PRIMARY METHODS AND KEY CONCEPTS FOR VALUING NON-POWER BENEFITS — CHAPTER 5

As noted in Chapter 4, the economic analysis supporting hydropower relicensing actions could be improved through a more complete examination of the non-power benefits associated with different dam operation alternatives. It is usually the case that non-power benefits cannot be measured directly from market transaction data, making them more difficult to analyze than power benefits. As a result, FERC has relied primarily on qualitative characterization of such benefits. However, resource economists have developed and refined techniques for valuing non-market and other amenities. These techniques provide a means for expanding and refining the calculation of net benefits associated with dam operation.

The purpose of this chapter is to attune FWS field staff to the basic analytic methods available for valuing non-power benefits. Many of the techniques can be complex and the research may require specialized expertise. Therefore, this discussion is not intended to offer step-by-step instructions on completing such analyses. However, these approaches are relevant for several reasons:

- In cases where the dam has major ecological and socioeconomic implications for the surrounding area, investment in the analytic methods discussed here may be warranted. This chapter will help field staff recognize applicable techniques and understand the data demands and budgetary resources required for the analysis.

- Similarly, field staff may encounter many of these methods when reviewing the contributions of other intervenors in the relicensing process. This chapter will help FWS staff better understand the methods and findings of such studies.

- Finally, the techniques discussed here provide the conceptual foundation for the simpler screening analyses discussed in Chapter 6.

In general, primary research is more costly than the secondary techniques (benefits transfer) described later in Chapter 6. Primary research may be advisable when the relicensing involves a highly contentious project and/or exceptionally valuable river resources that warrant precise economic characterization. Such a "value of information" approach is appropriate when mitigation of resource losses is expected to lead to large scale changes in resource use and value, i.e., benefits that outweigh the costs of conducting the original research.

☞ Determining when to use primary and secondary valuation methods requires expert judgment. FWS field staff are encouraged to seek assistance from experienced resource economists, including those in FWS's Division of Economics, when considering the relative merits of original and secondary research. The combined expertise of biologists who understand the affected natural resources and economists who understand valuation techniques will help ensure efficient allocation of research efforts.

This chapter begins by introducing "willingness to pay" and "consumer surplus," economic concepts common to all valuation methods. We then consider several categories of valuation techniques (including revealed preference approaches, stated preference approaches, averted cost methods, and factor income methods) and examine how these techniques may be useful in the context of hydropower relicensing.

OVERVIEW OF ECONOMIC VALUATION

When considering the economic benefits associated with changes in dam operation, it is appropriate to apply a welfare economic framework. Welfare economics is premised on the concept of economic efficiency, i.e., while a policy change may produce winners and losers, resources are allocated so that overall societal welfare increases. Stated differently, society should allocate resources such that the sum effect on societal welfare is greater than what is given up by diverting resources from other uses.[1] As reviewed earlier, this principle is also present in FERC's statutory commitment to give equal consideration to power and non-power values in hydropower relicensing. For example, overall social welfare may be increased if recreationalists' total willingness to pay for river flow (a natural resource) exceeds the value generated by using flow to produce hydropower (as measured by avoided costs of replacement power).

The type of welfare economic measures recommended below differ from common measures of regional economic activity frequently considered, such as jobs or business revenues. Regional economic impacts are often important in hydropower relicensing. For example, a dam may provide inexpensive power to a paper plant, ensuring continued profitability of that plant and the security of jobs and tax revenues. These measures of economic impact may be important at the local or regional level; however, they cannot be directly integrated into the net benefit calculation for a given licensing alternative because they do not represent net societal losses.

[1] Freeman, A. Myrick, *The Measurement of Environmental and Resource Values*, Resources for the Future, Washington, DC, 1993.

For example, if the paper plant was closed, production may increase at another plant, transferring the economic activity to another location. Assuming that paper prices and producer profits are unaffected (see later discussion of consumer and producer surplus), this change could potentially have limited effects on overall societal well-being. Nonetheless, the implications for the local or regional economy may still be great; therefore, regional economic impact analysis plays a useful role in FERC's relicensing analysis. Appendix A of this report further discusses current and potential uses of regional economic impact analysis.

