $f(w_j)$ reduces the visitation rate as $w_j$ becomes smaller. $W_8$ corresponds to 100 percent of 1982 flows for which data were collected, and therefore $f(W_8) = 1$. For $W_1$, the instream flow is zero, and $f(W_1) = 0$, implying no visitation. From survey data, where visitors were asked to indicate the percent of current flow below which they will not visit the site, hypothetical visitation at various $w_j$s were obtained. This information was compiled for four zones. From the plots, the visitation rates increased from $W_1 = 0$ at an increasing rate up to about 50 percent of 1982 flows and then it increased at a decreasing rate from 50 to 100 percent. The data used for the analysis and the plots are shown in Chapter VII. A logistic function of the form

$$\frac{V_j^k}{V_8^k} = f(w_j^k) = \frac{1}{1 + e^{-(\gamma+\delta w_j)}} \qquad k = 1,2,3,4 \quad . \quad . \quad (22)$$

appeared to provide the best fit. Although this form does not ensure $f(w_j)$ to be between 0 and 1, unrestricted estimation for four zone categorizations, and eight instream flow levels (with 32 observations) was carried out. The visitation Equation 20 was estimated separately for nine travel zones. Separate estimations of Equation 20 and Equation 22 involve some loss of efficiency but provide a convenient way of using ordinary least squares.

Based on these estimates, the visitation equation could be written as

$$\hat{V}_j^Z = \hat{f}(w_j)(\hat{A}P_Z^{\hat{\alpha}} D_Z^{\hat{\beta}}) \quad . \; . \; . (23)$$

The demand for recreation at site 1 is therefore

$$Q_j(P) = \sum_Z \hat{V}_j^Z = \hat{f}(w_j)\hat{A}\sum_Z (P_Z + P)^{\hat{\alpha}} D_Z^{\hat{\beta}}\cdot N_Z \quad . \; . \quad (24)$$

where $N_Z$ is the population of zone Z and P is the hypothetical price for entry at site 1. The consumers' surplus is

$$S(w_j) = \int_0^{\bar{P}} Q_j \, dQ_j = \hat{f}(w_j)\hat{A} \int_0^{\bar{P}} (\Sigma(P_Z + P)^{\hat{\alpha}} D_Z^{\hat{\beta}} N_Z) dP \quad . \; . \quad (25)$$

The value of $\bar{P}$ was chosen so that at $w_j = 8$, the demand $Q_j(P)$ in Equation 24 was less than 1. This means at prices above $\bar{P}$, no visitation will take place. Equation 25 was numerically estimated using the Gauss-Quadrative procedure for integration.

The procedure outlined in this section has shortcomings as an econometric estimation procedure, but is quite attractive from several viewpoints. First, it can be handled with ordinary least squares. Second, the linear visitation equation given by

$$V_j^Z = a + b\, P_Z + c\, D_Z + e\, w_j$$

is unsuitable since it implies that the $s(w_j)$ defined by Equation 25 increase at an increasing rate as $w_j$ increases resulting in positively sloped marginal benefits. The loglinear form given by

$$V_j^Z = a_0 + b_0 \ln P_Z + c_0 \ln D_Z + e_0 \ln w_j$$

can only capture visitation changes with respect to $w_j$ at higher values of $w_j$ where visitation rates actually increase at a decreasing rate. For lower values of $w_j$, where visitation rates increase at an increasing rate with respect to $w_j$, this model is likely to be unsuitable. A piecewise visitation equation could change the coefficient $e_0$ at an intermediate value of $w_j$ and provide an inflection in the visitation rate. An alternative is to use a more refined econometric estimation method.

# CHAPTER VI

# SURVEY OF STREAMSIDE RECREATION

The results of a streamside recreation survey conducted in the summer of 1982 in the Blacksmith Fork and Little Bear areas were made available to this study. Interviews were made at recreation sites on four weekends and four weekdays over a period of six weeks, beginning in July 1982. The interview period was chosen to ensure that variations in streamflow would be observed. The higher than normal flows of 1982 required a later start than would have been the case in an average year.

Sampling sites for the full survey were defined by stream reaches, three of which are in the area of the present study (Figure 3). The East Fork of the Little Bear River, below Porcupine Reservoir, forms one site. The second site extends from the mouth of Blacksmith Fork Canyon upstream to Hyrum City Park, and the third begins at the park and extends to Rock Creek below Hardware Ranch.

The primary variables used to set the sample size were the number of sites, the number of income groups, and the number of travel distance zones. It was hoped that about 225 interviews would be enough to obtain observations from the three sites in five to six income groups and distance zones. The study focus on evaluation of the recreationists of particular streams as flows varied dictated that the questionnaires be administered at the recreation sites, rather than by phone, mail, or at residences.

The sampling procedure consisted of setting a quota for each day of interviewing and apportioning the quota to sites according to their estimated capacity. The quota varied with whether the day was a weekend or weekday and with whether it was earlier or later in the season. Weekends were assigned relatively higher quotas because recreation use is higher and there is more time for interviewing. Days earlier in the sampling period were assigned relatively higher quotas because recreation use declines later in the summer. Interviewers were given quotas for the days and sites they worked and were instructed to count all cars in the site, divide the number of cars by the quota, and interview every nth car as determined by the quotient. It should be observed that a practically unavoidable sampling bias can be expected with this method: individuals fishing on streams frequently walk too far from their cars to be readily accessible for interviews. One would suspect the sample to undercount small parties who come primarily to fish.

## Survey Results

The questionnaire requested information on three general topics. In the demographic category, respondents were asked to report composition of party, education completed, household income, and residence. They were then asked about their recreational activities, length of stay, direct trip costs, and equipment. Finally, respondents were asked to evaluate the quality of various site characteristics, with instream flow receiving special attention.

