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Streamflow and Recreation

Bo Shelby

Thomas C. Brown

Jonathan G. Taylor

Note

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Abstract

The relation between streamflow and recreation quality has been studied by social scientists, physical and biological scientists, and engineers. These efforts, reviewed here, employed a wide variety of methods, yet nearly all studies found a similar, nonlinear relation of recreation to flow – quality increases with flow to a point, but decreases for further increases in flow. Critical flow levels (points of minimum, optimum, and maximum flow), of course, differ across rivers and activities. Many state laws and agency practices now provide for considering the effects of streamflow on recreation. Within this framework, knowledge of the flow-recreation relation, and its accurate calibration in specific locations, is an important ingredient in the determination of wise streamflow policies.

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Streamflow and Recreation

Bo Shelby, Associate Professor
Department of Forest Resources, Oregon State University

Thomas C. Brown, Economist
Rocky Mountain Forest and Range Experiment Station[1]

Jonathan G. Taylor, Research Social Scientist
National Ecology Research Center[2]

[1] Headquarters is in Fort Collins, in cooperation with Colorado State University.

[2] U.S. Fish and Wildlife Service, Fort Collins, CO.

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INTRODUCTION

River and stream corridors provide a variety of valuable resources, including aquatic habitat for fish and other organisms, riparian habitat for vegetation and terrestrial wildlife, and "recreation habitat" for water-dependent activities such as boating and fishing, as well as water-enhanced activities such as camping and bird watching. River corridors also provide exposure of geologic and geomorphic phenomena, and access to historic or cultural artifacts associated with past human activity. The value of many of these resources and activities is related to streamflow, either directly or indirectly.

This paper focuses on the relation of streamflow to recreation quality. The quality of water-dependent and water-enhanced recreation is intimately tied to streamflow. Yet, the specific relations of flow to recreation quality are not well understood or well documented. We review what is known about these relations and the methods that have been used to study them, and we examine the legal and administrative framework within which information about these relations can be used to protect flows for recreation.

LEGAL AND POLICY FACTORS DRIVING THE INSTREAM FLOW ISSUE

State and federal laws pertaining to water rights, environmental protection, and land management provide opportunities to protect instream flows. Within federal reservations, federal water rights were historically constitutionally immune from any state lawsuit requiring their adjudication. However, in the 1952 statute commonly known as the McCarran Amendment [43 U.S.C. 666] (Marks 1987), Congress granted a limited waiver of federal immunity and federal water rights became subject to state initiated general stream adjudications. Although these claims may be adjudicated in federal or state court, it is not unusual for such cases to be appealed to the U.S. Supreme Court. In addition to water rights, federal and state water, environmental, and land management legislation provides for several study, review, and permitting procedures that can affect instream flows both on and off federal land.

Instream flow protections, whatever their administrative character, do not remove water from the stream, and thus maintain flow for users downstream of the protected area. Instream flow protections constrain subsequent (junior) attempts to divert or store water within or upstream of the protected area.

FEDERAL PROTECTION OF INSTREAM FLOW

Federal protection of instream flow stems from express and implied statutory control, as well as from less direct authority. The first direct statutory mandate for federal protection of streamflow is contained in the Organic Administration Act (of the national forests) of 1897 [16 U.S.C. 475]. The act's protection was stated in the negative: "No national forest shall be established, except to improve and protect the forest within the boundaries or for the purpose of securing favorable conditions of water flows ...." The "favorable conditions of water flows" directive undoubtedly includes watershed protection, but such protection does not necessarily protect instream flow from being diverted. The U.S. Forest Service, however, has interpreted the Organic Act directive to include stream channel maintenance, which requires substantial instream flow (Romm and Bartoloni 1985, Wilkinson and Anderson 1985). (A Forest Service claim of reserved rights for channel maintenance is currently (1990-1991) being argued in Colorado District 1 water court.)

The most direct statutory mandate for federal instream flow protection is found in the Wild and Scenic Rivers Act of 1968 [16 U.S.C. 1271-1287]. Section 1284(c) states, again in the negative:

> Designation of any stream or portion thereof as a national wild, scenic, or recreational river area shall not be construed as a reservation of waters of such streams for purposes other than those specified in this chapter, or in quantities greater than necessary to accomplish these purposes.

With regard to the Act's purposes, it states in Section 1273 (b):

> It is hereby declared to be the policy of the United States that certain selected rivers of the Nation which, with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values, shall be preserved in free-flowing condition, and

that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations.[3]

The law thus expressly reserves rights under federal law, specifies the types of valuable resources that might cause rivers to be protected under the act, and establishes a connection between these resources and free-flowing streams. Providing the resource values associated with streamflows requires managers to determine necessary flows and to develop legal or administrative strategies to protect them.

The Wild and Scenic Rivers Act defines "free-flowing" as "existing or flowing in natural condition without impoundment, diversion, straightening, rip-rapping, or other modification of the waterway. The existence, however, of low dams, diversion works, and other minor structures at the time any river is proposed...shall not automatically bar its consideration for inclusion." Thus, the law recognizes as "facts of life" dams, diversions, and other factors that might be considered antithetical or at least compromising to the idea of a wild or free-flowing river.

The act also recognizes the need to integrate or coordinate policies regarding damming and preserving rivers: "The established national policy of dam and other construction...needs to be complemented by a policy that would preserve selected rivers or sections thereof in their free-flowing condition...." The need for coordination is further underscored by the statement: "The Federal Power Commission shall not license any...project works...on or directly affecting any river which is designated...as a component of the national wild and scenic rivers system...." However, the act goes on to say that "nothing in the foregoing sentence shall preclude the licensing of, or assistance to, developments below or above a wild, scenic, or recreational river area...which will not invade the area or unreasonably diminish the scenic, recreational, and fish and wildlife values."

These clauses point out the need to identify resource values of wild and scenic rivers, show their relation to streamflow, and work within the constraints imposed by other resource uses. Although the point may be debatable, the law appears to use "free flowing" as a relative term and to recognize that it will be necessary to identify the amount of water needed to protect resource values. This focus on purpose is in keeping with the reserved rights doctrine, which as described below limits federal claims to quantities necessary to fulfill the purpose of the land reservation. Thus, it has been argued that it may be difficult to reserve all the water in a stream simply because that is the natural flow (Jackson et al. 1989).

The Wild and Scenic Rivers Act stipulates that jurisdictions of the states and the federal government over waters included in the system "shall be determined by established principles of law.... The jurisdiction of the states over waters of any stream included in a national wild, scenic, or recreational river area shall be unaffected by this act." This language does not preclude the federal government from pursuing federal reserved water rights; it was included to allay states' concerns about federal "taking" or infringement of states' rights. Obviously federal needs for protection of flows in wild and scenic rivers may and probably should be integrated with state administration of water rights, so as to avoid situations where a state may be tempted to "ignore instream flow rights administratively if the state is philosophically hostile to a [federal] instream flow appropriation" (Jackson et al. 1989).

Three basic policy areas lend authority for federal control of instream flows (Shupe 1989): the reserved water rights doctrine, federal permitting and consultation requirements, and environmental protection statutes.

Reserved Rights

The reserved water rights doctrine for federal lands stems from the Winters Doctrine, which established water rights for Indian reservation lands held in federal trust. The Winters Doctrine was established by the U.S. Supreme Court decision in *Winters v. the United States* [207 U.S. 564 (1908)], which determined that the reservation of land for the Assiniboine Indian Tribe carried with it an implied reservation of waters from an adjoining river that were needed for the productive use of the reservation lands (Nelson 1977). The doctrine has developed through the broad application of "Winters Rights" protection for Indian reservations, and has been further broadened to include other federal reservations as well.[4]

In *Arizona v. California* [373 U.S. 546 (1963)] the U.S. Supreme Court upheld the finding of the Special Water Master that "the principle underlying the reservation of water rights for Indian reservations was equally applicable to other federal establishments such as National Recreation Areas and National Forests" (Kiechel 1976, p. 61). The Special Water Master held that national forests in the lower Colorado River basin were established for

[3] *One source of information about which rivers have been designed under this act is the "list of lists" compiled by American Rivers (Echeverria and Fosburgh 1988).*

[4] *Not all federal land is eligible for reserved rights. Reserved rights may apply to federal land reserved from the public domain, but not to land purchased by the government. This distinction between reserved and purchased property is not indicated on most maps showing agency ownership.*

purposes of "the protection of watersheds and the maintenance of natural flows in streams below the sheds [and] recreation for the general public."[5] The Special Water Master also found reservation of water rights for recreation appropriate for the national parks, monuments, and recreation areas found in the Lower Colorado River Basin.

The U.S. Supreme Court applied the reserved rights doctrine in 1976 in *Cappaert v. United States* [426 U.S. 128] to protect the Devil's Hole pupfish in a Nevada national monument of the same name, but limited the reserved right to "only that amount of water necessary to fulfill the purpose of the reservation, no more."

Since the U.S. Supreme Court 1978 decision in *United States v. New Mexico* [438 U.S. 696], non-Indian reserved rights have generally been restricted to those purposes clearly recognized as primary in the legislation setting aside the land. In that case, the U.S. Forest Service had claimed water rights on the Rio Mimbres in the Gila National Forest for stock watering, fisheries, wildlife, esthetics, and recreation. The majority (five-four) opinion of the Court held to a rather narrow interpretation of the 1897 Organic Act, stating that only two limited purposes were authorized for establishment of national forests (timber supply and "favorable conditions of water flows"). The Court further stated that additional purposes stated in the Multiple Use-Sustained Yield Act of 1960 were secondary, not primary, purposes and therefore not sufficient justification for reserved water rights under this Act with a reservation date priority date. For this conclusion the Court relied in part on language in the Multiple Use-Sustained Yield Act that "the national forests are established for outdoor recreation, range, timber, watershed, and wildlife and fish purposes" and that "the purposes of this Act are declared to be supplemental to...the purposes for which the national forests were established" in the Organic Act (Brooks 1979, Fairfax and Andrews 1979, Romm and Bartoloni 1985, Wilkinson and Anderson 1985). The Court left open the issue of whether a right based on the Multiple Use-Sustained Yield Act had been reserved with a 1960 priority date.

Some more recent decisions have placed limits on the purposes for which federal reserved rights could be rewarded, such as the Colorado Supreme Court's 1982 decision regarding the National Park Service's claim of a federal reserved water right for Dinosaur National Monument (Bassin 1985), and the 1983 agreement reached in the Big Horn adjudication in Wyoming regarding the U.S. Forest Service's claim of reserved rights for purposes specified in the Multiple Use-Sustained Yield Act (Mead 1986). However, several other state court decisions or settlements, in Idaho, Colorado, New Mexico, Washington, and Wyoming (Kiechel 1976, Mead 1986), have upheld the concept of federal reserved water rights to maintain streamflow. Future cases will no doubt continue to clarify the role of reserved rights in protecting instream flows.

[5] *Report of Special Master Simon H. Rifkin, Dec. 5, 1969, p. 96.*

Permitting and Consultation

Within the arena of permitting, the Federal Energy Regulatory Commission (FERC) must include in its hydropower license and relicense deliberations consideration of conditions that will ensure adequate facility-bypass flows for instream resource protection. Under the Federal Power Act (Public Law 1082), FERC must engage in comprehensive planning and achieve a balance of potential resource values in its licensing decisions. FERC generally considers recreation a fairly major issue in facility licensing, and it tries to balance its operations with both upstream (reservoir) recreation and downstream (river flow) recreation. Flows necessary for recreation, esthetic quality, and maintenance of fish populations must be balanced against costs such as revenue loss from reduced power generation. Executive Order 313 requires that FERC licensees provide both upstream and downstream recreation as part of the project, consistent with the needs of the area.

In 1990, at the urging of the American Rivers organization, Congress allocated funds to the National Park Service for the Riverwatch Program, under which the Park Service was to act as advocate for nonfishing recreation, considered to have been largely unrepresented in previous FERC license negotiations. More than 250 hydropower project licenses will expire during the 1990's (175 by 1993). Now considered by the Park Service to include fishing as well, the Riverwatch Program provides consultation assistance and cooperation and coordination to hydropower companies, public agencies, and interest groups regarding recreation and natural resources at existing and proposed hydropower projects; the goal is to avoid or mitigate adverse impacts on recreational resources. The primary tasks of the program are to establish lines of communication between the interested parties, and to consult about and provide comments on the hydro projects during the prefiling consultation phase of the FERC relicensing process. Park Service assistance includes reviews of economic evaluations, recreational use studies, exploration of river access issues, and consideration of alternatives to dam construction. The Riverwatch Program provides the only federal review specifically representing recreation interests outside federal areas in the hydro licensing process.

Federal land management agencies can also affect instream flow through issuance or denial of rights-of-way requested for water-related facilities. For example, the Federal Land Policy and Management Act of 1976 [43 U.S.C. 1701 et seq.] specifies that, in considering requests for rights-of-way for "reservoirs, canals, ditches, ... pipelines, tunnels and other facilities and systems for the impoundment, storage, transportation, or distribution of water" (section 1761), agencies will ensure that each right-of-way contains conditions to "minimize damage to scenic and esthetic values and fish and wildlife habitat and otherwise protect the environment" (section 1765) (see also Wilkinson and Anderson 1985).

Consultation requirements are included in several federal laws, a number of which can be related to instream flow protection. The most directly applicable statute is the Fish and Wildlife Service consultation on fish and wildlife affected by water projects constructed, licensed, or permitted by the federal government. This statute identifies fish and wildlife resources as valid elements of a development project, and it provides for mitigation or enhancement of these resources.

Environmental Protection

The seminal federal legislation in this policy area is the National Environmental Policy Act (NEPA) of 1969 [42 U.S.C. 4331 et seq.]. NEPA declares a federal commitment to environmental protection and requires careful consideration of environmental impacts, mitigation, and alternatives to federal actions. This legislation requires the preparation of an Environmental Impact Statement (EIS) for each major federal action that may significantly affect the quality of the human environment. Federal actions are broadly defined in NEPA to include not only construction, but also licensing, permitting, and funding a project as well.

NEPA specifically requires coordination with appropriate federal, state, and local agencies, as well as the general public, in the process of preparing and reviewing the EIS. Section 4332(c) requires federal officials to consult with and obtain the comments of any agency that has jurisdiction or special expertise with respect to any environmental impact involved. These considerations should include instream flow for any federal project that may alter flow in an existing watercourse.