Willingness to Pay

Alternative measures of economic value are needed to address social costs and benefits. Most importantly, economists have refined methods to measure individuals' "willingness to pay" for various amenities, including environmental amenities not typically bought and sold in markets (e.g., improved river ecosystems, better air quality). Willingness to pay represents the amount of money an individual would give up to receive an increase in such an environmental amenity.[2] Much of resource economics is built on the idea that social welfare can be maximized by placing natural resources in uses that yield the greatest benefits in terms of collective willingness to pay.

Consumer Surplus

Resource economists generally rely on consumer surplus as a measure of overall economic welfare. The concept of consumer surplus is based on the principle that some consumers benefit at current prices because they are able to purchase goods (or services) at a price that is less than their total willingness to pay for the good.[3]

The concept of consumer surplus is most easily understood through an example. Assume that the manager of a reservoir charges a $2 fee to individuals using a beach. Exhibit 5-1 shows a demand curve (D) for beach use. This curve shows the quantity of beach use demanded at various prices. As indicated by the downward slope, the quantity of beach use demanded goes down as the price rises. The horizontal line indicates the current price of beach use ($2). The shaded area represents the consumer surplus that accrues at the current price; i.e., some consumers' willingness to pay exceeds the price of the good. Consistent with this description, economists sometimes refer to consumer surplus as net willingness to pay.

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[2] Economists also sometimes consider a similar concept of "willingness to accept compensation"; i.e., the amount of monetary compensation that would make the individual indifferent between having an environmental improvement and foregoing the improvement (Freeman, 1993).

[3] Depending on the context, measurement of net economic welfare may also include estimation of producer surplus. Producer surplus measures the extent to which the price received for a good exceeds the cost that the producer incurs to produce the good. We discuss producer surplus more extensively in the section on market supply and demand models.

The consumer surplus associated with consuming a good can be affected in two ways. First, the price of the good may change because of supply changes or other factors. Continuing our example, if the price of beach use rises to $3, individuals will consume less and consumer surplus will be reduced. This change is illustrated in Exhibit 5-2 where the shaded area represents the loss in consumer surplus.

The second way that consumer surplus can change is through a shift in the demand curve. Such a change occurs when preferences for the good in question are altered. For example, beach improvements may make the location more attractive. The change in preferences for beach use is depicted as a shift in the demand curve, i.e., at any given price, individuals will choose to consume more of the good than previously. Exhibit 5-3 illustrates such a change. The shaded increase in consumer surplus results because of the increased beach use (from Q_1 to Q_2) and because of the improved experience for current beach users.