## Demographics

Average size of groups was remarkably similar over the three sites (Table

11). While groups of more than four people were relatively more likely on the Lower Blacksmith and Little Bear, the largest groups were found on the Upper Blacksmith, which has the only developed park facility in the study area. The age and sex distribution (Table 12) shows more males than females, though not in every age group. Table 13 indicates that females seldom visit these sites in groups that have no males. Together, Tables 13 and

Table 11. Group size by recreation site.

| Number in Group | Site<br>Upper Blacksmith (N = 96) | <br>Lower Blacksmith (N = 74) | <br>Little Bear (N = 45) | All Sites (N = 215) |
|---|---|---|---|---|
| 1 | 7 | 9 | 5 | 21 |
| 2 | 23 | 18 | 10 | 51 |
| 3 | 23 | 12 | 8 | 43 |
| 4 | 22 | 11 | 7 | 40 |
| 5-6 | 5 | 12 | 10 | 27 |
| 7-10 | 11 | 11 | 4 | 26 |
| More than 10 | 5 | 1 | 1 | 7 |
| Total Persons | 395 | 290 | 176 | 861 |
| Average Group Size | 4.1 | 3.9 | 3.9 | 4.0 |

Table 12. Age and sex distribution by site.

|  | Site |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  | Upper Blacksmith |  | Lower Blacksmith |  | Little Bear |  | Total |  | All |
| Age | Male | Female | Male | Female | Male | Female | Male | Female | Sites |
| 0-9 | 54 | 34 | 44 | 28 | 25 | 20 | 123 | 82 | 205 |
| 10-19 | 28 | 27 | 21 | 17 | 13 | 17 | 62 | 61 | 123 |
| 20-29 | 30 | 36 | 43 | 38 | 24 | 13 | 97 | 87 | 184 |
| 30-39 | 45 | 32 | 24 | 11 | 16 | 13 | 85 | 56 | 141 |
| 40-49 | 23 | 22 | 17 | 12 | 4 | 2 | 44 | 36 | 80 |
| 50-59 | 16 | 15 | 7 | 8 | 7 | 3 | 30 | 26 | 56 |
| 60-69 | 14 | 10 | 11 | 7 | 8 | 5 | 33 | 22 | 55 |
| >69 | 4 | 5 | 2 | 0 | 4 | 4 | 10 | 9 | 19 |
| Total | 214 | 181 | 169 | 121 | 101 | 77 | 484 | 379 | 863 |

14 suggest that couples and young families comprise the largest portion of the recreation population.

The median educational attainment of respondents (Table 14) was high school completion, and in every site, more had at least some college than had not completed high school. The noticeably higher level of education in the Lower Blacksmith sample is explainable in part by the relatively shorter distance of that site to the university community centered in Logan.

Distribution of household income (Table 15) was somewhat different in each site. The median income for the Upper Blacksmith and Little Bear sites was in the $20-24,000 range, but only 30 percent of the incomes from the Upper Blacksmith were less than $20,000 compared to almost half from the Little Bear. Median income of the Lower Blacksmith sample was in the $15-19,999 range, but there were proportionately more upper income respondents (24 percent with incomes over $30,000) than on either the Little Bear (23 percent) or the Upper Blacksmith (21 percent). This somewhat unusual pattern is more easily seen in Figure 7.

The relationship between education and income was weaker than expected (Table 16). Although none of the less educated respondents had annual incomes in the highest brackets, a higher education apparently was not always sufficient for obtaining an income above the lowest brackets. This may be due to the fact that many of the better educated would be low income graduate students.

Distance traveled varied from less than 2 to over 1,000 miles. Table 17 shows that most of those coming from distant locations ended up on the Lower Blacksmith or Little Bear giving

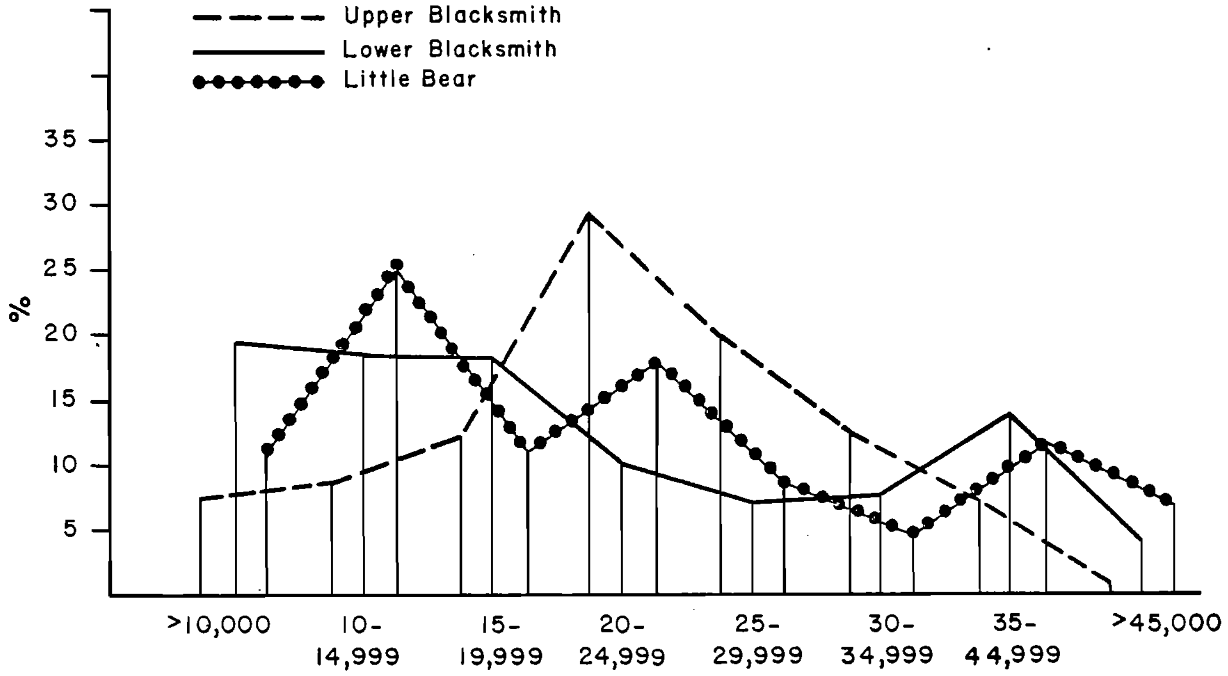

Figure 7. Distribution of annual incomes by sampling site.