Other environmental legislation also has the potential for engaging federal involvement in instream flow protection or enhancement for recreational or esthetic purposes. For example, the Clean Water Act of 1977 [33 U.S.C. 1251, et seq.] allows consideration of reservoir storage and releases not only for maintaining downstream water quality, but also for recreation, esthetics, and fish and wildlife (section 1252).

INSTREAM FLOW REGULATION BY STATES

The principal doctrines establishing rights to surface waters in the United States are riparian rights in the more humid East and prior appropriation rights in the more arid West (MacDonnell et al. 1989, Wilkinson 1989). Under the riparian doctrine, water rights are available to persons whose property adjoins the water body. In contrast, the prior appropriation doctrine emphasizes diversion under the principles of beneficial use and "first in time" being "first in right."

The traditional requirements for a valid water claim in the West include (1) intent to apply the water to a beneficial use, (2) actual diversion of water from a naturally occurring water body, and (3) application of the water to a beneficial use within a reasonable time. The designation of "beneficial use" water rights for preserving fish and wildlife habitat or for maintaining riverine resources for recreational use has not been the primary impediment to instream flow regulation. The difficulty most often encountered is the traditional requirement that water be diverted from the natural water course in order to establish a water right under the Prior Appropriation doctrine (Tarlock 1978, 1979). Therefore, a number of states have passed legislation that specifically allows protection and maintenance of water in the channel as instream flow.

In a 1986 survey of U.S. states and Canadian provinces, Reiser et al. (1989) identified legislation protecting instream flow in 16 states, 12 of which were west of or along the 100th meridian. Instream flow regulations in the western states have more recently been reviewed by McKinney and Taylor (1988) and MacDonnell et al. (1989). Table 1 shows the legal means of instream flow regulation for these 16 states plus Nevada. The table lists the year of enactment of the instream flow protection legislation or code. Oregon was the first state to establish rights for instream flows, passing legislation in 1955. The table also indicates whether recreation and esthetic quality are specifically designated as appropriate beneficial uses for which instream flow protection can be implemented. So far, 13 of the 17 states have specifically designated recreation as a legitimate reason for protecting instream flows. Texas currently is testing whether its water and fish and wildlife codes can be invoked to protect a "recreation resource," in this instance to preserve dinosaur tracks in a state park. Only six of the states allow protection for aesthetic or scenic reasons. However, several of the other states allow

Table 1. – State instream flow legislation: Protection of recreation and esthetics.[1]

State	Law	Year passed	Protects: Recreation	Protects: Esthetics
Alaska	AK Water Use Act (A5 46.15.145)	1980	Yes	Yes
Arkansas	State Act 1051	1985	Yes	No
	SA 469	1989		
Colorado	CO Min. Streamflow	1987	No	No
	SB-97 (CRS 37-92-102)	1973		
Hawaii	Instream Flow Use Protection Act (HRS 176D)	1982	Yes	Yes
Idaho	Minimum Streamflow Act (IC 42-1501 to 1505)	1978	Yes	Yes
Indiana	IN Code 13-2-6.1, Water Resource Mgnt.	1983	No	No
Kansas	Minimum Desirable Streamflow Act	1980	Yes	No
Minnesota	MN Statutes 195.39	1981	Yes	Yes
	Sub. 1, 105.4	1977		
Montana	Water Use Act (MCA 85-2-316)	1973	Yes	No
Nebraska	Instream Appropriations	1984	Yes	No
Nevada	NV Statutes 533.030,035	[2] 1988	Yes	No
Oregon	Minimum flow law (ORS 536.325)	1955	Yes	Yes
	Rev. (ORS 587.322-360)	1987	Yes	Yes
Pennsylvania	Scenic Rivers Act	1972	Yes	Yes
	Clean Streams Law	1975		
Texas	House Bill 2, Parks & Wildlife Code	1985	Court testing	No
Utah	Instream Flow Amendment HB 58 (4C 73-3-3)	1986	No	No
Washington	Water Resources Act (RCW 90.54)	1971	Yes	Yes
	Min. Flows & Levels Act (RCW 90.22)	1967		
Wyoming	Enrolled Act # 53 (WS 41-3-1001)	1986	No	No

[1] *Sources: Aiken 1983a; 1983b; Brandes 1985; Bristow and Gould 1986; Freeman and Robinson 1986; McKinney and Taylor 1988; Reiser et al. 1989; Trembly 1987; White 1982; White 1983.*
[2] *Date of Nevada Supreme Court decision (Potter 1990).*

instream flow rights to protect water quality that affects esthetic quality. In several states, natural resource department personnel consider water quality protection the means for preserving esthetic quality of riverine areas.

Lack of specific legislation authorizing instream flow protection does not always preclude such protection. For example, in Arizona the Department of Water Resources has approved permits for instream uses, based on its understanding of a 1976 Arizona Court of Appeals decision regarding in situ water use (Dishlip 1989). And in California the state's granting and regulation of permits and licenses, water quality management, and application of the public trust doctrine all offer opportunities that sometimes have the effect of protecting instream flows (Gray 1989).

Whitewater boating, unlike fishing, may not be able to rely directly on preservation of fish populations to protect recreation opportunities. Of the roughly 34,000 miles of river identified in the American Whitewater Affiliation's recent whitewater (class II or better rapids) inventory covering 39 states (Barrow 1989), 34% of the miles are found in the states identified in table 1 as allowing protection of instream flow for recreation (not counting Texas' 1,261 miles). The 34,000 miles are found along 2,133 segments of 1,348 rivers included in the inventory and compose about 1% of the total river mileage in the United States (Barrow 1989).

FEDERAL AGENCIES AND INSTREAM FLOW FOR RECREATION

As the preceding section indicates, a variety of legal mechanisms and administrative policies provide the impetus for determining the effect of instream flow on recreation. The Wild and Scenic Rivers Act, for example, establishes an express federal reserved right and gives federal agencies a clear legal opportunity to establish water rights for streamflow. But the needs must be quantified and justified as required by law, and the rights should if possible be filed in a way that is compatible with appropriate federal and state water law. In spite of the federal reserved rights doctrine, federal agencies with river management responsibilities may have an obligation to quantify and file for an instream flow water right in order to protect riverine resources, as directed by Congress or in ongoing McCarran Act adjudications. Although federal reserved rights cannot be abandoned or lost through non-use, agencies that fail to seek timely quantification of such rights may risk a more difficult task if they seek to quantify them in the future.

To carry out their charges regarding instream flow, federal agencies may need to file for water rights, modify hydroelectric energy production goals and procedures, alter schedules used to meet downstream consumptive use requests, and reconsider procedures used to provide flood protection or reservoir recreation. Further, as suggested by the U.S. Water Resources Council (1983), analysis of federally funded projects may incorporate economic valuation of the benefits and costs of alternative flow regimes. Where instream flow is important, adequate analysis and planning for all of these actions require an understanding of the underlying relation of flow to instream uses.

In this section we review some positions and past actions of federal agencies regarding determination of instream flow needs for recreation. Most agencies do not have official positions regarding this issue that are applicable to all situations. The following summaries are drawn from a variety of sources, including published and unpublished materials, various contacts inside and outside the agencies, and our own impressions. There may be unpublished studies by these agencies of which we are unaware. However, we hope these studies included in our review provide a reasonable idea of each agency's approach. There clearly are differences in agency approaches, and it makes sense to characterize them as best we can, in spite of the lack of official policy and the difficulty of obtaining an all-inclusive picture.

FACILITY-OPERATING AGENCIES

Bureau of Reclamation

The Bureau operates over 130 reservoirs in the West, and it has constructed or authorized an even greater number that are operated by other agencies. More than 50 million acres are irrigated wholly or partially by Bureau projects (Wahl 1989). Until recently, dam operations were primarily aimed at meeting water demands for uses such as irrigation and power generation. Recreation opportunities were produced as secondary benefits--opportunistic recreation users could take advantage of these benefits, but could not demand them. However, Bureau policy regarding management of resources that affect recreation opportunities appears to be changing. Recent Bureau policy regarding fishing describes the extent of sport fishery resources under Bureau management, reviews figures regarding fishing as the country's second-most-popular recreation activity, and states that the Bureau needs to be responsive to this demand by developing fishery management plans that will protect and enhance fishery resources: "If opportunities exist to improve fishery management without negatively impacting Reclamation's contractual obligations, fishery management plans will balance such opportunities with other project purposes and resource amenities.... Plans may include changes in reservoir operations that will enhance fisheries, both within the reservoir and in downstream areas." Although this policy is clearly limited to instream flow impacts on fisheries, it represents a change from earlier agency policy. Furthermore, some of the Bureau's instream flow considerations have extended beyond fishery concerns. For example, the Bureau's study of the effects of operations at Glen Canyon Dam (Bishop et al. 1987) includes whitewater boating as well.

Corps of Engineers

The Corps manages, designs, or constructs numerous dams affecting flows used for river recreation. Although the Corps has no standard methodology for determining the relation of flow to recreation or scenic quality, it has carefully examined the relation in several locations. One recent effort occurred during deliberations about construction of a dam below Buford Dam on the Chattahoochee River north of Atlanta, in a river stretch managed by the National Park Service as the Chattahoochee National Recreation Area. In cooperation with the Fish and Wildlife Service, the Corps assessed the relation of flow conditions to potential for various recreation activities (Nestler et al. 1986). The Corps used the Fish and Wildlife Service's Physical Habitat Simulation Model (PHABSIM) to simulate water depth and velocity for different flow levels for several reaches along the study area, and to relate flow to recreation potential using suitability criteria. Relations were developed for wading, several types of angling, two levels of canoeing, and three levels of rafting. Recreation suitability curves for all but two activities were initially taken from Hyra (1978). The study team then modified some of Hyra's curves and developed others on its own. The canoeing and rafting curves also benefitted from the advice of a local panel of experts. The results of the PHABSIM analyses were estimates of "weighted usable area" versus flow for each activity in each reach (see the discussion of Hyra's (1978) approach in the "Direct Effects" section below for more on the methods employed).

Tennessee Valley Authority

In response to concerns about the impact of dam operations on the quality of river floating, TVA recreation planners have taken a straightforward approach to investigating the relation of flow quantity to recreation quality. They organized float trips for interested persons at different flow levels that were controlled by the upstream dams. After repeatedly floating the river, participants discussed their experiences, indicating the flow levels at which recreation was acceptable, optimal, and seriously impaired because of too little or too much water. In 1973 on the Ocoee River downstream of Ocoee No. 2 Dam in southeastern Tennessee, about 30 canoers, kayakers, and rafters floated the river at three controlled flows (over 2 consecutive days) ranging from 1,200 to 4,000 cubic feet per second (cfs). Maximum turbine efficiency release (1,200 cfs) was good for canoeing but at the low end of the acceptable range for kayaking and rafting. After considering tradeoffs between electric energy and recreation, an agreement was reached in 1984 providing for release of 1,200 cfs for 114 days each floating season (March through October). In 1983 at the Bear Creek Floatway in northwestern Alabama, about 10 canoers floated the river at three flows ranging from 140 to 500 cfs. The canoers concluded that 140 cfs was the acceptable flow, and a flow model was used to evaluate the feasibility of providing such a release from May to October. Opportunities for occasionally increasing the release level are now being explored.[6]

The TVA Act directs TVA to manage its reservoir system primarily for navigation and flood control, and (consistent with those purposes) for power generation. Because other benefits of reservoir operations have become increasingly important, TVA recently completed a reevaluation of its reservoir system (TVA 1990). The study evaluated velocities, increased wettable surface, drain time, and other hydraulic characteristics to establish minimum flows below 15 dams. Although the improved flows should increase biological diversity, the flows are far below levels needed to significantly increase opportunities for float fishing or canoeing.

OTHER FEDERAL RESOURCE MANAGEMENT AGENCIES

Bureau of Land Management

In 1977 the BLM established an interdisciplinary task force to develop an instream flow assessment system to be used by its field offices. The task force's report (Cuplin and Van Haveren 1979) covers general background information, a strategy for obtaining instream flow rights, criteria for identifying key riverine resources and considering flow needs, and hydrologic methods for quantifying flows. In addition, the BLM has conducted a series of instream flow studies using a common method described by Jackson et al. (1989), from which the following summary is drawn. These studies, described in more detail in the following section, occurred on Beaver Creek (Van Haveren et al. 1987) and the Gulkana River (Shelby et al. 1990) in Alaska, the San Pedro River in Arizona (Jackson et al. 1987), and the Dolores River in Colorado (Vandas et al. 1990).

The BLM approach, dubbed the "interdisciplinary process," emphasizes the need to take a holistic, integrated approach to determining and protecting streamflow needs. Because "resource values" (defined for this process as the unique conditions or uses for which the resource was designated) and their related physical, legal, and administrative environments differ widely from one river to another, the BLM approach emphasizes a process that brings together experts in relevant resource disciplines, as required by the unique characteristics of the river in question. The process includes the following steps:

1. Identify unique resource values, select relevant experts for the project team, and identify the range of possible research and protection strategies.
2. Identify flow-dependent values in order to focus the project on the important resource characteristics that are affected by flows.
3. Quantify hydrology and geomorphology in order to understand how the system works, with emphasis on the unique needs of the key resource values.
4. Describe effects of flows on resource values; this will form the basis for evaluating different flow regimes in terms of their effects on activities and concerns.
5. Identify recommended flows to protect resource values, integrating the different flow needs and reconciling conflicts when necessary.
6. Develop a flow protection strategy that is legally defensible and administratively feasible; usually this will result in an instream flow water right under applicable state law, but a variety of other water rights strategies are possible.

Use of this approach resulted in the first instream flow water right granted to a federal agency by the State of Alaska. The approach is currently being reviewed in a court adjudication of a federal reserved instream flow right on the San Pedro River in Arizona.

Fish and Wildlife Service

The approach adopted by the FWS to identify and protect instream flows for recreation follows from its work in instream flow protection for fish habitat. The PHABSIM model, which is part of the Instream Flow Incremental Methodology (IFIM), uses depth, velocity, and substrate as the three primary microhabitat factors for determining the suitability of habitat areas for specific fish species and life stages.[7] The FWS determined that other (i.e., not wildlife-dependent) forms of recreation were largely outside its jurisdiction. Thus, incorporating recreation suitabilities into instream flow measures has been limited. However, Hyra[8] published a methodology for measuring instream flows for recreation in 1978.