Exhibit 5-1

CONSUMER SURPLUS

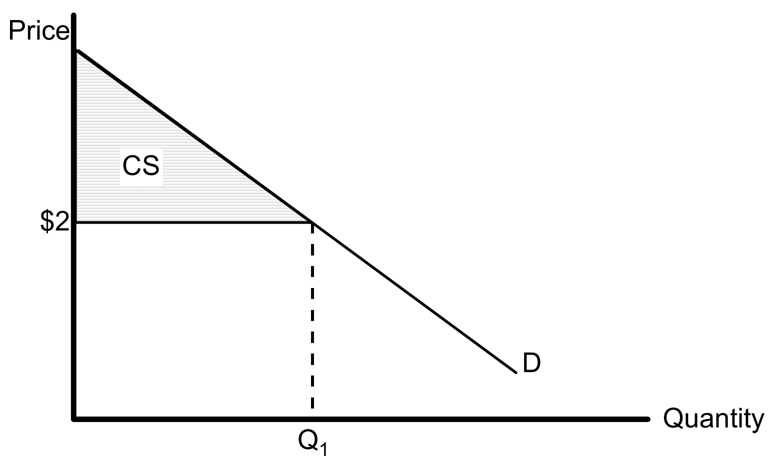


Exhibit 5-2

CHANGE IN CONSUMER SURPLUS RESULTING FROM A PRICE INCREASE

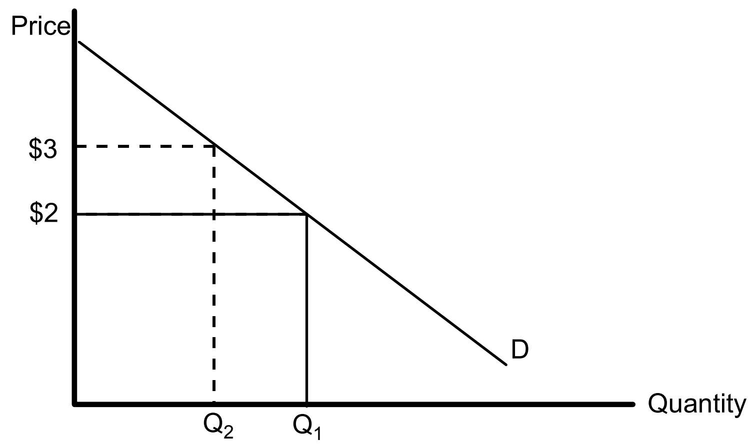
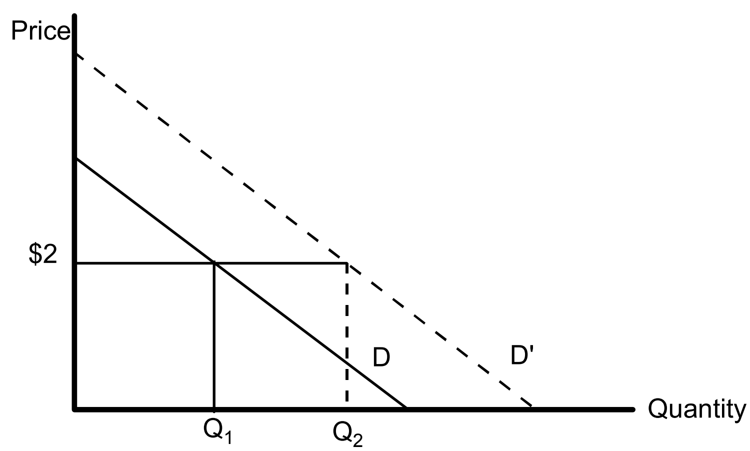


Exhibit 5-3

CHANGE IN CONSUMER SURPLUS RESULTING FROM A SHIFT IN DEMAND



Overview of Valuation Methods

In many cases, individuals' willingness to pay for a resource or service can be observed in the marketplace. First, in some cases, the resource or service itself is bought and sold, providing direct information on consumers' willingness to pay. For example, as we review below, changes in dam operation may affect fish stocks important to commercial fisheries, a market-based good. In general, however, markets do not exist for most of the non-power benefits relevant to dam relicensing actions. For example, recreational fishing opportunities are not bought and sold in a conventional market. As a result, we must estimate non-power benefits through alternative methods. Many of these methods consider how behavior in related markets reveals individuals' value for a good (revealed preference approaches). For example, people may exhibit their value for environmental quality through purchases in the housing market, paying more for homes near clean water, conservation land, or other environmental amenities.

In some cases, there may be no existing market, either direct or indirect, for the non-power benefit of interest. In these instances, economists rely on survey methods that allow individuals to express their willingness to pay for the resource or service in question (the stated preference approach).

Below, we review these analytic approaches and variations that incorporate elements of the basic approaches. Specifically, we cover the following topics:

- Revealed preference approaches, including market supply and demand models and indirect measurement methods such as travel cost and property value models;

- Stated preference approaches such as contingent valuation;

- Methods useful for valuing non-power project services (e.g., water supply), including averted cost methods and factor income methods; and

- Models for valuing instream flow and comparing marginal benefits and costs of restoring river flow.