Table 13. Distribution of number of each sex by size of group.

| Number in Group | Distribution by Sex | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | 1 | | 2 | | 3-4 | | 5-6 | | 7-10 | | |
| | M | F | M | F | M | F | M | F | M | F | M | F | |
| 1 | 2 | 19 | 19 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21 |
| 2 | 0 | 10 | 41 | 41 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 51 |
| 3 | 1 | 9 | 13 | 20 | 20 | 13 | 9 | 1 | 0 | 0 | 0 | 0 | 43 |
| 4 | 0 | 1 | 4 | 8 | 27 | 27 | 9 | 4 | 0 | 0 | 0 | 0 | 40 |
| 5-6 | 1 | 2 | 0 | 1 | 4 | 12 | 20 | 11 | 2 | 1 | 0 | 0 | 27 |
| 7-10 | 0 | 0 | 0 | 1 | 1 | 4 | 17 | 16 | 6 | 4 | 2 | 1 | 26 |
| >10 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 2 | 3 | 5 | 7 |
| Total | 4 | 41 | 77 | 73 | 62 | 56 | 56 | 32 | 11 | 7 | 5 | 6 | 215 |

Table 14. Education level of respondent by site.

| Education Level | Site | | | All Sites (N = 209) |
|---|---|---|---|---|
| | Upper Blacksmith (N = 94) | Lower Blacksmith (N = 72) | Little Bear (N = 43) | |
| Less than high school | 28 | 3 | 3 | 34 |
| High school | 35 | 29 | 22 | 86 |
| Some college | 21 | 18 | 11 | 50 |
| Bachelors or more | 10 | 22 | 7 | 39 |

Table 15. Annual household income by site.

| Annual Income | Site | | | Total |
|---|---|---|---|---|
| | Upper Blacksmith | Lower Blacksmith | Little Bear | |
| <$10,000 | 7 | 14 | 5 | 26 |
| $10-14,999 | 8 | 13 | 11 | 32 |
| $15-19,999 | 12 | 13 | 5 | 30 |
| $20-24,999 | 28 | 7 | 8 | 43 |
| $25-29,999 | 19 | 5 | 4 | 28 |
| $30-34,999 | 12 | 6 | 2 | 20 |
| $35-44,999 | 7 | 10 | 5 | 22 |
| >$45,000 | 1 | 3 | 3 | 7 |
| Total | 94 | 71 | 43 | 208 |

Table 16. Annual household income by education.

| Income \ Education | Less Than High School | High School | Some College | College Degree or More | Total in Income Group |
|---|---|---|---|---|---|
| < $10,000 | 3 | 12 | 7 | 4 | 26 |
| $10,000-14,999 | 6 | 15 | 4 | 7 | 32 |
| $15,000-19,999 | 3 | 16 | 7 | 4 | 30 |
| $20,000-24,999 | 9 | 17 | 9 | 8 | 43 |
| $25,000-29,999 | 6 | 11 | 9 | 2 | 28 |
| $30,000-34,999 | 7 | 4 | 1 | 8 | 20 |
| $35,000-44,999 | 0 | 8 | 8 | 6 | 22 |
| ≥ $45,000 | 0 | 2 | 5 | 0 | 7 |
| Total in ed. level | 34 | 86 | 50 | 39 | 208 |

Table 17. Travel distances by sampling site.

| Distance from Home in miles | Site<br>Upper Blacksmith (N = 96) | Lower Blacksmith (N = 74) | Little Bear (N = 45) | All Sites (N = 215) |
|---|---|---|---|---|
| 0-10 | 1 | 13 | 2 | 16 |
| 11-25 | 25 | 19 | 7 | 51 |
| 26-40 | 25 | 23 | 7 | 55 |
| 41-60 | 30 | 7 | 8 | 45 |
| 61-90 | 7 | 4 | 15 | 26 |
| 91-130 | 7 | 3 | 3 | 13 |
| >130 | 1 | 5 | 3 | 9 |
| Average Distance | 54 | 69 | 86 | 66 |

those sites a higher average travel distance than the Upper Blacksmith. One would generally expect that most of the visitors to a site would live in the nearest zone, but the survey sample departs somewhat from this pattern. Part of the discrepancy arises from the distribution of population around the sites. Very few people live within 10 miles of the Little Bear or the Upper Blacksmith sites. Adjusting the number of visits from distance zones to account for differences in population would produce a pattern closer to the expected one. A second factor that seems to be at work, however, is the distance between home and the nearest alternative site offering a similar recreation experience. The population concentrations nearest the Little Bear and Upper Blacksmith are also nearer to equivalent alternative sites, so that the relative participation rates within the nearest zones are probably lower than would be the case if closer alternatives were not available.

## Recreation Activities

The median length of stay was 24 hours, somewhat less than the mean of 33 hours. Table 18 shows that the Lower

Blacksmith has proportionately higher day use, while the Little Bear has the highest proportion of overnight visitors. In general, the length of visit was likely to be shorter for shorter travel distances (Table 19).

Respondents were asked how much they spent on food and other items related to their visit (Table 20), and how much they had spent for the more durable recreation equipment they brought (Table 21). The relative totals are as expected, given the proportion of day to overnight use, although it is interesting that the difference is greater in equipment than in food expenditures. One would expect higher durable equipment costs where overnight camping was more common, and this was borne out by the higher equipment costs reported by the Little Bear and Upper Blacksmith samples.

As expected, fishing was the dominant activity overall (Table 22), followed by sleeping and eating. On average, those who traveled further fished and slept more than those closer to home, but there is no clear relationship between distance and eating or other activities (Table 23).

Those in small groups were more likely to spend more time fishing than those in larger groups, who were

Table 18. Length of visit by site.

| Hours at Site | Site<br>Upper Blacksmith | <br>Lower Blacksmith | <br>Little Bear | All Sites |
|---|---|---|---|---|
| 4 or less | 11 | 25 | 9 | 45 |
| 5-8 | 22 | 15 | 4 | 41 |
| 9-15 | 7 | 1 | 2 | 10 |
| 16-30 | 14 | 9 | 15 | 38 |
| 31-55 | 25 | 13 | 9 | 47 |
| 56 or more | 17 | 11 | 6 | 34 |
| Average Visit | 34 | 34 | 30 | 33 |
| Total N | 96 | 74 | 45 | 215 |

Table 19. Length of visit by travel distance.

| Distance Traveled | Hours at Site<br>4 or less | <br>5-8 | <br>9-15 | <br>16-30 | <br>31-55 | <br>56 or more | Total |
|---|---|---|---|---|---|---|---|
| 0-10 | 7 | 3 | 2 | 2 | 2 | 0 | 16 |
| 11-25 | 17 | 16 | 1 | 5 | 5 | 7 | 51 |
| 26-40 | 12 | 7 | 1 | 8 | 16 | 11 | 55 |
| 41-60 | 3 | 11 | 5 | 5 | 11 | 10 | 45 |
| 61-90 | 1 | 2 | 1 | 13 | 4 | 5 | 26 |
| 91-130 | 2 | 1 | 0 | 2 | 8 | 0 | 13 |
| >130 | 3 | 1 | 0 | 3 | 1 | 1 | 9 |
| Total | 45 | 41 | 10 | 38 | 47 | 34 | 215 |

Table 20. Average expenditures for food and equipment, by site.