[6] *Personal communication, George Humphrey, TVA, Norris, TN, 1990.*

[7] *For an application of PHABSIM that focuses on fish habitat, see Cavendish and Duncan (1986).*

[8] *Working at the F&WS's Western Energy Land Use Team (now the National Ecology Research Center) on a detail from the Bureau of Outdoor Recreation (now the National Park Service).*

Essentially, Hyra adapted the PHABSIM model by expressing the quality of various recreation activities as a function of water depth and velocity. The system was designed to be compatible with the IFIM, hopefully making the recreation measures more likely to be applied by resource managers. Hyra's method is discussed in greater detail below in the Direct Effects section, where studies of the streamflow-recreation relation are reviewed.

Forest Service

The Forest Service currently has no standardized methodology for assessing the relation of flow to either recreation quality or scenic beauty. However, the need to learn about this relation has occurred numerous times in various locations. In the early 1980's, the Pacific Southwestern Region developed standards for determining streamflow needs in California (USDA 1981). Other efforts have been more site-specific. For example, in the early 1970's on the Plumas National Forest an irrigation company proposed diverting water from Fall River upstream of the 600-foot Feather Falls. The agency hydrologist took photos of the falls at various flow rates and informally asked people which photo showed the minimum flow below which the scenic beauty of the falls significantly deteriorated.[9] This effort was never subjected to close scrutiny because the irrigation company went out of business.

The need for more quantitative assessments of recreation quality has resulted in studies such as a recent Master's thesis that examined the relation of flow to boating quality (Williams 1991) and a study using psychometric methodology to determine the relation of flow to scenic beauty (Brown and Daniel 1991).

The relation between instream flow and recreation is not only a matter of water volume, but also water quality and temperature. In the Flaming Gorge National Recreation Area, in northeastern Utah, the Forest Service is studying the interactive carrying capacity of anglers and boaters along the Green River corridor below Flaming Gorge Dam (Pratt et al. 1991). Prior to 1980, this flow-regulated reach provided an excellent novice boating experience, attracting some 50,000 recreationists, with an increase rate of over 4% per year. In 1979, depth-selective withdrawal gates were installed on Flaming Gorge Dam, allowing temperature regulation for more optimal fish production. This action, plus limited selective harvest regulations implemented in 1985, created a nationally recognized fishery on the Green River, increasing the total number of recreationists and doubling by 1987 the proportion of those recreationists seeking a fishing experience. Although the flow rates in this portion of the Green River have remained fairly consistent (at 800 cfs) over the past several years, the nature of the recreational use has changed substantially.

Although the Forest Service has no standard methodology yet for assessing how recreation quality is affected by flow, it is using methodology to assess flow needs for channel maintenance. The Forest Service Manual (section 2541.1, 1984) states that the flow needed "includes the volume and timing of flows required for adequate sediment transport, maintenance of streambank stability, and proper management of riparian vegetation." While the objective for such flows is certainly not to provide recreation opportunities, channel maintenance indirectly affects recreation via effects of sediments on fish habitat and therefore fishing quality, and effects of high flows on gravel bars, riparian vegetation, and other features (see Indirect Effects of Flows on Recreation).

Park Service

The Park Service has not developed an official policy or single, accepted method for assessing relations of instream flow to recreation. In an early effort, Cortell and Associates (1976) produced a handbook for evaluating and planning recreation and river flow for the Bureau of Outdoor Recreation (later absorbed into the Park Service). The authors identified minimum, maximum, and optimum flows for several types of fishing, whitewater boating, tranquil-water boating, and water-contact recreation based on width, depth, and velocity of the river reach. They then compared the initial relations with actual conditions observed in the field, amending their initial judgments where necessary. The final relations were then used to make judgments about nonobservable flows.

The Park Service administers designated wild and scenic rivers in national parks, evaluates the wild and scenic potential for rivers in national parks and elsewhere, and provides technical assistance to state agencies on designation and protection of wild and scenic rivers. In 1982 the Park Service compiled a Nationwide Rivers Inventory of over 1,500 river segments that may be eligible for national wild and scenic status. The Park Service reviews development proposals on all inventory rivers to help ensure that eligibility potential is maintained, and in 1990 it began to upgrade and add to the inventory.

In 1990 Congress directed the Park Service to serve as the advocate for recreation interests in FERC hydropower facility licensing and relicensing negotiations, which resulted in the Riverwatch Program. This effort and the Park Service's Wild and

[9]Personal communication, Peter Stender, Intermountain Region, U.S. Forest Service, Ogden, UT, 1990.

Scenic Rivers efforts and its Nationwide Rivers Inventory activities were subsequently consolidated in 1990 under an overall "National Rivers Program."

In an effort unrelated to the National Rivers Program, the water rights branch within the Water Resources Division in Fort Collins, Colorado, has proposed an approach called "departure analysis," which has been applied to the streamflow issue (Johns and Williams 1987, Williams et al. 1988). Landscapes are constantly being modified by natural events and human intervention, and these events affect the physical and biological attributes of resource settings. Departure analysis is an attempt to model existing conditions and then observe the effects of perturbations on these conditions. Perturbations that sufficiently alter existing conditions are called "departures."

This analysis of departures was applied by Burley (1990) to hydrologic issues on the Virgin River in Zion National Park, Utah. Modeling efforts addressed resource attributes such as aquatic organisms, riparian vegetation, groundwater-dependent vegetation (hanging gardens), and esthetic and recreational characteristics of the river corridor. Recreation impacts were further characterized by applying incremental instream flow information from hydraulic simulation to quantitative recreation measures as described by Hyra (1978).

How this approach determines or defines the desired conditions towards which management efforts will be directed is not clear. The Park Service's enabling legislation directs the agency to protect park resources so as to leave them unimpaired for the enjoyment of future generations. Johns and Williams (1987) argued that the results of the departure analysis can be presented in court "to display the effects of altered flow regimes...upon existing park resource conditions. These results will allow an impartial judgment...as to whether or not impairment of park resources occurs under altered flow regimes." The court would decide whether "the Congressionally-mandated requirement for 'unimpairment'...could be met with a regime of flow other than existing" (Johns and Williams 1987).

The implicit assumption of this approach appears to be that any departures (i.e., reductions) from current flow conditions are unwanted and to be contested in court if necessary. This approach seems to contrast with that of the Riverwatch Program, which attempts to facilitate communication among parties to achieve equitable mitigation of impacts on recreation users, so as to avoid court battles. This difference in approach is partially due to two facts: (1) departure analysis is meant to be applied to rivers in national parks, whereas the Riverwatch Program applies to rivers with hydroelectric facilities wherever they occur (many being on private land), and (2) departure analysis focuses on natural resource conditions in general, whereas the Riverwatch Program emphasizes recreation.

UNDERSTANDING THE RELATION OF STREAMFLOW TO RECREATION

Streamflow contributes to both water-dependent and water-enhanced activities. Water-dependent activities such as fishing and boating are impossible without at least a minimum level of flow. Water-enhanced activities, such as hiking to view a waterfall or camping along a stream, are possible even if the stream dries up completely, although such activities may cease to attract participants without water to view and hear.

Like other human-natural resource interactions, the relation of recreation to streamflow has descriptive and evaluative components (Shelby and Heberlein 1986). The descriptive component provides objective information about resource characteristics; it describes the effects of different management alternatives on resource conditions. Descriptive data regarding instream flows might show how different amounts of water affect biophysical resource conditions such as size and number of pools, size and number of rapids, necessity for and length of portages, likelihood of boating accidents, and navigability by different craft.

The evaluative component shows how humans respond to the physical conditions. For example, at very low flows, rapids on a river may be too easy for whitewater boaters, and at very high flows they may become dangerous. Evaluative information is needed to decide which set of conditions is better or more desirable and what conditions (e.g., characteristics of rapids or camp areas) are necessary for that experience. Both descriptive and evaluative information are typically, though not necessarily, quantitative in nature.

Figure 1 shows a model of how descriptive and evaluative components are combined to determine instream flow needs for recreation. Descriptive information is needed to show how different hydrologic regimes produce different biophysical conditions. Evaluative information is needed to show what flows are necessary to provide minimally-acceptable to high-quality conditions for desired recreation experiences. Based on this relation, and additional information on management goals, a range of flows can be identified that will provide minimum to optimum conditions. This approach fits with recently developed models for determining appropriate instream flows for recreation (Jackson et al. 1989, Milhous 1990), as well as for recreation planning (e.g., Stankey and McCool 1984).

Research on recreation and streamflow is generally recent and has been done in a variety of settings, for a variety of purposes, and from a variety of disciplinary perspectives. For example, studies have focused on recreation activities, economic value, esthetics, carrying capacities, and interactions of recreation streamflow needs with other water needs, both in and out of stream. The following review first looks at direct or short-term effects of flows on recreation quality in general or on specific recreation attributes such as quality of rapids, fishing success, scenic beauty, or boating travel times. The review then explores indirect or long-term effects such as the impacts of flows in creating and clearing gravel bars for camping, improving scenic visibility, or maintaining channel form and function for fish habitat. Most of the 28 direct-effects studies reviewed here (table 2) focus on evaluative measures, although some (those using acoustical equipment to measure sound level) are purely descriptive; the three studies of indirect effects focus on descriptive measures. There is some overlap in these studies, as some of the indirect-effects studies also measured direct effects. These studies demonstrate the range of methods being applied to enhance our understanding of the relation of streamflow to recreation. The many studies (not included here) relating streamflow to fish habitat or populations might also be classified as indirect, descriptive studies (see Stalnaker 1980).

DIRECT EFFECTS

Sixteen of the direct-effects studies reviewed here measure recreation quality, five focus on scenic or acoustic quality, and seven focus on economic value. We categorized these studies into four groups, based on the methods used to understand the relation of flow to recreation quality. The first group includes those studies that rely mainly on the judgment of experts who apply their knowledge and past experience plus perhaps some current onsite investigation in the course of the study. While many of these studies incorporate informal interviewing of a limited number of selected individuals, there is no concerted attempt to survey the user population or to systematically assess several alternative flow levels. The second group includes those studies that use a systemic assessment of a range of flows, each experienced by the same individuals. While all of these studies used a small number of subjects, and some included only a small group of experts, the uniqueness and promise of this approach warrants keeping it as a separate category. The third group includes studies employing formal surveys of the user population. The fourth group includes those studies based on mechanical measurement, where little or no subjective judgment was used.

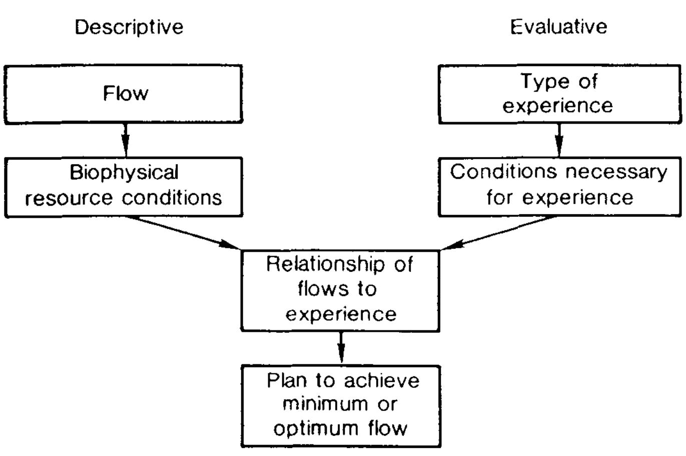

Figure 1.–Descriptive and evaluative information to determine streamflow needs for recreation.

Studies emphasizing formal surveys to obtain user judgments are further subdivided into three groups, depending on whether user responses were obtained for (1) experienced flows where each respondent experienced only one flow level, (2) flow levels depicted photographically, or (3) flow levels described verbally.

Within several of the groups, studies may have focused on determining minimally acceptable flows, on the relation of flow to recreation quality over the full range of flows, or on both minimum and optimum flows. Most of the studies or methods emphasizing minimum flows are based on the expert opinion approach. Studies emphasizing the full range of flows used a variety of methods; nearly all studies using controlled flows or public surveys focused on the full range of flows.

While some studies fit naturally into one of our categories, others did not. Some studies used more than one method (such as expert opinion for one activity and controlled flows for another) and were categorized rather arbitrarily. And the distinction between use of a small sample and a formal user survey was not always clear, forcing us to draw a somewhat arbitrary line between the two groups.

Studies Relying Mainly on Expert Judgment

Some studies of the relation of recreation to streamflow have focused only on determining the minimum flows considered necessary for the relevant recreation activity. These studies have tended to rely on expert judgment as the source of evaluative information. Focus on minimum flows is perhaps realistic where recreation is given little importance relative to other water uses, and managers would have a difficult time requesting more flow than the minimum necessary.

Emphasis on Minimum Flows

Hyra (1978) developed two methods for assessing streamflow needs for recreation, and one of them focuses on minimum flows. His "single cross section method" is based on the assumption that a single, properly located cross-section can define minimum flow requirements. By choosing the shallowest area along a stream reach, one can ensure boat passage by providing at least the minimum required depth at this location. Other variables, such as travel time, are not considered. This approach is only well suited where a quick assessment of minimum flow is needed, and to activities such as boating, where a single critical reach can be identified to represent the entire section under study.

Most of the Bureau of Land Management instream flow studies have utilized user surveys. The first study, however, was on the remote Beaver Creek National Wild River in Alaska (Van Haveren et al. 1987), where it was not possible to sample the user population because access is by plane, use is low, and the agency has few records with user names and addresses. Hence, expert judgment and field reconnaissance were used, along with interviews of managers and a few experienced river users, to determine the relation of recreation to streamflows. Although the river has no whitewater, flows affected floatability in terms of ability to get down the river with a reasonable number of portages or "boat drags." Flows also affected the time needed to float the river, and the flexibility and time for other activities. All of these attributes required minimum flows, below which the quality of recreation experiences was clearly impaired.

Jackson et al. (1987) also looked at esthetics of flows in their study of the San Pedro River in Arizona. They judged that recreationists would clearly prefer some visible water to a dry streambed, but that higher flows providing visibly moving water (rather than stagnant pools) with accompanying sounds would be the most-preferred situation. Still higher flows that filled the low-flow wash impaired the esthetic diversity associated with water flowing in a sand wash. Results emphasized minimum flows considered necessary to maintain an esthetically pleasing environment.