To summarize the potential applicability of the valuation methods discussed in this chapter, Exhibit 5-4 lists the methods and provides examples of how each may be useful in analyzing different categories of environmental resources and services typically addressed in FERC environmental impact statements (EISs). As shown, the methods may be useful in valuing a number of key non-power benefits such as changes in recreational activity, aesthetics, non-use values associated with free-flowing rivers, and other environmental impacts resulting from changes in dam operation and dam removal. As part of each methodological discussion below, we review this applicability in more detail.

It is noteworthy that values associated with a given resource can be addressed by more than one analytic method. As a result, the analyst should be vigilant for double-counting of non-power benefits. In particular, some methods will capture a broad range of economic effects and raise the potential for double-counting. For example, a contingent valuation study of dam removal could capture total use and non-use values associated with such an action. If a separate study of recreational fishing values is undertaken, the two studies could overlap significantly.

Exhibit 5-4

OVERVIEW OF VALUATION METHODS AND APPLICABILITY IN HYDROPOWER RELICENSING

Valuation Methods		Services and Resources Potentially Addressed by Valuation Methods					
		Water Quality and Quantity	**Aquatic Resources**	**Recreation**	**Aesthetics**	**Threatened & Endangered Species**	**Socio-economics**
Revealed Preference	Market Supply and Demand		Value changes in commercial fishing catch based on producer surplus or market value				
	Travel Cost			Value fishing, rafting, and other recreation based on travel costs	Value waterfall and other viewing based on travel costs		
	Property Value						Evaluate effect of reservoir management on property values
Stated Preference	Contingent Valuation and Other Stated Preference Methods	Assess use and non-use values for wild and scenic rivers based on stated willingness to pay		Assess use values for fishing, rafting, and other recreation based on stated willingness to pay	Assess use values for aesthetic enjoyment (e.g., waterfall viewing) based on stated willingness to pay	Assess value of species preservation based on stated willingness to pay	

Exhibit 5-4

OVERVIEW OF VALUATION METHODS AND APPLICABILITY IN HYDROPOWER RELICENSING (continued)

Valuation Methods		Services and Resources Potentially Addressed by Valuation Methods					
		Water Quality and Quantity	**Aquatic Resources**	**Recreation**	**Aesthetics**	**Threatened & Endangered Species**	**Socio-economics**
Other Methods	Avoided Cost	Value current reservoir-dependent water supply by evaluating costs associated with likely alternative	Estimate reduced cost of fish stocking operations as benefit of enhanced habitat				Value reservoir benefits based on cost of alternative flood control
	Factor Income	Value irrigation water supply based on farming net income with and without water					
	Instream Flow Valuation	Value increased instream flow by considering willingness to pay for instream uses		Value increased instream flow by considering willingness to pay for instream uses			

Note: The applications noted are those relevant in the context of hydropower licensing. Other applications of the methods may exist. For example, property value models have been used to value water quality, although such an application is unlikely in hydropower licensing.

The methods reviewed in the remainder of this chapter have been widely accepted and applied in the public management of natural resources. First, the revealed preference and stated preference techniques discussed here are included in the Water Resources Council guidelines governing water project formulation and evaluation.[4] These guidelines apply to the U.S. Army Corps of Engineers, the Bureau of Reclamation, the Tennessee Valley Authority, and other groups. Furthermore, the methods in this chapter have been applied extensively in natural resource damage assessment cases conducted by DOI and the National Oceanic and Atmospheric Administration, and are approved for estimation of compensable damages in the regulations governing natural resource damage assessment (43 CFR 11.83 and 15 CFR 990). Finally, other resource management organizations such as the U.S. Environmental Protection Agency rely on many of the techniques described here in estimating the costs and benefits of alternative regulatory strategies. It is important to note, however, that these methods are not without controversy and may be limited by data availability or other factors. Throughout this chapter, we call attention to the strengths and weaknesses of the various methods.