| Average Expenditure | Site | | | All Sites |
|---|---|---|---|---|
| | Upper Blacksmith | Lower Blacksmith | Little Bear | |
| Food | $29.61 | $24.85 | $32.53 | $28.60 |
| Equipment | 13.86 | 5.01 | 13.93 | 10.87 |
| Total | $42.47 | $29.86 | $46.46 | $38.47 |

Table 21. Cost of durable recreation equipment.

| Equipment Type | $ by Site | | | All Sites |
|---|---|---|---|---|
| | Upper Blacksmith | Lower Blacksmith | Little Bear | |
| RV, camper, trailer | 1,790 | 1,044 | 1,923 | 1,561 |
| Tents and awnings | 50 | 169 | 44 | 90 |
| Sleeping bags, etc. | 51 | 70 | 67 | 61 |
| Food preparation and amenities | 38 | 76 | 92 | 63 |
| Fishing equipment | 63 | 64 | 88 | 68 |
| Licenses | 16 | 10 | 16 | 14 |
| Other | 0 | 9 | 35 | 10 |
| Average Total | 2,009 | 1,442 | 2,266 | 1,868 |

Table 22. Average percentage of time allocated to different activities, by site.

| Activity | Site | | | All Sites (N = 215) |
|---|---|---|---|---|
| | Upper Blacksmith (N = 96) | Lower Blacksmith (N = 74) | Little Bear (N = 45) | |
| Fishing | 27.7 | 25.2 | 21.2 | 25.5 |
| Eating | 11.1 | 6.1 | 11.0 | 9.4 |
| Sleeping | 13.3 | 4.8 | 14.2 | 10.5 |
| Water play | 5.5 | 3.6 | 5.4 | 4.8 |
| Hiking | 3.4 | 2.7 | 2.6 | 2.9 |
| Games | 3.6 | 0.6 | 2.2 | 2.3 |
| Other | 4.2 | 3.8 | 6.5 | 4.6 |

more likely to be involved in other recreation activities (Table 24). Sleeping was less significant at the extremes of group size, while time spent eating showed no clear trend related to group size.

## Site Evaluations

Respondents were asked to rate their recreation site on a scale of 1 to 10 in terms of several site characteristics, with 10 designating an ideal site. As shown on Table 25, the Lower Blacksmith had the highest overall rating, and the Little Bear the lowest. Water consistently rated high, with Little Bear respondents showing the greatest sensitivity to stream flow, and Upper Blacksmith the lowest. When asked to rate several flow levels (Table 26), Little Bear respondents were less likely to be bothered by higher than present flows, and more likely to be bothered by lower flows, than respondents at either of the other sites. Little Bear respondents also preferred higher minimum acceptable flows (Table 27), and were willing to pay 20 percent more, on average, to maintain an acceptable flow (Table 28).

Respondents were asked to specify the maximum number of others who would

Table 23. Number and percent of respondents spending more than 10 percent of their time fishing, sleeping, eating, or other activities, by travel distance.

| Travel Distance | Activity |  |  |  |  |  |  |  | Total in Distance Zone |
|---|---|---|---|---|---|---|---|---|---|
|  | Fishing |  | Sleeping |  | Eating |  | Other |  |  |
|  | # | % | # | % | # | % | # | % |  |
| 0-10 | 4 | 25 | 4 | 25 | 2 | 13 | 4 | 25 | 16 |
| 11-25 | 14 | 27 | 9 | 18 | 18 | 35 | 19 | 37 | 51 |
| 26-40 | 30 | 55 | 24 | 44 | 8 | 15 | 18 | 33 | 55 |
| 41-60 | 24 | 53 | 17 | 38 | 9 | 35 | 12 | 27 | 45 |
| 61-90 | 13 | 50 | 14 | 54 | 8 | 31 | 13 | 50 | 26 |
| 91-130 | 9 | 69 | 8 | 62 | 1 | 8 | 2 | 15 | 13 |
| >130 | 3 | 33 | 1 | 11 | 3 | 33 | 2 | 22 | 9 |
|  |  |  |  |  |  |  |  |  | 215 |

Table 24. Number and percent of respondents spending more than 10 percent of their time fishing, sleeping, eating, or in other activities, by group size.

| Number in Group | Activity |  |  |  |  |  |  |  | Total Number |
|---|---|---|---|---|---|---|---|---|---|
|  | Fishing |  | Sleeping |  | Eating |  | Other |  |  |
|  | # | % | # | % | # | % | # | % |  |
| 1 | 12 | 57 | 3 | 14 | 5 | 24 | 5 | 24 | 21 |
| 2 | 30 | 59 | 18 | 35 | 6 | 12 | 10 | 20 | 51 |
| 3 | 24 | 56 | 16 | 37 | 11 | 26 | 12 | 28 | 43 |
| 4 | 14 | 35 | 20 | 50 | 7 | 18 | 18 | 45 | 40 |
| 5-6 | 10 | 37 | 9 | 33 | 12 | 44 | 10 | 37 | 27 |
| 7-10 | 6 | 23 | 8 | 31 | 5 | 19 | 9 | 35 | 26 |
| > 10 | 1 | 14 | 2 | 29 | 3 | 43 | 7 | 100 | 7 |
|  |  |  |  |  |  |  |  |  | 215 |

Table 25. Ratings of site characteristics, by site.

| Characteristic | Site<br>Upper Blacksmith | <br>Lower Blacksmith | <br>Little Bear | All Sites |
|---|---|---|---|---|
| Distance | 7.7 | 8.1 | 7.3 | 7.8 |
| Privacy | 7.9 | 7.3 | 7.5 | 7.6 |
| Facilities | 4.2 | 5.9 | 3.0 | 4.5 |
| Landscape | 8.5 | 8.3 | 7.3 | 8.2 |
| Insects | 4.0 | 5.5 | 4.9 | 4.7 |
| Water | 8.7 | 8.1 | 8.4 | 8.4 |
| Fishing suitability | 5.8 | 6.9 | 6.8 | 6.4 |
| Composite | 6.7 | 7.2 | 6.5 | 6.8 |

Table 26. Average streamflow evaluations, by site (1 = unacceptably low, 5 = unacceptably high).

| Flow Level | Site<br>Upper Blacksmith | <br>Lower Blacksmith | <br>Little Bear | All Sites |
|---|---|---|---|---|
| 2 x present level | 1.6 | 1.6 | 1.8 | 1.7 |
| 1.5 x present level | 1.9 | 2.0 | 2.0 | 2.0 |
| Present level | 3.1 | 3.1 | 3.1 | 3.1 |
| 0.5 x present level | 4.2 | 4.3 | 4.4 | 4.3 |
| No water | 4.9 | 5.0 | 5.0 | 5.0 |