Recently, Corbett (1990) developed a statistical relation of minimum boating flows to mean annual flows. He presents data from 45 rivers showing "canoeing zero" flows, defined as the flow where an open canoe "touches gravel bars lightly in shallow areas two or three times without slowing down," assuming the person paddling is a skilled technical paddler "accomplished in reading water on very shallow streams." Canoeing zero flow was estimated from the personal experience of the author and his acquaintances, selected interviews, and reference to selected canoeing guide books. Corbett also collected U.S. Geological Survey data on mean annual flow for each river. Regression of canoeing zero flow on mean annual flow resulted in a formula that appears in a graphic presentation to quite accurately specify the relation between these two variables (statistical measures of association were not reported). More recent, as yet unpublished, work by Corbett[10] indicates that some of the dispersion in his two-dimensional relation can be accounted for by distinguishing between whitewater and calm-water rivers (i.e., accounting for bottom roughness) and standardizing the location of flow measurement to a common point (e.g., the beginning) of each relevant stream reach.

Emphasis on Full Range of Flows

Hyra's (1978) "incremental method" more completely defines relations between instream flow and recreation than is possible with the simpler "single cross-section method." Using a simulation model that parallels techniques employed in fishery habitat analysis, the incremental method has four steps: (1) computer simulation of the depth and velocity of a stream reach based on cross-sectional transect data, (2) use of the computerized model to develop a matrix showing the amount of surface area of the stream at different combinations of depth and velocity, (3) determination of composite "probability of use" (PU) for each combination of depth and velocity by multiplying the PU for the depth by the PU for the velocity, and (4) calculation of "weighted usable surface area" by multiplying actual surface areas for a given depth and velocity combination (from step 2) by the composite PU for areas with that depth and velocity combination (from step 3). The result is given in terms of area (e.g., square feet) for a given depth and velocity combination. The actual surface area of the depth and velocity combination is converted into a weighted usable surface area that may vary from 100% of the original area if composite PU is 1.0, to near 0 if composite PU is very small. Assuming a linear relation of recreation quality to surface area, Hyra concludes that if two different flows produce the same weighted usable surface area, they are equal in recreation "potential." Hyra's approach is notable for its attempt to account for the spatial element of the recreation environment.

Hyra's method is based on the following assumptions: (1) depth and velocity are the two most important streamflow characteristics for determining recreation quality; (2) it is possible to determine minimum, maximum, and optimum depth and ve-

[10] *Presented at the workshop, "Instream Flows and Recreation" at Oregon State University in March 1991.*

Table 2. – Studies determining relations between recreation-related variables and flow.

Author (Date)[1]	River (State)	Method	Representation of conditions	Activity	Judges	Dependent variable[2]	Relation[3]
DIRECT EFFECTS							
Bayha & Koski (1974)	Snake (Idaho)	Onsite activity and discussion	Controlled flows (5 levels)	Power boating Swimming, wading Shoreline use Viewing Ww boating Fishing	6 specialists 6 specialists 6 specialists 6 specialists 3 specialists 7 specialists	Rec. quality Rec. quality Rec. quality Esthetics Rec. quality Fishing success	Strong effects Strong effects No effect Minor effect Concave[4] No effect
Bishop et al. (1987)	Colorado (Arizona)	Mail survey	Verbal description	Rafting Rafting Fishing	286 guides/leaders 506 recreationists 235 recreationists	Preference WTP/trip WTP/trip	Concave Concave Concave
Brown & Daniel (1991)	Cache La Poudre (Colorado)	Offsite interview	Video sequences (8 flow levels)	Viewing	198 general public	Scenic beauty	Concave
Corbett (1990)	45 rivers (several)	Review guide books and technical references, onsite interview and inspection	Actual flows	Canoeing	Experts and experienced recreationists	Boatability	Minimum flow only
Daubert & Young (1981)	Cache La Poudre (Colorado)		Photos (8 flow levels)	Fishing Shoreline use Ww boating	49 recreationists 45 recreationists 40 recreationists	Total WTP/day Total WTP/day Total WTP/day	Concave Concave Inc. linear
Duffield et al. (1991)	Big Hole (Montana)	Onsite interview	Actual flow	Fishing	590 recreationists	Visits/day Total WTP/day	Concave Concave
	Bitterroot (Montana)	Onsite interview	Actual flow	Fish & shoreline	319 recreationists	Visits/day Total WTP/day	Concave Concave
EA Eng.,Sci, Tech (1990)	Clavey (California)	Offsite interview	Video sequences (8 levels)	Swimming	6 specialists	Suitability	Concave
EA Eng., Sci, Tech (1991)	McKenzie (Oregon)	Onsite activity	Controlled flows (3 levels)	Boating	10 users	Suitability	Various depending on craft
Garn (1986)	Red (New Mexico)	Acoustical equip.	Actual flows	Listening	NA	Decibels	Inc. at dec. rate
Giffen & Parkin (1991)	Kennebec (Maine)	Onsite activity and evaluation	Actual flows (6 levels)	Boating Fishing	15 users 2 users	Rec quality Rec quality	? ?
Hawkins (1975)	several streams (Utah)	Acoustical equip.	Actual flows	Listening	NA	Decibels	Concave
Humphrey (TVA) (1973 unpublished)	Ochoee (Tennessee)	Onsite activity and discussion	Controlled flows (3 levels)	Ww boating	About 30 users	Rec. quality	Concave
Humphrey (TVA) (1983 unpublished)	Bear Creek (Alabama)	Onsite activity and discussion	Controlled flows (3 levels)	Canoeing	About 10 users	Rec. quality	Concave
Hyra (1978)	NA	Prof. judgment	NA	Fishing, boating, water contact	Author	Suitability	Concave or inc.[5]
Johnson & Adams (1988)	John Day (Oregon)	Onsite interview	Verbal description	Fishing	62 recreationists	Total WTP/year	Increasing or dec.[6]
Litton (1984)	Toulumne (California)	Prof. judgment	Photos (10 flow levels)	Viewing	Author	Visual quality	Concave
Milhous (1990)	Salmon (New York)	Prof. judgment	Site visit	Fishing, boating, water contact	Author	Suitability	Concave or inc.

Moore et al. (1990)	Aravaipa Creek (Arizona)	Mail survey	Actual flow	Hike & swim	665 recreationists	Preferred flow	Concave
Narayanan (1986)	Blacksmith Fork (Utah)	Onsite interview	Verbal description	Camp, hike, fish	200 recreationists	Visits/year	Inc. sigmoid
Nestler et al. (1986)	Chattahoochee (Georgia)	Prof. judgment	Past experience and site visit	Several	Panels of specialists	Rec. quality	Concave
			Aerial photos of controlled flows (2 levels)	Shoreline use	Panel of specialists	Available space	Minor effect
Shelby et al. (1990)	Gulkana (Alaska)	Onsite interview	Actual flow	Canoeing, rafting, jetboating	101 trip leaders	Rec. quality	Concave
Stender (USFS) (1972 unpublished)	Fall (California)	Offsite informal interview	Photos	Viewing	Selected individuals	Esthetic quality	Minimum flow only
Van Haveren et al. (1987)	Beaver Creek (Alaska)	Prof. judgment	Site visit	Canoeing	Specialists, expert users	Floatability	Min. flows impt
Vandas et al. (1990)	Dolores (Colorado)	Mail survey	Verbal description	Canoeing, ww boating	128 experienced users	Rec. quality	Concave
Walsh et al. (1980)	Homestake, Frying Pan, & Eagle (Colorado)	Onsite interview	Verbal description	Fishing	60 recreationists	Total WTP/mi/day	Concave
	Crystal, Roaring Fork, & Colorado (Colorado)	Onsite interview	Verbal description	Kayaking	60 recreationists	Total WTP/mi/day	Inc. sigmoid
	Roaring Fork, Colorado, & Yampa (Colorado)	Onsite interview	Verbal description	Rafting	86 recreationists	Total WTP/mi/day	Inc. sigmoid
Ward (1987)	Chama (New Mexico)	Onsite interview	Photos (7 flow levels)	Fishing Ww boating	338 recreationists Visits/season	Visits/season Concave	Concave
	Fish & boat		Total CS/season	Concave			
Watson (1985b)	American (California)	Onsite activity, prof. judgment	Actual flows (4 levels)	Boating	5 specialists	Suitability	Concave
Williams (1991)	Cache La Poudre (Colorado)	Offsite interviews using Delphi	Verbal description	Rafting Kayaking Canoeing Tubing Fishing Wading	10 specialists 8 specialists 6 specialists 6 specialists 10 specialists 6 specialists	Rec. quality Rec. quality Rec. quality Rec. quality Rec. quality Rec. quality	Concave[4] Concave[4] Concave[4] Concave[4] Concave[4] Concave[4]
INDIRECT EFFECTS							
Jackson et al. (1987)	San Pedro (Arizona)	Prof. judgment	Site visit, modeling	Viewing Viewing Hiking	Specialists	Riparian veg. Reprod. of veg. Clear bars	Min. flows impt. High flows impt. High flows impt.
Van Haveren et al. (1987)	Beaver Creek (Alaska)	Prof. judgment	Site visit, modeling	Camping Viewing Canoeing	Specialists	Clean gravel bars Depth of view Channel width	High flows impt. High flows impt. High flows impt.
U.S. Dept. of Interior (1988)	Colorado (Arizona)	Onsite measurement, prof. judgment	Site visits, modeling	Rafting Camping	Specialists	Beaches Riparian veg.	Dam operation impt. Dam operation impt.

[1]*Publication date, or year of study for unpublished efforts.*
[2]*In some of the economic studies, the dependent variable listed here is not the variable that judges responded to.*
[3]*Concave to the horizontal (flow) axis, indicating an increasing and then decreasing function of the dependent variable to flow volume.*
[4]*Based on just 3 points: minimum, optimum, maximum. Most are concave, some are increasing.*
[5]*Hyra presents relations of flow velocity and flow depth (not flow volume) to probability of use.*
[6]*Johnson & Adams coupled a fish production model with results of a CVM. The resulting relation was increasing or decreasing depending on season.*

locity combinations for recreation activities; and (3) recreation "potential" is best expressed in terms of (weighted) surface area that meets certain depth and velocity requirements.

"Probability of use," as the term is used by Hyra, does not necessarily imply a survey or estimate of actual use, and it is perhaps better termed "desirability" or "suitability." The PU of depth and of velocity for a recreation activity are represented on a scale of 0 to 1, where 0 indicates absolute minimum or maximum depth or velocity for recreation use and 1 indicates optimum depth or velocity. Minimum and maximum levels are expected to be determined on the basis of physical limitations. Optimum levels indicate the range that is preferred.

PU curves of depth and velocity have typically been delineated by experts. Based on his personal judgment, Hyra (1978) developed PU curves for different activities, choosing 0.5 as the PU at which 50% of the users will consider the depth or velocity safe for use. Figure 2 is a reproduction of Hyra's curve for boating-canoeing-kayaking. Identifying the utility of curves showing direct effects of the full range of potential flow on recreation quality is a major contribution of Hyra's work.

Hyra's incremental method has been applied on the Chattahoochee River in Georgia (Nestler et al. 1986) and the Salmon in New York (Milhous 1990). In both of these applications, attempts were made to calibrate curves for depth and velocity vs. recreation use to specific conditions found on the study reaches. However, as stated by Milhous (p. 32), "Future development should include more field work to develop criteria. The present criteria are all (with two exceptions) based on judgment and have been developed based on discussions with users." In addition, empirical work is needed to determine what flow-related river characteristics will best identify appropriateness of flows for recreational uses. For example, in the Salmon River study, Milhous used the "Froude number" as a measure of river turbulence in establishing kayaking suitability criteria.

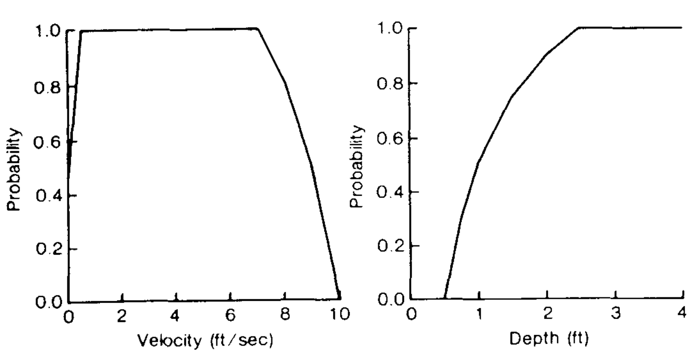

Figure 2. –Example of suitability curves from Hyra (1978).

Hyra's incremental method was also applied on the American River in California in an assessment of recreation potential needed for FERC relicensing deliberations (Watson 1985a). Briefly, previous fish habitat IFIM work was adapted to estimate recreation "usable area" by revisiting the earlier transects and identifying additional transects, reassessing the transects and applying recreation depth and velocity criteria to them, and then generalizing the "usable area" findings of the transects to the entire reach by categorizing the reach into "channel hydraulic types." In addition to the IFIM approach, the recreation assessment relied on direct observation and photographic and video recording of changing hydraulic conditions as flow changed, observations of user behavior patterns, discussions with local experts, and raft and canoe trips by the study team (four in rafts, one in a canoe) at four flow levels ranging from 1,500 to 2,250 cfs (Watson 1985b). The IFIM "usable area" approach was determined to be of only secondary usefulness in assessing the relation of flow to recreation quality. It was less helpful for boating than for wading and swimming, and least applicable in narrow channel areas where only one boat could pass at a time and effective area became insensitive to flow.[11]

Williams (1991) based her examination of flows and recreation on the Cache La Poudre River on expert judgment. For each of six activities (rafting, kayaking, canoeing, tubing, fishing, and wading), some of which were represented by up to four different skill levels, from 6 to 10 local experts specified by a Delphi process the minimum and maximum flow levels, and the optimum flow range, on relevant stretches of the Poudre. While the Poudre receives considerable use, the limited scope of this effort precluded a user survey.

Systematic Assessment of a Range of Flows Judged by Each Participant

Systematic assessment of a series of flow levels requires that these levels be experienced or otherwise depicted over a short period so that the frame of reference of the participants remains relatively constant. This can be accomplished by capturing the flow levels on film or by controlling the flows.