Table 27. Minimum acceptable flow as a percent of current flow, by site.

| Flow Level | Site<br>Upper Blacksmith (N = 95) | <br>Lower Blacksmith (N = 73) | <br>Little Bear (N = 45) | All Sites (N = 213) |
|---|---|---|---|---|
| 10 | 1 | 3 | 0 | 4 |
| 25 | 6 | 4 | 0 | 10 |
| 33 | 11 | 9 | 1 | 21 |
| 50 | 30 | 19 | 17 | 66 |
| 67 | 29 | 10 | 6 | 45 |
| 75 | 11 | 12 | 14 | 37 |
| 99 | 7 | 16 | 7 | 30 |
| Mean Level | 58 | 62 | 67 | 61 |

be acceptable at the site before it became too crowded. Respondents used their own definition of site boundaries. They were asked to indicate whether the number of others they had seen was about right, too high, or too low. Table 29 shows that most people were satisfied with the number of others at the site. Even for the lowest crowding thresholds, those who felt crowding pressure did not greatly exceed those who would like to have seen more people. Those in smaller groups tended to have lower crowding thresholds (Table 30).

Table 28. Willingness to pay to maintain acceptable flow levels.

| Dollars Willing to Pay | Site: Upper Blacksmith (N = 96) | Site: Lower Blacksmith (N = 74) | Site: Little Bear (N = 45) | All Sites (N = 215) |
|---|---|---|---|---|
| 0 | 15 | 21 | 5 | 41 |
| 1-2 | 60 | 22 | 22 | 104 |
| 3-4 | 14 | 20 | 11 | 45 |
| 5-6 | 2 | 7 | 3 | 12 |
| 7-10 | 4 | 3 | 3 | 10 |
| >10 | 1 | 1 | 1 | 3 |

Table 29. Perceived congestion, by crowding threshold.

| Number of Others Seen | Crowding Tolerance: 1-2 | 3-4 | 5-6 | 7-8 | 9-10 | >10 | Total |
|---|---|---|---|---|---|---|---|
| Fewer than preferred | 12 | 8 | 4 | 2 | 2 | 5 | 33 |
| About right | 39 | 21 | 22 | 15 | 17 | 25 | 139 |
| More than preferred | 17 | 7 | 7 | 2 | 2 | 7 | 42 |
| Total | 68 | 36 | 33 | 19 | 21 | 37 | 214 |

Table 30. Crowding tolerance by group size.

| Number in Group | Crowding Tolerance: 1-2 | 3-4 | 5-6 | 7-8 | 9-10 | >10 | Total |
|---|---|---|---|---|---|---|---|
| 1 | 5 | 7 | 4 | 0 | 0 | 5 | 21 |
| 2 | 19 | 9 | 8 | 4 | 4 | 7 | 51 |
| 3 | 19 | 4 | 7 | 2 | 4 | 7 | 43 |
| 4 | 16 | 10 | 4 | 3 | 3 | 4 | 40 |
| 5-6 | 4 | 3 | 4 | 5 | 4 | 7 | 27 |
| 7-10 | 4 | 3 | 4 | 4 | 5 | 6 | 26 |
| >10 | 2 | 0 | 2 | 1 | 1 | 1 | 7 |
| Total | 69 | 36 | 33 | 19 | 21 | 37 | 215 |

# CHAPTER VII

## DATA COMPILATION AND MODEL RESULTS

The survey was conducted on-site for 12 days in July, August, and September of 1982. These included four weekdays and eight weekend days. The sampling period during the recreation season was 93 days of which 67 days were weekdays and 26 days were weekends. The number of groups surveyed on the four weekdays was 50 and on the eight weekend days was 150. An automobile count was used to estimate the total number of groups (to account for the unsampled visitors). The number of automobiles counted on the 12 survey days was 300. Based on this information, the total estimated visits for the season adjusted for weekdays, weekends and unsampled visitors on survey days is 1988. (The automobile count was proportioned among weekdays and weekends based on the number of groups interviewed. This corresponds to 75 vehicles on the 4 weekdays and 225 vehicles on the 8 weekend days. For a total of 67 week days and 26 weekend days, the number of vehicles is estimated to be 1988.) This excludes out-of-state visitors estimated at 85.

### Estimating Instream Flow Effects on Visitation

Two zone classifications, one for estimating visitation equation and the other for estimating instream flow effects on visitation, were used. The first classification specified four zones based on average distances of 8, 15, 33, and over 40 miles from the site. This classification was used to estimate the effect of hypothetical changes in instream flow on visitation rates. Visitors were asked to indicate the percentage of current flow below which they would not visit the site. The percentages given as options were 0, 10, 25, 33, 50, 67, 75 and 100. The maximum was limited to the present flow levels since 1982 had much higher than average flows. The estimated number of visitors for various flow levels as a percent of the number of visitors at 100 percent of the flow was recorded for the four zones (Table 31). Zonal differences were not significant, and the average for all zones could have been used. However, a check was needed to insure that the responses were not dependent on the distance traveled. A plot of the data is shown in Figure 8. The figure indicates an S shaped curve with increasing rates initially and decreasing rates at higher values of $W_j$. The logistic function defined in Equation 22 can be rewritten in stochastic form as

$$\ln \frac{f(w_j)}{1 - f(w_j)} = \gamma + \delta w_j + \varepsilon \quad . \quad . \quad (26)$$

where $\varepsilon$ is assumed random normal with zero mean and constant variance. The estimated equation is

$$\ln \left(\frac{f(w_j)}{1 - f(w_j)}\right) = \underset{(0.321)}{-5.061} + \underset{(0.006)}{0.106}\, w_j \quad . \quad . \quad (27)$$

The values in parentheses are the standard error of the estimates. The corresponding t values are -15.78 and 18.23. The F(1,31) ratio is 332.5 and the $R^2$ was 0.92.