Flow Levels Depicted Photographically

To examine the relation of flow to scenic beauty, Litton (1984) reviewed photographs taken at various flow levels from several photo points along two California rivers. He concluded that some segments

[11]*Personal communication, Chuck Watson, WRC-Environmental, Sacramento, CA, 1991.*

of a stream show more visual response than others as flow volumes fluctuate, and that "at both flood stage and lowest stage, it can be expected that aesthetic quality is diminished." Negative effects of abnormally high flows include "drowning out the contrasts between riffles and pools, masking apparent differences of velocity with the impression of a single kind of movement," and disappearance of islands and bars. Negative effects of low water include loss of vitality with reduction or loss of whitewater, a condition of abandonment suggested by stranded features, and the loss of vividness of contrast between pools and flowing water.

Swimming suitability along the Clavey River near its confluence with the Tuolumne River in California was assessed in preparation for FERC deliberations about a proposed dam (EA Engineering, Science, and Technology 1990). During the summer of 1988, study participants swam in each of 10 pools at eight different flow levels ranging from 8 to 385 cfs. Each event was videotaped and later shown to a panel of six judges who rated the conditions for swimming suitability. The panel's assessment of flow suitability was plotted and summarized as "acceptable" from 10 to 250 cfs, "optimal" between 20 and 50 cfs, and "unsafe" above 350 cfs. However, in late summer after several weeks of flows below 20 cfs, water quality declines so that such flows also become unacceptable.

Controlled Flows

Upstream dams offer a unique opportunity to provide a range of actual flow levels over a relatively short period. Where the cooperation of dam operators has made this approach possible, it has clearly contributed to understanding flow-recreation interactions. Two early studies in which controlled releases were used were reported in the TVA section. Another early study was the multiagency effort to evaluate flows on the Hells Canyon section of the Snake River (Bayha and Koski 1974). The study team arranged for several flow levels ranging from 5,000 to 27,000 cfs from Hells Canyon Dam over a 5-day period, with representatives from a variety of disciplines (e.g., hydrology, fisheries, recreation) observing a wide range of impacts. Recreation impacts were monitored at seven sites along the river. In addition, a whitewater assessment team ran the river at the different flow levels and described effects on rapids, while a power-boating team distributed evaluation forms to a few power boat operators and also chartered a boat of their own. Assessments of streamflow effects were primarily limited to team members' descriptions of beach, water, and boating conditions at the different flow levels. However, the study is noteworthy for its actual manipulation of the independent variable (flow from Hells Canyon Dam), and for its effort to look at effects of flows on a variety of resource values in an integrated manner. This study also addressed esthetics. The principal esthetic element noted was the negative effect of exposure of green algae on rocks and shoreline at lower flows. Also mentioned was the decrease in turbulence of the flowing water at low flows, but apparently the authors were not in complete agreement about whether this decreased esthetic quality.

Controlled flows were also used in 1990 along the McKenzie River in Oregon to study boating suitability (EA Engineering, Science, and Technology 1991). Three flow levels were floated on separate day-long trips during the same week. Ten selected individuals, ranging from novice to expert, participated in each trip, floating the river in a drift boat, canoe, raft, or kayak. Each of 11 sections of the river were evaluated by each participant using a standardized response form, with no discussion among panel members regarding their evaluations. In addition to the controlled flow evaluation, recreational boaters were videotaped at selected locations on several days during the boating season, and visitors were asked in a survey to evaluate the flow level they encountered on their trip and the "overall quality of today's boating experience." Results showed that, within the range from about 500 to 1,050 cfs emphasized in the study, flow preferences differed by craft. Drift boat and rafting quality steadily improved with increased flow on the two key study reaches, kayaking quality steadily improved on one reach and peaked at about 700 cfs on the other, and canoeing quality peaked at about 850 cfs on one reach and was rather constant for all flows on the other. Drift boat suitability was most sensitive to low flows. Low flows provided opportunities for unskilled boaters, who did not feel safe at higher flows. Interestingly, user satisfaction was largely dependent on boater skill level, experience, and expectations. While statistically significant overall flow preferences were obtained for specific craft in specific reaches, the flow level, within the range of flows studied, was not a major determinant of trip satisfaction. Further, different flows favored different craft and individuals, suggesting that some variety in flows over the season might best meet the needs of the user population.

In perhaps the most concerted field evaluation of alternative flows so far, Central Maine Power Corporation provided a range of flows over the summer of 1990 in the 3½ mile long East Outlet of Moosehead Lake, at the headwaters of the Kennebec River in western Maine. The objective was to determine the necessary and optimal flows for boating and fishing, in preparation for an upcoming FERC relicensing deliberation. This study incorporated a three-pronged approach (Giffen and Parkin 1991). The first approach utilized controlled flows on two separate 1-day occasions. For the boating assessment, on each occasion, six different flow levels were provided, ranging roughly from 900 to 5,500 cfs. These different flow levels were floated by about 15 people in rafts, kayaks, and canoes. Participants included local boaters, Park Service and Central Maine Power representatives, the study team, and a commercial rafter from another part of the country, with no stake in the outcome. Participants were encouraged to take detailed notes of each flow level. On the first occasion, boating participants discussed each float trip as a group, while on the second, group discussion was discouraged and participants provided independent written evaluations of the alternative flow levels. For the fishing assessment, which occurred only once following the first boating assessment, flows of from 600 to 1,600 cfs were fished by two anglers in different locations. Anglers' comments were recorded onsite by accompanying members of the study team. In addition, key points of the stretch were videotaped at each level as participants floated by, for later careful review by the study team.

The second approach was an onsite survey of users over the course of the summer, in conjunction with controlled releases to create flows from about 1,000 to 3,500 cfs, which were announced ahead of time. About 1,300 respondents were asked, among other things, whether the flow they encountered that day was "about right," or whether they would have preferred higher or lower flows. The third approach was to record use levels for each activity over the same summer period.

These three approaches tended to support each other, and the study team found that using three approaches markedly improved their understanding of the issues. In particular, the field evaluation facilitated interpretation of the survey and observation results. In general, the study showed that many users were unaware of the flow level before they arrived at the site and were tolerant of nonoptimum flow levels (Giffen and Parkin 1991). Specific findings of the effect of flows on recreation quality have not yet been released.[12]

Studies Employing User Surveys

The bulk of the studies have relied on user surveys, of various sample sizes, to obtain judgments about the relation of flows to recreation-related variables. These studies are categorized here into three subclasses, based on whether they used photographic media, verbal descriptions, or actual flows to represent the conditions of interest.

[12]*Personal communication, Dan Muller, BLM, Denver, 1991.*

While most of these studies focused directly on recreation or scenic quality, several measured the economic value of riverine recreation. Economic value measures can indicate recreation quality, but also provide an indication of the *importance* that users place on the loss of recreation quality as flows deviate from the optimum level (curves of recreation quality alone give no idea of the value of changes in quality). In addition, measures of economic value can facilitate decision-making if the values of competing uses of streamflow are also expressed in monetary terms.

Experienced Flow Levels, Only One per Participant

If each participant cannot be brought to each flow level, another approach is to record the actual flow experienced by the participant during the trip on which the interview occurred, and then statistically relate user responses to measured flows. This requires a much larger sample of users than the condition where each participant can experience all levels over a short period in the course of the study, but in some cases it is the only option available for a study of experienced flows. Three studies have used this approach.

Moore et al. (1990) surveyed by mail visitors to Aravaipa Canyon Wilderness in Arizona, which contains one of the few relatively pristine perennial desert streams in southern Arizona. Visitors were asked whether they preferred the flow volume they encountered, or would have preferred higher or lower flows. These responses were compared with gauged flow at the time of the visit, revealing that visitors generally preferred average flow levels (28 cfs) over lower and higher flows. At lower flows, swimming holes were less useful, mats of algae and other aquatic plants were exposed, and some pools became stagnant. At higher flows, minor flooding occurred. Visitors were also more likely to purify the stream water before drinking it at times of below-median flows, indicating a perceived degradation in water quality with low flows.

The Gulkana River (Shelby et al. 1990), a National Wild River that supports a diverse fishery with king salmon, red salmon, rainbow trout, and grayling, is unusual among Alaskan rivers because it offers a multiday backcountry canoeing trip with road access to both the put-in and take-out points. As with Beaver Creek, a major study objective was to determine minimum flows needed to make it possible for river runners to get down the river and negotiate rapids without too much time spent dragging boats off the rocks.

The Gulkana offers three different types of recreation experiences, each with different flow needs.

One section of the river contains a half mile of class 3-4 whitewater; to provide high quality whitewater there requires 3,000 cfs. The rest of the river offers easier, class 2 whitewater suitable for family or novice canoeing; this requires 2,100 cfs so that boaters with minimal skills can negotiate the river. Finally, the river is used by a group of relatively "hard core" boaters who are highly skilled and do not mind extensive boat dragging and portaging; this requires 1,400 cfs. Onsite interviews of floaters at the take-out over the entire season were used to gather evaluative information. Based on these interviews, field reconnaissance, and expert judgment, the study team then developed a schedule of flow needs, with minimum winter flows to maintain the fishery, high spring flows for channel and riparian maintenance, high flows just after breakup for whitewater boating, moderate flows during the summer for family-novice canoeing, and minimum flows for hard-core drag boating during the fall hunting season.

Duffield et al. (1991) employed a dichotomous choice, contingent valuation survey on two Montana rivers to estimate users' additional willingness to pay (WTP) for their current recreational experience, and compared those responses to actual flows at the time of the interviews. On the Bitterroot River, actual flows were related to both participation rate and additional WTP, while on the Big Hole River flows were related only to participation rate. In both cases, a concave or inverted "U" (to the flow axis) relation of total recreationists' WTP per day to flow was found, with economic value increasing to a point and then decreasing as flows increased further.

Photographic Media

Photos can greatly facilitate the representation of environmental conditions to respondents. They have been used extensively in the assessment of the scenic beauty of forests (Ribe 1989) and other environments. Photos allow a full range of conditions to be shown to a respondent at the same time, and they have been shown in many studies to rather faithfully depict the actual scene (see Shuttleworth (1980) on photo validity).

Perhaps the first effort using photos to represent alternative flow levels was conducted by the USDA Forest Service on the Fall River in California in the early 1970's. Photos that depicted Feather Falls at various levels were shown to an informal sample of people. While this study focused on minimum flows, it is mentioned here because of the early use of photographic media to depict a range of flows.

The first formal user survey using photos to depict streamflow was part of an economic study. Daubert and Young (1981) used the contingent valuation method (CVM) to estimate willingness to pay for instream flow for kayakers, anglers, and shoreline users on the Cache La Poudre River in Colorado. Respondents were shown photographs depicting flows of 50, 100, 200, 350, 400, 600, 850, and 1,150 cfs and were asked about their WTP. For anglers and shoreline recreationists, WTP increased to a point (500 and 750 cfs, respectively), then decreased. Kayakers indicated a positive WTP for additional water at even the maximum flow level considered in the analysis. Flow was more important for water-dependent activities than it was for water-enhanced activities; flow explained about 45% of the variance in willingness to pay among kayakers, but only 20% among anglers and 5% among shoreline recreationists. The study also suggested that water may have more value for instream recreation use than for irrigation at low-flow times.

In another economic value study, Ward (1987) constructed a model for water management agencies to use in choosing instream flow augmentation to maximize net recreation benefits. The problem was to assess trade-offs between winter reservoir releases, which avoid evaporation loss, and late summer releases, which enhance recreation. Recreationists were divided into two groups, anglers and boaters, and demand was modeled for each group at each flow level. Respondents were asked onsite for their estimated participation rate for each of seven flow levels depicted by color photographs. The travel cost method (TCM) was used with these data to value streamflow augmentation for each flow rate. Then a dynamic programming model was developed for the City of Albuquerque to optimally allocate reservoir releases to New Mexico's Rio Chama over the whitewater season. The study results provide quantitative information on whitewater recreation demand associated with various flow levels, angler and boater demand functions, and benefits as a function of streamflow.

Brown and Daniel (1991) investigated the relation of flow to public perception of river corridor scenic beauty. Because flow movement and sound may play a role in the beauty of river scenes, they used video sequences to represent different flow levels. Respondents rated the scenic beauty of video sequences of the Cache La Poudre River in Colorado that showed flows ranging from 120 to 2,650 cfs. Ratings were scaled to an interval-scale metric of scenic beauty that was regressed on variables describing flow and other scene features. Flow explained 10% to 25% of the variance in scenic beauty estimates. Perceived scenic beauty increased as flow increased up to about 1,100 to 1,500 cfs, then fell as flow increased further (fig. 3).

Verbal Descriptions

Several studies have used verbal descriptions to represent alternative flow levels to respondents.

Four of these studies focused on economic value as the dependent variable (for more on economic studies, see Loomis (1987) and Douglas (1988)). The first study surveyed users of nine rivers on the West Slope of the Colorado Rockies (Walsh et al. 1980). This study added a procedure for estimating the effects of congestion, arguing that streamflow has both a qualitative and quantitative effect on recreation. Respondents were asked their maximum WTP (above and beyond travel costs) to reduce congestion. Changes in hypothetical WTP were then estimated at five different instream flow levels. The study concluded that instream flow has a substantial effect on total benefits, and warned that instream flow benefits may be underestimated because they are "use" values and do not include option and existence value (see also Sanders et al. (1990) and Douglas and Johnson, in press).

Narayanan (1986) interviewed visitors to the Blacksmith Fork River in Utah, obtaining information necessary for applying the TCM, along with visitors' judgments of the percent of existing flow at which they would cease to visit the site for the season. An increasing S-shaped relation of overall visitation to flow was derived, varying from no visits at zero flow to 100% of actual visits at the above-average flows that occurred during the interview season. Estimates were not obtained for flows above those experienced during the interviews. The hypothetical visitation schedule was used along with a TCM-based demand function to indicate an S-shaped increasing relation of total annual WTP to flow.

Johnson and Adams (1988) combined a steelhead production model with an onsite contingent valuation survey of steelhead anglers' WTP for fishing as a function of posited catch rates. The combined model gave the economic value of steelhead fishing as a function of seasonal flows that occurred during

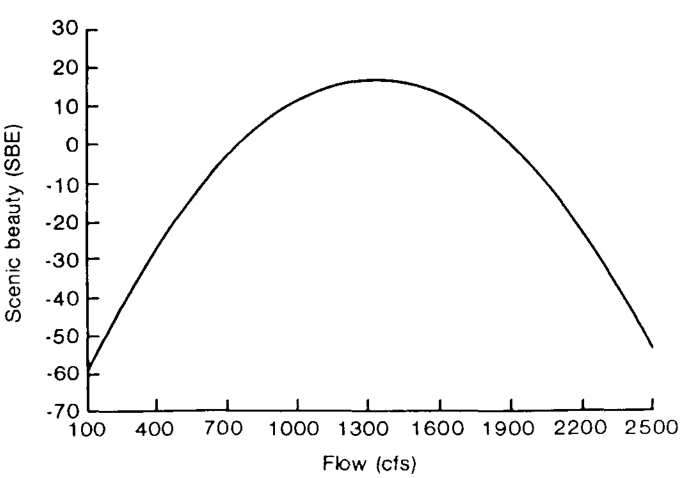

Figure 3.–Scenic beauty changes with flow based on multiple regression model of public's scenic preferences on Cache La Poudre River, Colorado.

spawning (5 years earlier). Aggregate angler WTP was expressed by season; it increased (at a decreasing rate) for previous summer and winter flows, and decreased (at a decreasing rate) for previous spring flows. The implications of this information for water management were then discussed.

In the Grand Canyon, Bishop et al. (1987) identified direct effects of water release patterns from Glen Canyon Dam on river recreation (both river running and fishing). The descriptive component of the study identified the specific aspects of the recreation experience affected by instream flow. The evaluative component used preference data and the CVM to show the effects of flow on recreation value. Expert opinions of river guides and trip leaders were also used as evaluative input (HBRS 1986). First, an attribute survey sampled passengers on commercial river trips, most of whom had little river running experience, either generally or in Grand Canyon. Results identified important characteristics of the whitewater trip in general and of rapids and campsites in particular.

The next step was to determine which of these trip attributes were related to streamflows, and for them, the exact relation. The Grand Canyon study made it clear that inexperienced users are not particularly helpful in this regard; even if they noticed changes in flows, they were not readily aware of how these changes affected trip attributes. The survey of commercial guides and noncommercial trip leaders solved this problem, since most had run numerous Grand Canyon trips at a variety of flow levels, and they were specific about the effects of flows on trips.

Among the guides and trip leaders, there was substantial agreement about minimum, maximum, and optimal flow levels. Trip characteristics related to flows included running the river safely with passengers, quality of ride for passengers, access to and use of campsites, availability of camps, time spent traveling on the river, access to and use of attraction sites, time available for stops at attractions, quality and difficulty of rapids, flexibility in running the trip, ability to avoid other parties, and accidents. Survey data were used to generate curves showing the direct effects of flow levels on these variables. For positive attributes such as the overall best level or the quality of ride for passengers, evaluations were lower at very low and very high flows, with the highest evaluations at flows of around 25,000 cfs (fig. 4). For negative attributes such as accidents or passengers having to walk around rapids, there were more problems at very low or very high flows (fig. 5). In addition, moderate daily fluctuations in flow were acceptable to most guides, and predictability of flow was a primary concern in their efforts to mitigate the effects of flows on their trips.

The Grand Canyon study used the CVM to estimate monetary values associated with different flow regimes. This part of the project showed that relatively low flow regimes produced the greatest benefit for anglers, while higher flow regimes produced greater benefits for whitewater boaters. As the peak seasons for these two types of use occur at different times of the year, it was possible to work out combinations of flow regimes that produced an optimal combination of benefits. The study also explored the issue of trade-offs between using water for recreation versus power generation.

The wild river section (below McPhee Dam) of the Dolores River in southwestern Colorado was studied by Vandas et al. (1990). As with the Grand Canyon study, a survey of experienced river users provided evaluations that made it possible to develop curves (fig. 6) of the relation between flows and recreation quality (Shelby and Whittaker 1990). There are several interesting differences between the Dolores and the Grand Canyon studies. First, there were major differences in flow needs for different boat types. Canoeing (in nonwhitewater boats) required considerably less water than rafting or kayaking (in whitewater boats), and kayakers showed less tendency to decrease their evaluations at the highest flow levels considered in the study. Second, there were distinctly different recreation experiences. Scenic boating that uses the river as a waterway for transportation requires less water than whitewater boating, where rapids and river hydraulics become an important part of the experience. Third, there was a distinct difference in flow needs between minimally acceptable whitewater and optimal or high quality whitewater. Finally, the prior commitment of much of the natural flow for irrigation required the study team to develop alternative flow scenarios that involved trade-offs between different resource values, as well as possible mechanisms to obtain rights for more water.

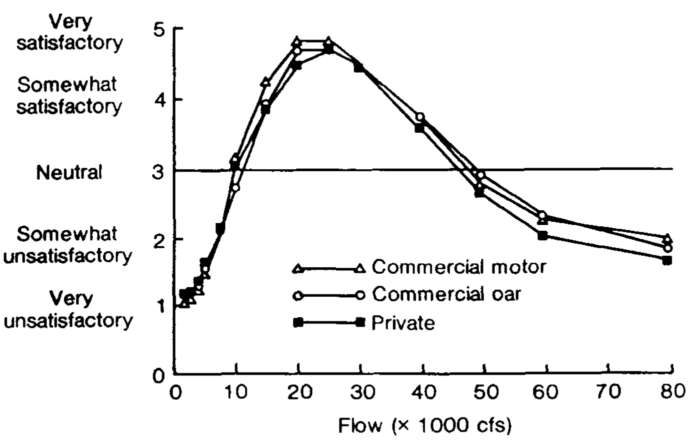

Figure 4.–Guides' constant flow level preference ratings for Grand Canyon.

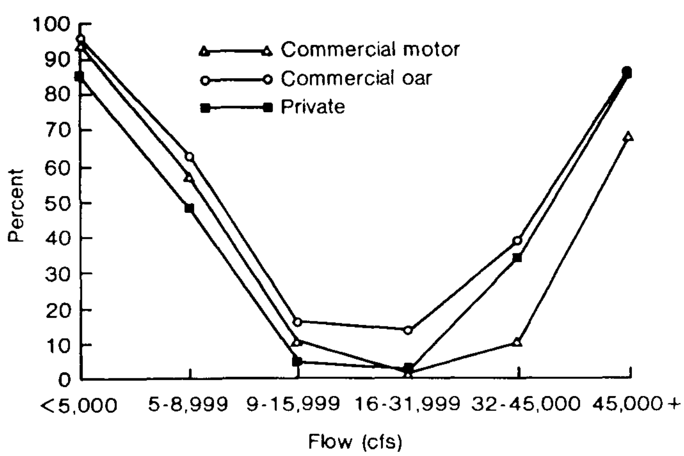

Figure 5.–Guides' reports of flow levels at which accidents are more likely to happen in Grand Canyon.

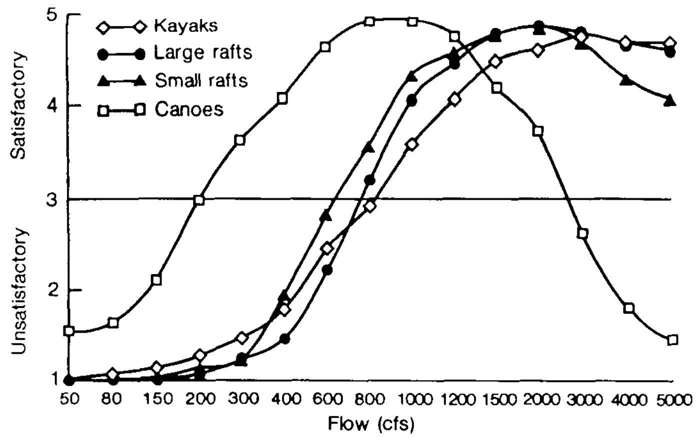

Figure 6.–Flow evaluations on the Lower Dolores River.

Studies Using Mechanical Measurement of Descriptive Effects

Two studies of sound, an esthetic feature of rivers, used a mechanical device (a decibel meter) to provide a purely descriptive measure. Hawkins (1975) measured noise level and flow rate at several streams in Utah. He found a nonlinear relation of sound to flow. Above a minimum threshold flow, noise was noticeable; as flow increased, the noise level increased to some maximum level (where many outfalls and impediments to flow create whitewater); with further increases in flow the bed elements became submerged and the noise level dropped. Garn (1986) adapted this methodology to measure sound output at various flow levels at a river stretch in New Mexico. He also found a nonlinear relation. Sound level rose sharply with flow up to about 50 cfs, and then rose more slowly over the remaining flow range assessed. Garn recommended that, from the esthetic standpoint, flow should be at least 50 cfs.

INDIRECT EFFECTS OF FLOWS ON RECREATION

In addition to the direct effects described above, streamflows have a number of indirect or long-term effects. Some have long been recognized and are well documented. For example, flows affect fish reproduction and survival, and the quality of the fishery can have a profound effect on recreation experiences; Hyra (1978) noted that in early studies it was even assumed that recreation values could be protected simply by providing enough water to maintain the fishery. Although the field is clearly more sophisticated now, the point remains that flow has important indirect effects on recreation.

The Beaver Creek study (Van Haveren et al. 1987) showed that high flows affect a number of characteristics of the stream channel and riparian zone, which in turn affect recreation quality. The high flows that occur with ice breakup in the spring are responsible for the open gravel bars that line the riverbanks. Gravel bars that have not been scoured by recent high flows quickly grow alder thickets close to the water's edge, forming "walls" and even a partial canopy above the river, which limits scenic vistas and the likelihood of seeing wildlife. Hiking opportunities are also limited to forcing one's way through alders, rather than walking on open gravel bars. Gravel bars also provide clean, unlittered campsites close to the river, with scenic vistas and well-drained, vegetation-free flat areas for tents; they are also the only areas relatively free of swarms of insects. High flows keep the channel relatively free of debris and sweepers (stationary over-hanging or submerged tree branches), which are both dangerous and an impediment to canoe travel. The formation of meanders, associated with gravel bars, also facilitates other river corridor processes, such as vegetation succession and formation of oxbows and sloughs.

Fishing is another key component of float trips on Beaver Creek. Anglers fish from gravel bars, which require high flows for maintenance. The quality of the fishery also requires high flows that maintain channel morphology features such as pools and sloughs, as well as minimum low flows that sustain fish through the dry summer months. Fishing is a resource value that shows an obvious interdependency between flows, channel morphology, the fishery, and recreation, underscoring the need for interdisciplinary approaches to instream flow needs assessment.

Another study, on the San Pedro River in Arizona, shows other indirect effects of flows on recreation attributes (Jackson et al. 1987). The San Pedro is a small desert stream with virtually no recreational boating opportunities; it was designated as a Riparian National Conservation Area primarily because it has a relatively unspoiled riparian ecosystem. Recreation quality is tied to the presence of flowing water, the relatively natural setting, the presence of flora and fauna, and the opportunities for hiking and camping. Low flows are necessary to provide direct esthetic effects of flowing water, as well as to provide the indirect effects of maintaining the riparian vegetation and related wildlife. The riparian vegetation that supports wildlife also provides shade, a rare and valuable commodity in the desert.

High flows clear areas of vegetation, which otherwise would be overgrown by dense stands of willow and tamarisk, except where large cottonwoods maintain an open understory. Open areas provide varied scenery and allow scenic views. They also provide a "corridor" through which visitors can travel in the river channel, walking on sand and gravel bars, with occasional river crossings. This allows pleasant hiking and close interaction with the river and riparian ecosystem, a primary reason for the San Pedro's designation as a Conservation Area. Open areas scoured by high flows also provide clean, unlittered campsites, with flat areas for tents and good views of scenery and wildlife. Stream channel morphology, specifically the role of occasional high flows in maintaining the ability of channels to fulfill various functions, is currently receiving increased attention.

In addition to scouring effects, streamflow rates determine the sediment load that can be carried and the rate of deposition in creating sandbars and other features desirable for recreation uses. The National Park Service and U.S. Geological Survey have an ongoing concern with maintenance of sandbar campsites in the Grand Canyon (see several of the "Glen Canyon Environmental Studies" technical reports prepared by agencies of the U.S. Department of Interior (1988)). Glen Canyon dam, upstream from the Grand Canyon, creates a still-water pool into which the Colorado River drops much of the sediment that might be deposited at sandbar and tributary junction sites in the Grand Canyon.

USE OF RECREATION-FLOW INFORMATION IN DECISION-MAKING

We do not intend to discuss the complex field of multiobjective decision-making. However, we will briefly discuss the potential role of information about the relation of recreation to flow in the difficult task of deciding on a recommended streamflow regime.

In nearly all situations where managers have some control over flows (by reservoir management or diversions), there are competing water uses.

Often, several uses compete in the determination of flow regimes (fig. 7). Each use may call for a different flow regime.

Requests for different objectives can be combined in a variety of ways into different flow management scenarios, each of which produces unique combinations of resource benefits. For some examples, see the interdisciplinary studies by Van Haveren et al. (1987), Shelby et al. (1990), and Vandas et al. (1990).

Choice of a final flow regime requires managers and other decision-makers to balance competing demands, costs, and benefits. This requires evaluative information about management objectives (indicating the kinds of opportunities managers want to provide) and standards (specifying the conditions managers consider necessary to provide those opportunities). Controversy over resource management issues usually centers on the evaluative dimension. There may be disagreements about management objectives: Should water in a stream be used to provide mining opportunities, fish habitat, or recreation? There may also be disagreement about specific evaluative standards: How much water is needed to provide optimal whitewater boating opportunities? Successful resource management decisions require a degree of consensus about management objectives and standards. These evaluative criteria usually involve a combination of expert judgment and the opinions of the public, interest groups, and resource users.

Ultimate consideration of the trade-offs involved in choosing one streamflow regime over another would be facilitated by information about economic measures of costs and benefits. Several of the studies summarized above provide measures of economic value of instream flow for recreation that can be compared with the more easily determined values of water diversions or hydropower production (indeed, some of these studies, such as Daubert and Young (1981) and Duffield et. al (1991) report such comparisons). However, even where managers consider economic costs and benefits in choosing a preferred flow regime, decisions rarely rely solely on economic analysis. In the end, the evaluative judgments of managers and water user and instream flow interests play an important role. A clear understanding of the flow-recreation relation is particularly important in such discussions.