Table 31. Data for estimating $f(w_j)$ function.

| $w_j$ | Zone 1 (15 Miles) $f(w_j)$ x 100 | Zone 2 (7 Miles) $f(w_j)$ x 100 | Zone 3 (33 Miles) $f(w_j)$ x 100 | Zone 4 (Over 40 Miles) $f(w_j)$ x 100 |
|---|---|---|---|---|
| 0 | 3.22 | 3.18 | 0.00 | 0.00 |
| 10 | 6.44 | 6.35 | 1.34 | 2.00 |
| 25 | 9.68 | 12.71 | 9.33 | 8.00 |
| 33 | 22.58 | 25.40 | 18.67 | 18.00 |
| 50 | 48.38 | 50.79 | 49.33 | 40.00 |
| 67 | 67.74 | 76.20 | 70.67 | 66.00 |
| 75 | 90.32 | 88.91 | 86.67 | 87.82 |
| 100 | 100.00 | 100.00 | 100.00 | 100.00 |

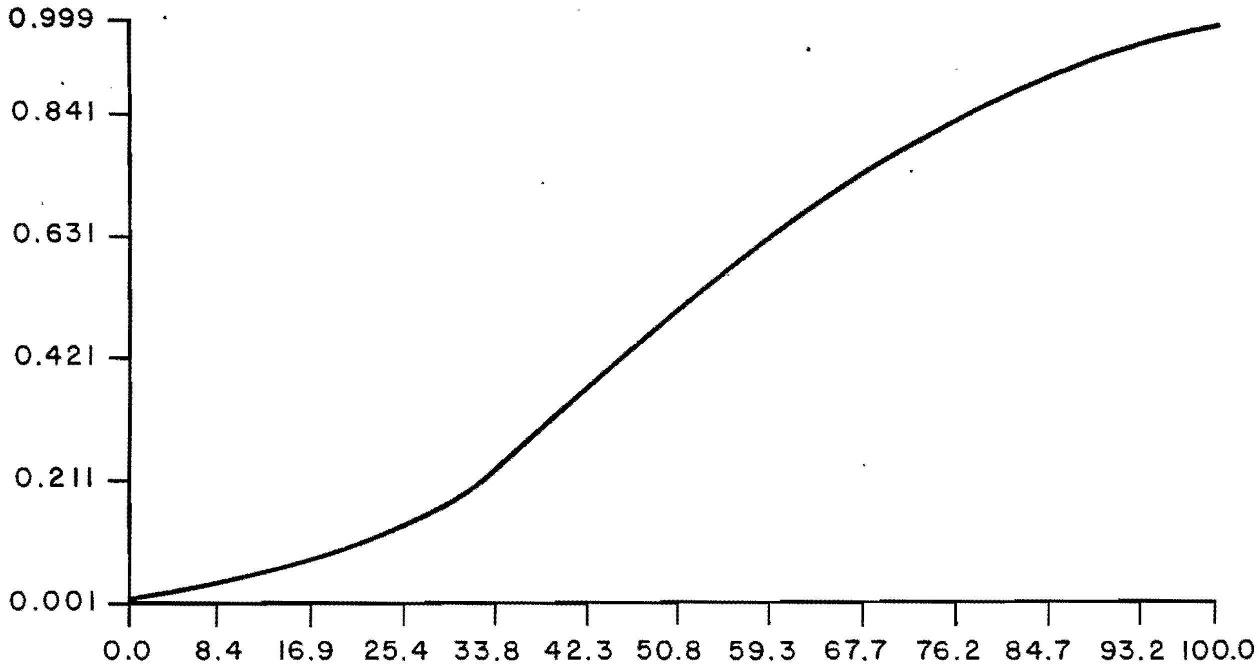

Figure 8. Data plot indicates an S shaped curve with increasing rates initially, and decreasing rates at higher values of $W_j$.

## Estimating Visitation Equation

For estimating the demand for recreation at site 1 by the travel cost approach, nine distance zones were constructed. Since the potentially competitive Logan Canyon area is within 15 miles of the Blacksmith Fork site, the zones were defined with respect to both distance as well as direction. This allowed estimation of distances to alternate sites more precisely. Zonal boundaries were defined in such a way that population could be estimated using census district maps.

The data used for estimating visitation equations are shown in Table 32. The cost equation suggested by James (1968) is given by

$$c = 2d((1 + a)m + t/v)/bp$$

where m is vehicle operating cost per mile, a is food and other costs over and above spent at home expressed as a fraction of vehicle operating cost, t is the time cost of travel per hour (depends on income), b is the number of days spent at site, p is the number of people in the group and d is the total distance. It was assumed that a = 0, b = 1 and t was one-third of the wage cost of family wage income. Based on these assumptions, the cost per trip from any zone was calculated for each sample and averaged for the group from each zone. The distances to alternate sites were also calculated for each sample and averaged for the group. The data used for estimating the visitation equation (Equation 20) along with population estimates are shown in Table 32. The estimated form of Equation 20 is

$$\ln V_8^Z = \underset{(2.469)}{-6.369} - \underset{(0.677)}{3.829} \ln P_Z + \underset{(1.167)}{3.236} \ln D_Z \quad . \; . \; . \; (28)$$

The numbers in parentheses are the standard errors. The t values are 2.579, -5.659, 2.773 for six degrees of freedom. The F(2,6) ratio was 25.58 and the $R^2$ value was 0.9. The price elasticity obtained from the visitation equation indicates that the visitation response is relatively elastic as compared to the range given by Boyet and Tolley (1966) of -1.0 to -2.5. This is perhaps due to availability of alternative sites for recreation at very low additional cost.

Table 32. Data for estimating visitation equation.

| Zone | Estimated Visits | Population | Visitation Rate $(V_8^Z) \times 10^6$ | Cost $(P_Z)$ in \$ Per Visit | Distance to Alternate Site $(D_Z)$ Miles |
|---|---|---|---|---|---|
| 1 | 311 | 5,836 | 53,290 | 3.05 | 14.89 |
| 2 | 321 | 33,877 | 9,475 | 5.13 | 9.61 |
| 3 | 60 | 12,344 | 4,861 | 8.94 | 21.0 |
| 4 | 90 | 7,441 | 12,095 | 15.05 | 32.78 |
| 5 | 501 | 18,176 | 27,564 | 11.05 | 33.22 |
| 6 | 392 | 149,716 | 2,618 | 20.97 | 35.51 |
| 7 | 181 | 175,946 | 1,029 | 23.18 | 39.44 |
| 8 | 111 | 671,290 | 165 | 35.74 | 39.09 |
| 9 | 21 | 250,000 | 84 | 43.50 | 40.00 |

## Derivation of Demand and Benefits

The visitation equation (Equation 28) was used to derive a demand schedule (Equation 24) plotted in Figure 9. The number of visits predicted by the equation is 2142 as opposed to the estimated visits of 1988. The total benefits for various instream flows expressed as percentages of 1982 flows are shown in Table 33 as estimated by numerical integration of Equation 25. The total benefit at 1982 flows is estimated to be $9,359. The marginal benefits were calculated by differentiating Equation 25 with respect to $w_j$. From Table 33, the largest marginal benefit of $244 per percent was at 50 percent of the flow. Amounts decreased to $3.86 per percent at 1982 flows. The total benefits increased at a decreasing rate in this range.

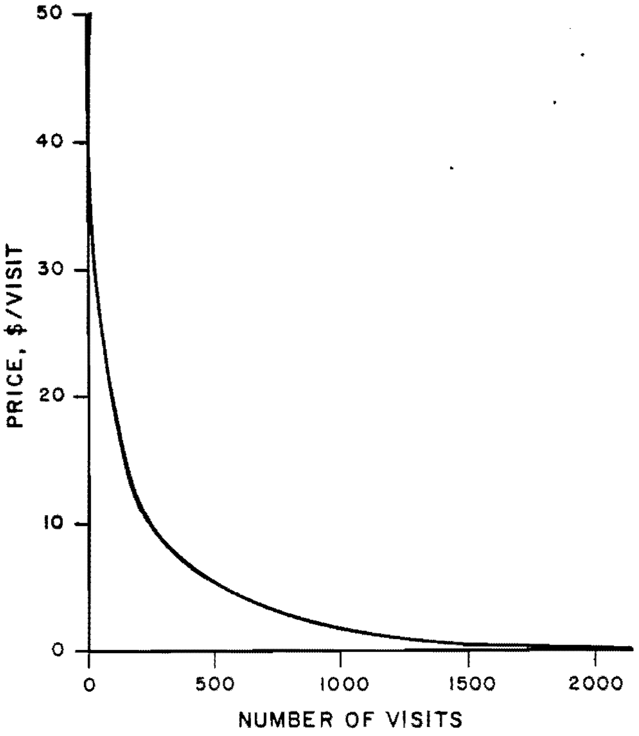

Figure 9. Demand schedule for recreation in Blacksmith Fork area.

## Sensitivity of Benefits

The estimate by this approach should be regarded as an estimate of minimum benefits from recreation activities because:

a) The use of Marshallian demand for estimating CV underestimates the total benefits. However within the conditions given by Willig (1976), the error is probably less than 5 percent.

b) The survey was taken during afternoons and evenings. Visitors in the morning and night hours and not present during the survey hours would have been missed in the vehicle count. Therefore, the numbers of visitors could have been underestimated perhaps by as much as 20 to 25 percent.

c) The cost $P_Z$ could have been underestimated by not taking into account food and other costs that were incurred over and above what the visitors would have spent at home. This may have been a relevant cost for visitors coming from distant zones. Not taking this cost tends to underestimate benefits by shifting the demand to the left. An error in $P_Z$ by 1 percent would increase benefits by 1 percent.

d) Due to the conditions required for weak complementarity, preservation demands are not taken into account. Therefore, benefits associated with this component are ignored.

Table 34 shows the sensitivity of changes in $P_Z$, $N_Z$ and $D_Z$ by 10, 20, 30, 40 and 50 percent on the benefits and the percent change in benefits. It is clear that the percent increase in benefits is approximately equal to percent underestimates of the data $P_Z$ and $V^Z$. Assuming that $P_Z$ was underestimated by 50 percent, $V_Z$ was underestimated by 25 percent and the use of Marshallian demand underestimates true benefits by 5 percent, the upper bound on recreation benefits (using Table 34) for 1982 would be

Table 33. Total and marginal benefits of instream flow.

| Percent of 1982 Flows | Seasonal Average Flows in cfs | Marginal Instream Flow Benefits ($/percent)[d] | Total Recreation Benefits ($) |
|---|---|---|---|
| 100 | 159.38[b] | 3.86 | 9322 (9359)[a] |
| 95 | 151.41 | 4.09 | 9296 |
| 90 | 143.44 | 10.99 | 9254 |
| 85 | 135.47 | 18.39 | 9182 |
| 80 | 127.50 | 30.43 | 9062 |
| 75 | 119.50 | 49.47 | 8866 |
| 70 | 111.50 | 78.19 | 8551 |
| 65 | 104.76[c] | 118.18 | 8064 |
| 60 | 95.60 | 166.96 | 7354 |
| 55 | 87.70 | 214.59 | 6396 |
| 50 | 79.70 | 244.00 | 5237 |
| 45 | 71.70 | 242.90 | 4005 |
| 40 | 63.80 | 210.57 | 2861 |

[a] Benefits when $f(W_8) = 1$. The estimated $f(W_8)$ is slightly less than 1.

[b] Observed values for July, August, and September 1982, at Blacksmith Fork River.

[c] Observed mean for July, August, and September for 1951-70 at Blacksmith Fork River.

[d] One percent equals 285 AF.

Table 34. Sensitivity of benefits (percent change in benefits) to changes in data.

| Percent Change | Parameter | | |
|---|---|---|---|
| | $P_Z$ | $V^Z$ | $D_Z$ |
| 0 | 9,359<br>(0) | 9,359<br>(0) | 9,359<br>(0) |
| 10 | 10,271<br>(9.74) | 10,294<br>(10) | 9,359<br>(0) |
| 20 | 11,176<br>(19.4) | 11,230<br>(20) | 9,359<br>(0) |
| 30 | 12,073<br>(29.0) | 12,167<br>(30) | 9,359<br>(0) |
| 40 | 12,962<br>(38.5) | 13,103<br>(40) | 9,359<br>(0) |
| 50 | 13,843<br>(47.9) | 14,039<br>(50) | 9,359<br>(0) |

$$B_u(w_8) = 9359 \times 1.479 \times 1.25 \times 1.05$$

$$= \$18,169$$

This estimate is 94 percent more than the estimated benefits. The upper bounds for marginal and total benefits could be derived by multiplying the figures in Table 33 by 1.94. The average flow during July, August and September is about 0.65 times the 1982 flow levels (Table 33). This means that the recreation benefits for average years range from $8,064 to $15,644.

### Implications for Cost-Benefit Analysis

In order to provide information for policy making with respect to instream flows, benefits of all instream uses as a function of flows are needed. The only component quantified in this study is the benefits resulting from recreation. Some of the instream values omitted include:

a) The relative land values adjacent to the river and changes in these values as a function of flows.

b) The relative home values by the river and changes in the values of the structure as a function of flows.

c) The demands for preserving instream flows on the part of non-visitors to the recreation sites.

d) Increased population and income and the resulting demand growth for instream flows.

e) Benefits of preventing irreversible damages to the aquatic life.