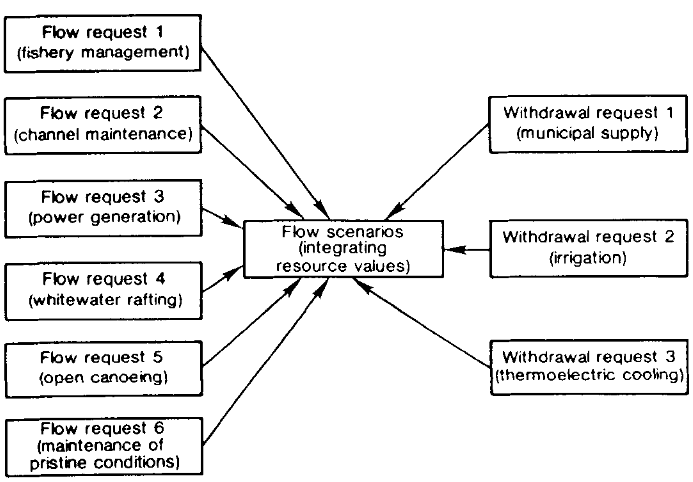

Figure 7.–Flow requests for different uses.

SYNTHESIS AND CONCLUSIONS

Legislation passed in the last 25 years at both the state and national levels has recognized the importance of maintaining instream flow in rivers, and the growing conflicts caused by increasing demands for both streamflow-based recreation and water withdrawals. In response to these changes, numerous researchers and government agencies have studied the relation of streamflow to recreation quality. These efforts have used a variety of methods: some measured economic value of recreation, while others focused directly on recreation quality; some focused on the direct impact of flow on recreation, while others emphasized indirect impacts; some focused on minimum flows, while others emphasized the full range of flows; and some relied on expert judgment, while others surveyed recreation users and other members of the general public. These efforts have added considerably to our understanding of the relation of streamflow to recreation.

CURVES SHOWING THE RELATION OF FLOW TO RECREATION QUALITY

The studies documenting direct effects of flow on recreation quality were broadly separated into two groups based on methods used for depicting these direct effects. Hyra's (1978) cross-sectional approach and the Beaver Creek, San Pedro, and to some extent the Gulkana studies all selected "critical reaches" and then identified minimum flow needs based on what was necessary for those areas. If flows were sufficient in the critical reaches, they would be sufficient elsewhere – the emphasis is on the minimum.[13]

The other studies developed evaluative judgments at a number of different flow levels, thereby more completely documenting the relations between flows and recreation. Hyra's (1978) incremental method did this with researcher-generated probability of use (suitability) curves that showed hypo-

[13]Corbett's (1990) study of minimum canoeing flows also essentially uses this approach. "Canoeing zero," estimated by floating a river at different flow levels, is determined by conditions at those critical points that most restrict canoe passage at low water.

thetical relations. The economic studies developed functions showing willingness to pay at different flow levels. The Grand Canyon guides' study, the Dolores River study, and the Aravaipa Canyon study developed curves based on users' evaluations of a range of flow levels as satisfactory or unsatisfactory. Brown and Daniel's (1991) scenic beauty study developed curves based on public assessment of video sequences. All of these studies showed a similar shape of curve describing the relation between flow and recreation quality (see the summary of the relation in table 2, column 8). Low flows below a certain point are unacceptable; somewhere in the middle range, flows reach an optimum; and at very high levels, flows again become unacceptable. The specific points at which flows are minimally acceptable, optimum, and too high vary for different size channels, for different recreation activities, and different user skill levels, but the shape of the curve describing the relation is similar.

Because instream flows have often been protected or administered as minimum flows, there is a tendency to think of flow needs for recreation in terms of a single value. Our review indicates that a more complete picture is gained by describing the entire flow-quality relation. Such a description shows how recreation quality is affected by the full range of flows, highlights the differences between activities, and clarifies the difference between unacceptable, minimum, and optimum flows.

Any designation of instream flows for recreation should require the delineation of curves showing the effects of the complete range of flows on each recreation activity. Even if curves are generated as "hypothesized" relations, without supporting data, they still force a clearer understanding of the assumptions about how flow affects recreational quality. A curve also requires that one identify the point along the curve where a flow request is being made, thereby clarifying whether the request will provide acceptable minimum or optimum flows for the activity in question.

MODELS FOR SPECIFYING THE RELATION OF FLOW TO RECREATION

Models of the flow-recreation relation have considerable appeal. The basic idea is to develop a model that uses generally available hydrologic data to determine the needed flows for recreation. A model is particularly useful when a site-specific study of the relation of flow to recreation quality would be too expensive or too time-consuming to conduct, when a reasonable range of flows cannot be observed (e.g., when dam operators are uncooperative), or when the user population is difficult to identify (e.g., on remote Alaskan rivers). At times, the flows to be considered are not observable or measurable, for example, when recreation assessments are being made for a flow-regulating facility that does not yet exist. For such assessments, some model of the effects of instream flow on recreation is essential. Two important efforts in this direction, Hyra (1978) and Corbett (1990), demonstrate the utility of a modeling approach, as well as the difficulties and pitfalls.

Hyra's (1978) recreation modeling approach, adapted from a fish habitat modeling procedure, suffers from several shortcomings. First, depth and velocity may not be the best flow variables for predicting recreation quality. Experienced river users are more accustomed to thinking of boating quality in relation to flows, expressed in cubic feet per second or stage readings from a gage, so translating into depths and velocities may be both unnecessary and confusing. Second, hydraulic modeling of flow based on selected transects will often inadequately describe the complex nature of water movement in rapids. The effects of rocky, uneven surface formations at various flow levels on boating quality can probably be more directly and accurately assessed by simply running the river at selected flow levels (or by interviewing people who have experience doing so). Third, the researcher typically supplies the evaluative judgments (the suitability curves) for different activities and translates those judgments into velocity and depth requirements. Lacking a survey of knowledgeable users, the researcher may rely on his or her personal judgment, or the judgment of a small number of "experts," running the risk of invalid evaluative judgments. Finally, "weighted surface area" seems a forced and unnecessarily complex way to express recreation potential in relation to flows. While Hyra's approach is notable for the attempt to express the spatial element of recreation potential, for some activities (e.g., boating) an area measurement may not be as relevant as a simple measure of length or travel time. Further, combining the area measure with the estimate of recreation quality (using the suitability curve) tends to obscure the spatial information.

Hyra's suitability curves must be calibrated for each specific river reach and should not be generalized to different reaches, where primary recreation demands may be different. Recalibration becomes a problem when resource managers want to apply recreation curves, developed elsewhere, to their own rivers. The same problem occurs when fish species suitability curves are applied to dissimilar habitats. Hyra warns that there is no valid optimal flow for recreation in general. Power boating, boat fishing, whitewater rafting, and swimming all demand different depths and flows. Indeed, some of the more significant conflicts over the allocation of impounded river water are between different recreation groups; for example, optimal flows for fishing may be useless for whitewater rafting.

Efforts have been undertaken to incorporate width of the river reach and geomorphic class (boulder, braided, or meander zone) as IFIM parameters (Scott and Hyra 1977). Some such parameters are critical for calculating suitability for different types of recreation, especially whitewater rafting, canoeing, and kayaking. Incorporating these aspects into the IFIM would allow calculation of suitability for specific recreational uses as part of a normal IFIM study. Other parameters currently under consideration include turbulence and rapid changes in flow. Dropping flows, which strand fish, are already considered within the IFIM; rising flows, which strand fishermen, would be somewhat the inverse consideration, but could be incorporated into this methodology.[14]

However, the question remains: Is the IFIM framework the best one for addressing all flow-based recreation problems? The advantage of using this framework – that it is also used to assess fish habitat, thus offering comparability with habitat assessment – is perhaps outweighed by the time-consuming requirement for transects to obtain depth and velocity measurements and by the weighted surface area computations. Depth and velocity are not the most direct ways to depict the physical environment, at least for activities such as boating and viewing. And weighted surface area lacks a demonstrated relation to the dependent variable, recreation quality. Further, an onsite, experience-based assessment of recreation quality is generally needed for the Hyra approach to calibrate the suitability curves. Once this is done, the essential recreation quality information has been obtained, and it can generally be more easily obtained in terms of flow or stage than depth and velocity. Thus, at least for nonfishing activities, the IFIM framework may divert effort from the key need – a direct assessment of recreation quality.

Corbett's (1990) method avoids the complication of depth and velocity criteria by expressing the "canoeing zero" judgments directly in terms of flow. By incorporating data for 45 river sections and statistically relating the recreation variable to flows, the method also moves toward greater generalizability. However, there are a number of shortcomings (Shelby and Jackson 1991). Average annual discharge may by itself be insufficient to adequately represent the boating environment of all but carefully selected hydrologically and morphologically similar rivers. Corbett acknowledged the potential importance of additional variables such as bottom roughness and geologic composition. Other potentially important hydrologic characteristics include tightness of meanders and presence of boulders. Without such refinement for further stratifying rivers, there may be considerable prediction error. For example, Corbett showed New England streams where the formula predicts canoeing zero at 150 cfs, but *measured* canoeing zero ranged from 100 to 300 cfs.

It should also be remembered that canoeing zero is not the only important boatability criterion. For example, Shelby et al. (1990) showed that minimum boatable flows are different for open canoes than for rafts, and that minimum boatable flows are considerably less than what is needed for minimum or optimal whitewater.

Corbett's conclusion that "the river planner can develop a defensible statement of the minimum instream flow for recreational boating when average annual flow is known" oversimplifies the issue. But his modeling effort, the first attempt at an empirical boating recreation model based on data from multiple rivers, demonstrates an important direction for future work. Modeling efforts hold promise as a means of transferring understanding of the relations between recreation and instream flow from one situation to another. Such models will be essential for characterizing recreational suitabilities for flows that do not currently exist or that cannot be easily observed.

The key to pursuing better modeling efforts lies in designing studies that systematically collect comparable data. It is possible to examine relations across studies only if those studies include the same hydrology and recreation measures. Although Corbett's data set contains comparable measures for 45 rivers, the focus on single-value minimum flows (canoeing zero) and averaging across time (annual average flow) limit the usefulness of these data. There is tremendous potential in such broad data sets, however, if comparable parameters are measured from one study to another and if the information is made available through publications. A critical need in this regard is some agreement on the variables that should be routinely measured (an obvious improvement would be to report flow in terms of percent of bankfull flow in addition to discharge).

Despite the potential of generalized statistical models, carefully designed site-specific studies are still necessary for the foreseeable future. The work reviewed here indicates that users can provide judgments based on controlled flows, photographs of alternative flows, or even verbal descriptions if the user population is sufficiently familiar with the options. Such studies offer viable, defensible means of learning about the streamflow-recreation relation.

[14]*Personal communication, Robert Milhous, U.S. F&WF, Fort Collins, CO, 1990).*

LITERATURE CITED

Aiken, J.D. 1983a. Opportunities to protect instream flows in Nebraska and Kansas. FWS/OBS-83/2. Fort Collins, CO: U.S. Fish and Wildlife Service. 57 p.

Aiken, J.D. 1983b. Opportunities to protect instream flows in Minnesota and Iowa. FWS/OBS-83/7. Fort Collins, CO: U.S. Fish and Wildlife Service. 64 p.

Barrow, Pope, ed. 1989. The American Whitewater Affiliation nationwide whitewater inventory. Washington, DC: American Whitewater Affiliation.

Bassin, N. Jay. 1985. Dinosaur National Monument: the evolution of a federal reserved right. Water Resources Bulletin. 21(1): 145-149.

Bayha, K.; Koski, C., eds. 1974. Anatomy of a river: an evaluation of water requirements for the Hells Canyon reach of the Snake River. Vancouver, WA: Pacific Northwest River Basins Commission.

Bishop, R.; Boyle, K.; Welsh, M.; Baumgartner, R.; Rathbun, P. 1987. Glen Canyon Dam releases and downstream recreation: an analysis of user preferences and economic values. Madison, WI: Heberlein-Baumgartner Research Services.

Brandes, K. 1985. Opportunities to protect instream flows in Idaho, Oregon, and Washington. Fort Collins, CO: U.S. Fish and Wildlife Service. Biol. Rep. 85/9. 103 p.

Bristow, E.T.; Gould, G.A. 1986. Opportunities to protect instream flows in Montana. Fort Collins, CO: U.S. Fish and Wildlife Service. Biol. Rep. 86/4. 34 p.

Brooks, H.T. 1979. Reserved water rights and our national forests. Natural Resources Journal. 19(2): 433-443.

Brown, T.C.; Daniel, T.C. 1991. Landscape aesthetics of riparian environments: relationship of flow quantity to scenic quality along a wild and scenic river. Water Resources Research. 27(8): 1787-1976.

Burley, J. 1990. Departure analysis: A decision tool to evaluate landscape perturbations. Mimeo. Fort Collins, CO: Colorado State University, Department of Landscape Architecture.

Cavendish, Mary G.; Duncan, M.I. 1986. Use of the instream flow incremental methodology: a tool for negotiation. Environmental Impact Assessment Review. 6: 347-363.

Corbett, Roger. 1990. A method for determining minimum instream flow for recreational boating. SAIC Special Report 1-239-91-01. McLean, VA: Science Applications International Corporation.

Cortell and Associates. 1976. Recreation and flow: river evaluation manual. Final Report Volume II, Minimum Streamflow Study for Bureau of Outdoor Recreation. Washington, DC: U.S. Dept. of Interior.

Cuplin, P.; Van Haveren, B. 1979. Instream flow guidelines. Denver, CO: U.S. Department of the Interior, Bureau of Land Management, Denver Service Center.

Daubert, J.; Young, Y. 1981. Recreational demands for maintaining instream flows: a contingent valuation approach. American Journal of Agricultural Economics. 63(4): 666-675.

Dishlip, Herb. 1990. Instream flow water rights: Arizona's approach. In: MacDonnell, L.J.; Rice, T.A.; Shupe, S.J., eds. Instream flow protection in the west. Boulder, CO: University of Colorado Natural Resources Law Center: 173-180.