The above list is by no means comprehensive. If information on total benefits could be computed, the quantitative information for policy-making would be improved. However, the benefit function derived for recreation in this study provides a methodology for cost-benefit analysis.

Based on observed flows for May-September of 1982, the water availability was estimated to be 149,000 AF. From Table 1, this flow occurs with a probability of 0.029. The mean water availability for the 5-month period is 56 percent of the 1982 flows. However on Table 33, the mean flows in Blacksmith River for the recreation months (July, August, and September) are shown to be 65 percent of the 1982 flows in the same period. This small discrepancy is due to the assumption of perfect correlation between monthly flows and seasonal total water availability. Since the allocation of water to irrigated agriculture is determined over the 5-month period, instream flow benefits will be calculated based on flows during that 5-month period.

## Expected Agricultural Benefits

The decision rules for water allocations corresponding to the cost-minimization model are shown in Tables 6-10. If these decision rules are followed for diversion points in the stream, the expected reduction in agricultural output resulting from maintaining various levels of instream flows through different strategies are shown in Table 5. The expected agricultural output for the base solution (with no instream flow requirement) was $1,489,836. The expected agricultural benefits corresponding to various expected instream flows could be found by subtracting the costs in Table 5 from the base solution value of $1,489,836.

## Expected Instream Flow Benefits

Given a benefit function for instream flows, $B(w_j)$, the expected benefits could be calculated for any one of the five strategies corresponding to the expected instream flows of 40 percent, 50 percent, 60 percent or 70 percent of average flow. For example, the expected benefits corresponding to strategy EIF1, for 40 percent flow, could be calculated from the decision rules under column 3 of Table 6. The instream flows from Table 6 are shown in the first column of Table 35. They are converted to percentage of 1982 flow (148,972 AF) in the second column. Using the benefit function derived in Equation 25, the benefits are calculated in column 3. The fourth column gives the corresponding probabilities. The expected benefit which is $3700 is obtained by multiplying the probabilities by the corresponding benefits and summing. For each of the strategies, using similar procedure, expected instream flow benefits could be calculated for expected instream flows of 40 percent, 50 percent, 60 percent, and 70 percent.

Table 35. Expected benefits from instream flows.

| Instream Flows (AF) | Percent of 1982 Flows | Benefits $ | Probability of Occurrence |
|---|---|---|---|
| 11,551 | 7.75 | 133 | 0.029 |
| 27,252 | 18.29 | 395 | 0.1176 |
| 38,804 | 26.05 | 853 | 0.1764 |
| 58,804 | 39.47 | 2749 | 0.3235 |
| 78,791 | 52.87 | 5924 | 0.1470 |
| 98,789 | 66.31 | 8211 | 0.1470 |
| 118,789 | 79.74 | 9054 | 0.029 |
| 138,789 | 93.16 | 9283 | 0.029 |

## Optimal Instream Flows

For each strategy, the total expected benefits (agricultural benefits and instream flow benefits) could be calculated for each expected instream flow level. The expected flow level for which the total expected benefit is a maximum is optimal. The strategy that yields the maximum expected benefits should be selected as a preferred strategy, and the corresponding decision rules in Tables 6-10 should then be followed.

The marginal instream flow benefits estimated are less than $0.50/AF in a normal year assuming average flow condition of 56 percent of 1982 flows. Even if the upper bound is used, it is still less than $1 per acre foot during the recreation season. The agricultural values are far greater. The average agricultural productivity of water in the study area is estimated at $18/AF. This is obtained by dividing the expected output of $1,489,836 for the base solution by the expected water availability. If uncertainty is taken into account, the productivity of water is likely to be high. Based on these findings, should conflicts arise between instream and off-stream uses, it seems reasonable that at present flow levels, the productivity of diverted water is likely to be greater and therefore marginal allocations for off-stream uses are recommended.

However, large depletions in any stream reach can cause irreversible damages. These damages might affect future recreation potential, and the associated costs are difficult to estimate. In fact, there are parts of stream reaches where in certain years, the stream is already practically dewatered. These stream reaches may have to be protected.

# CHAPTER VIII

## CONCLUSIONS

In the first phase of the study, a stochastic linear programming model for Blacksmith Fork and Little Bear Rivers estimated the expected reduction in agricultural output required to maintain any given level of expected instream flow. The analysis is repeated for instream flows corresponding to 40, 50, 60, and 70 percent of the average annual flow. Five legal strategies for maintaining instream flows were compared. The first strategy, EIF 1, assumes that water rights of different seniority are used to maintain a fixed expected instream flow. In the second strategy, EIF 2, the allocation decisions are made annually and vary. The third strategy, IF, reserves the most senior rights to provide a specified instream flow. This strategy is the most commonly used technique in many of the western states. The fourth and the fifth strategies, CF 1 and CF 2, are similar to EIF 1 and EIF 2 except that the most senior rights are used to preserve 20 percent of average annual flows to avoid any irreversible damages and the rest is obtained from a combination of senior and junior rights to meet the desired level of epected instream flows.

Due to differences in the values of junior and senior rights, the EIF strategy involves a consistently lower cost in terms of foregone agricultural benefits as compared to IF. At higher levels of expected instream flow requirements, the cost differences in between various strategies are narrowed. However, the maintenance of expected instream flows of 70 percent and above would eliminate agriculture. The disadvantage of EIF 1 is that the solution could provide decision rules that could allow flows to be zero during certain periods. To avoid this problem, the CF strategy is used. This strategy while guaranteeing 20 percent of average flows, does not involve an appreciably greater cost than EIF strategy. The irrigated acreage is stable between wet and dry years for both EIF strategies as well as CF strategies for most ranges of water availability. Under minimum flow strategy IF, larger acreages are irrigated under high flow conditions, but irrigated land is zero for low and medium streamflow conditions. Based on these results, the EIF strategy with provisions for maintaining a small instantaneous flow appears to be a promising criterion for establishing policies with respect to instream flows.

To choose an efficient level of expected instream flow, benefit functions for instream uses are needed. By using the survey conducted for another research project, data on recreation are compiled to estimate one component of instream flow benefits. A modified method based on travel cost approach is used to estimate recreation demand from sample data. Changes in visitation rates for hypothetical changes in instream flows obtained from survey are used to derive a demand function for instream flows. The total recreation benefits for the study area are determined to be $8,000 to $16,000 annually.

Based on this benefit function, a methodology for determining the optimal level of expected instream flow is outlined. However, this methodology is described only for illustrative purposes. Further methodological development is needed before setting policies on instream flows.

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