Douglas, Aaron J. 1988. Annotated bibliography of economic literature on instream flows. Biological Report 88(39). Fort Collins, CO: U.S. Fish and Wildlife Service.

Douglas, A.J.; Johnson, R. L. [In press]. Aquatic habitat measurement and valuation: imputing social benefits to instream flow levels. Journal of Environmental Management.

Duffield, J.; Ehlers, S.; Brown, T. C. 1991. Recreation benefits of instream flow: application to Montana's Big Hole and Bitterroot Rivers. Draft. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station.

EA Engineering, Science, and Technology. 1990. Application for license for major unconstructed project, Clavey River Project: Exhibit E (Environmental Report), Report 7 (Recreational Resources). Lafayette, CA: EA Engineering, Science, and Technology.

EA Engineering, Science, and Technology. 1991. Boating and fishing suitability of the lower McKenzie River, Oregon. Lafayette, CA: EA Engineering, Science, and Technology.

Echeverria, John D.; Fosburgh, Jamie Fosburgh. 1988. American rivers outstanding river list. Washington, DC: American Rivers Inc.

Fairfax, Sally K.; Andrews, B.T. Andrews. 1979. National forests and reserved rights in the western United States. Journal of Forestry. 77: 648-651.

Freeman, R.L.; Robinson, F.W. 1986. Opportunities to protect instream flows in Vermont and Pennsylvania. Biol. Rep. 86/1. Fort Collins, CO: U.S. Fish and Wildlife Service. 86 p.

Garn, H.S. 1986. Quantification of instream flow needs of a wild and scenic river for water rights litigation. Water Resources Bulletin. 22(5): 745-751.

Giffen, R.A.; Parkin, D.O. 1991. Using systematic field evaluations to determine instream flow needs for recreation. Draft. Hallowell, ME: Land and Water Associates.

Gray, Brian E. 1989. A reconsideration of instream appropriative water rights in California. In: MacDonnell, L.J.; Rice, T.A.; Shupe, S.J., eds. Instream flow protection in the west. Boulder, CO: University of Colorado, School of Law, Natural Resources Law Center: 181-235.

Hawkins, R.H. 1975. Acoustical energy output from mountain stream channels. Journal of the Hydraulics Division, ASCE Proceedings; 101(HY3): 571-575.

Heberlein-Baumgartner Research Services. 1986. Grand Canyon whitewater boating guides survey. Draft Report, Madison, WI: Heberlein-Baumgartner Research Services.

Hyra, R. 1978. Methods of assessing instream flows for recreation. Instream Flow Info. Paper No.6, FWS/OBS-78/34. Fort Collins, CO: U.S. Fish and Wildlife Service. 52 p.

Jackson, W.; Martinez, T.; Cuplin, P.; Minckley, W.; Shelby, B.; Summers, P.; McGlothlin, D.; Van Haveren, B. 1987. Assessment of water conditions and management opportunities in support of riparian values on the San Pedro River. Denver, CO: Bureau of Land Management Service Center, PO Box 25047.

Jackson, W.; Shelby, B.; Martinez, A.; Van Haveren, B. 1989. An interdisciplinary process for protecting instream flows. Journal of Soil and Water Conservation. 44(2): 121-127.

Johns, A.E.; Williams, O.R. 1987. Assessment of potential impacts to water-related resource attributes in Zion national park, UT. Fort Collins, CO: National Park Service, Project plan, Water Rights Branch.

Johnson, N.S.; Adams, R.M. 1988. Benefits of increased streamflow: the case of the John Day River steelhead fishery. Water Resources Research. 24(11): 1839-1846.

Kiechel, W. Jr. 1976. Federal instream flow rights. In: Orsborn, J.F.; Allman, C.H., eds. Instream Flow Needs: Bethesda, MD: American Fisheries Society: 55-67. Vol. 1.

Litton, R. 1984. Visual fluctuations in river landscape quality. In: Popadic, J.S.; Butterfield, D.I.; Anderson, D.H.; Popadic, M.R., eds. Proceedings of the 1984 National River Recreation Symposium, Oct. 31-Nov. 3, Baton Rouge, LA: 369-382.

Loomis, John. 1987. The economic value of instream flow: methodology and benefit estimates for optimum flows. Journal of Environmental Management. 24: 169-179.

MacDonnell, L.J.; Rice, T.A.; Shupe, S.J. 1989. Instream flow protection in the west. Boulder, CO: University of Colorado School of Law, Natural Resources Law Center. 426 p.

Marks, Jason. 1987. The duty of agencies to assert reserved water rights in wilderness areas. Ecology Law Quarterly. 14: 639-683.

McKinney, M.J.; Taylor, J.G. 1988. Western state instream flow programs: a comparative assessment. Instream Flow Info. Paper No. 18, Biol. Rep. 89(2). Fort Collins, CO: U.S. Fish and Wildlife Service. 78 p.

Mead, Katherine L. 1986. Wyoming's experience with federal non-indian reserved rights: the Big Horn adjudication. Land and Water Law Review. 21: 433-453.

Milhous, R.T. 1990. Recreational river space as related to discharge in the Salmon River, Oswego County, NY. Fort Collins, CO: National Ecology Research Center, U.S. Fish and Wildlife Service.

Moore, S.D.; Wilkosz, M.E.; Brickler, S.K. 1990. The recreational impact of reducing the Laughing Waters of Aravaipa Creek, AZ. Rivers. 1(1): 43-50.

Narayanan, R. 1986. Evaluation of recreational benefits of instream flows. Journal of Leisure Research. 18(2): 116-128.

Nelson, M.C. 1977. The Winters doctrine: seventy years of application of reserved water rights to indian reservation. Arid Lands Info. Paper. No. 9. University of Arizona, Office of Arid Lands Studies. 147 p.

Nestler, J.M.; Fritschen, J.; Milhous, R.T.; Troxel, J. 1986. Effects of flow alterations on trout, angling, and recreation in the Chattahoochee River between Buford Dam and Peachtree Creek. Technical Report E-86-10. Vicksburg, MS: US Army Engineer Waterways Experiment Station. 73 p. plus appendixes.

Potter, Lori. 1990. *Nevada v. Morros:* instream flow rights for Nevada rivers. 1(1): 65-66; 1990.

Pratt, J.; Nielsen, J.; Nordstrom, A. 1991. The recreation use capacity of the Green River Corridor below Flaming Gorge Dam. Sonoma, CA: Institute for Human Ecology report to the USDA Forest Service. 272 p. plus appendixes.

Reiser, D.W.; Wesche, T.A.; Estes, C. 1989. Status of instream flow legislation and practices in North America. Fisheries. 14(2): 22-29.

Ribe, Robert G. 1989. The aesthetics of forestry: what has empirical preference research taught us? Environmental Management. 13(1): 55-74.

Romm, Jeff; Bartoloni, K. 1985. New rules for national forest water. Journal of Forestry. 83(6): 362-367.

Sanders, L.D.; Walsh, R.G.; Loomis, J.B. 1990. Toward empirical estimation of the total value of protecting rivers. Water Resources Research. 26(7): 1345-1357.

Scott, J.W.; Hyra, R. 1977. Methods for determining instream flow requirements for selected recreational activities in small and medium size streams. Unpublished. Paper presented to the 13th AWRA Conference; Oct.

Shelby, B.; Heberlein, T. 1986. Carrying capacity in recreation settings. Corvallis, OR: Oregon State University Press.

Shelby, B.; Jackson, W.B. 1991. Determining minimum boating flows from hydrologic data. Review of "A method for determining instream flows for recreational boating" by Roger Corbett. Rivers. 2(2): 161-167.

Shelby, B.; Van Haveren, B.P.; Jackson, W.L.; Whittaker, D.; Prichard, D.; Ellerbroek, D. 1990. Resource values and instream flow recommendations, Gulkana National Wild River, Alaska. Denver, CO: Bureau of Land Management. 76 p. plus appendixes.

Shelby, B.; Whittaker, D. 1990. Recreation values and instream flow needs on the Dolores River. Paper presented at the Conference on Social Science and Natural Resources, College Station, TX.

Shupe, S.J. 1989. Keeping the waters flowing: streamflow protection programs, strategies and issues in the west. In: MacDonnell, L.J., Rice, T.A.; Shupe, S.J., eds. Instream flow protection in the west. Boulder, CO: University of Colorado School of Law, Natural Resources Law Center: 1-21.

Shuttleworth, S. 1980. The use of photographs as an environmental presentation medium in landscape studies. Journal of Environmental Management. 11: 61-76.

Stalnaker, Clair B. 1980. Effects on fisheries of abstractions and perturbations in streamflow. In: John H. Grover, ed. Allocation of Fishery Resources, Proceeding of the Technical Consultation on Allocation of Fishery Resources held in Vichy, France, April 1980. United Nations, NY: Food and Agriculture Organization. 366-383.

Stankey, G.; McCool, S. 1984. Carrying capacity in recreational settings: evolution, appraisal, and application. Leisure Sciences. 6(4): 453-474.

Tarlock, A. 1978. Appropriation for instream flow maintenance: a progress report on "new" public western water rights. Utah Law Review. 211: 211-247.

Tarlock, A. 1979. The recognition of instream flow rights: 'new' public western water rights, Twenty Fifth Annual Rocky Mountain Mineral Law Institute. 24: 1-64.

Tennessee Valley Authority. 1990. Tennessee River and reservior system operation and planning review, final environmental impact statement. Knoxville, TN: TVA.

Trembly, T.L. 1987. Opportunities to protect instream flows in Colorado and Wyoming. Biol. Rep. 87/10. Fort Collins, CO: U.S. Fish and Wildlife Service. 91 p.

U.S. Department of Agriculture, Forest Service. 1981. Procedural standards for determining instream flow and standing water requirements for national Forest Service system lands in Region 5. (Unpublished). San Francisco, CA: U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station and Region 5.

U.S. Department of Interior. 1988. Glen Canyon environmental studies technical report. Washington, DC.

U.S. Water Resources Council. 1983. Economic and environmental principles for water and related land resources implementation studies. Washington, DC: U.S. Government Printing Office.

Vandas, S.; Whittaker, D.; Murphy, D.; Prichard, D.; MacDonnell, L.; Shelby, B.; Muller, D.; Fogg, J.; Van Haveren, B. 1990. Dolores River instream flow assessment. Denver, CO: Bureau of Land Management, Denver Federal Center.

Van Haveren, B.; Jackson, W.; Martinez, T.; Shelby, G.; Carufel, L. 1987. Water rights assessment for Beaver Creek National Wild River, AK. Denver, CO: Bureau of Land Management, Service Center, PO Box 25047.

Wahl, Richard W. 1989. Markets for federal water: subsidies, property rights, and the Bureau of Reclamation. Resources for the Future, Washington, DC. 308 p.

Walsh, R.; Ericson, R.; Arostegy, D.; Hansen, M. 1980. An empirical application of a model for estimating the recreation value of instream flow. Fort Collins, CO: Colorado State University, Colorado Water Resources Research Institute, Completion Report No. 101.

Ward, Frank A. 1987. Economics of water allocation to instream uses in a fully appropriated river basin: Evidence from a new Mexico Wild River. Water Resources Research. 23(3): 381-392.

Watson, Chuck. 1985a. Review of water depth and velocity criteria for instream recreation, Lower American River, CA. Sacramento, CA: Environmental Consulting.

Watson, Charles. 1985b. Stream flow and recreation on the Lower American River. Sacramento, CA: Environmental Consulting.

White, M.R. 1980. Opportunities to protect instream flows based on federal law. Unpublished manuscript. Fort Collins, CO: U.S. Fish and Wildlife Service, National Ecology Research Center.

White, M.R. 1982. Opportunities to protect instream flows in Alaska. FWS/OBS-82/33. Fort Collins, CO: U.S. Fish and Wildlife Service. 30 p.

White, M.R. 1983. Opportunities to protect instream flows in Texas, Oklahoma, and Arkansas. FWS/OBS-83/22. Fort Collins, CO: U.S. Fish and Wildlife Service. 94 p.

Wilkinson, C.F. 1985. Western water law in transition. University of Colorado Law Review. 56(3): 317-345.

Wilkinson, C. F.; Anderson, H.M. 1985. Land and resources planning in the national forests. Chapter 5, Water. Oregon Law Review. 64: 201-241.

Williams, Kathleen. 1991. Application of instream flow quantification to recreational rivers: a case study of the Cache La Poudre River, Colorado. Fort Collins, CO: Colorado State University, Master's Thesis.

Williams, O.R.; Ponce, S.L.; Johns, A.E. 1988. The use of departure analysis in decision making. In: W. Waterstone and R. John Burt, eds. Water use data for water resources management. Technical Publication Series TPS-88-2. Bethesda, MD: American Water Resources Association: 447-453.

Shelby, Bo; Brown, Thomas C.; Taylor Jonathan G. 1992. Streamflow and recreation. Gen. Tech. Rep. RM-209. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 27 p.

Studies by social scientists, physical and biological scientists, and engineers of the relation between streamflow and recreation quality have employed a wide variety of methods. Nearly all studies found a similar, nonlinear relation of recreation to flow – quality increases with flow to a point, but decreases for further increases in flow. Critical flow levels (points of minimum, optimum, and maximum flow) differ across rivers and activities. Many state laws and agency practices now provide for considering the effects of streamflow on recreation. Knowledge of the flow-recreation relation, and its accurate calibration in specific locations, is an important ingredient in the determination of wise streamflow policies.

Keywords: Recreation, streamflow, water law, water management

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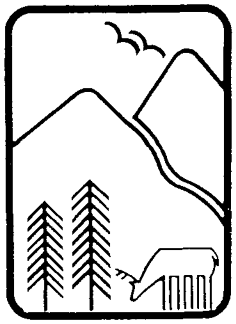
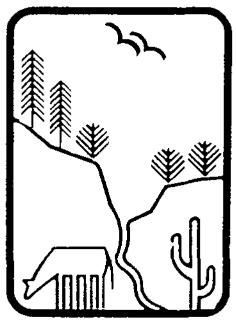


Rocky Mountains



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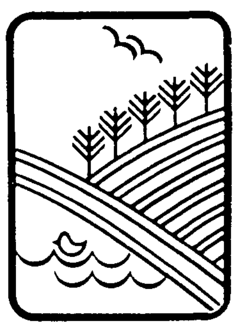

Great Plains

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

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Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

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