REVEALED PREFERENCE MODELS

A range of valuation techniques exist under the general category of revealed preference. Revealed preference techniques examine individuals' behavior in markets in response to changes in environmental or other amenities, i.e., people "reveal" their value by their behavior.[5] The revealed preference approaches discussed here include both direct methods (based on observed willingness to pay for resources sold in commercial markets) as well as indirect methods premised on the assumption that resource values can be estimated based on observation of individual behavior in a related market. Revealed preference techniques potentially relevant to dam relicensings include market supply and demand models, travel cost models, and property valuation models. We discuss these methods below.

Market Supply and Demand Models

While most of the methods discussed in this chapter focus on valuation of non-market resources, some relevant natural resources are purchased and sold in conventional markets. Market prices can be used to value natural resources when the resources (or some service they provide) are regularly traded in a competitive market. That is, the market must be characterized by several buyers and sellers and must not be constrained in any undue fashion. The correct measure of value using this technique is the change in consumer surplus and producer surplus associated with the resource as a result of the change in environmental conditions. Analogous to

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[4] U.S. DOI, *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*, U.S. Water Resources Council, 1983.

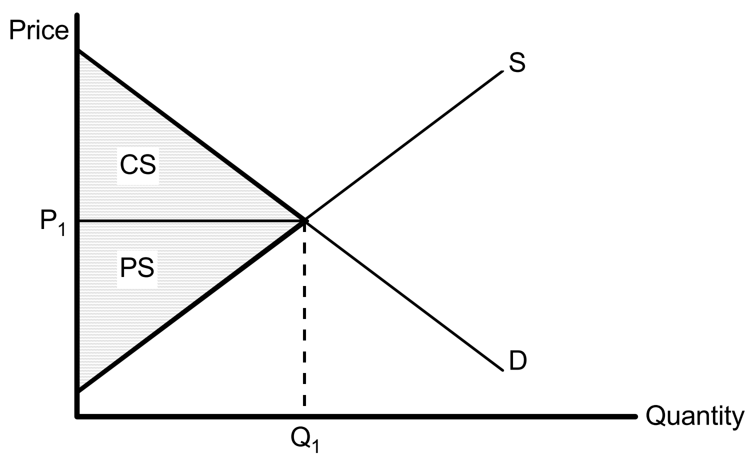
[5] Throughout this chapter, portions of the descriptions of valuation methods are based on Unsworth, Robert E. and Timothy B. Petersen, *A Manual for Conducting Natural Resource Damage Assessment: The Role of Economics,* prepared for Division of Economics, U.S. Fish and Wildlife Service, 1995.

consumer surplus, producer surplus is realized when the price charged for a unit of a good exceeds the cost to produce that unit. This is depicted in the supply/demand relationship shown in Exhibit 5-5. The shaded area PS shows the portion of revenues that exceed the production costs along the supply curve S. For market goods, societal welfare is the total of producer and consumer surplus (shown as shaded area PS and CS).

Calculation of producer and consumer surplus requires estimation of the supply and demand curves for the industry in question. The data generally required include the quantity of the resource or service demanded at different prices and the quantity supplied at different price levels. These data should be considered both before and after the change in environmental conditions. From the supply and demand curves, the analyst can estimate how significant changes will affect producer and consumer surplus. These values can then be used to approximate the economic welfare change associated with the change in environmental conditions.

Exhibit 5-5

CONSUMER AND PRODUCER SURPLUS IN A SUPPLY AND DEMAND FRAMEWORK



In some cases it may be possible to apply a simplified market-based approach to estimate resource values. For example, economic benefits associated with improvements to a commercial fishery may be developed using estimates of the increase in commercial harvest levels and prevailing market prices.[6] If the change in harvest is small, this approach will approximate increases in producer surplus because there is no change in the resources devoted to harvesting fish (i.e., production costs) but revenues increase. Overall, if the impact of the harvest increase

[6] DOI, 1983, op cit., pp. 87-91.

is limited, economic damages may be approximated by the incremental quantity of fish harvested multiplied by the market price of the species in question.

For large scale changes in regional catch rate, however, a market price approach may not be appropriate. Large scale changes will likely lead to changes in market prices or commercial fishing effort. In such cases, application of a simplified market-based approach may not be appropriate. Instead, a more sophisticated analysis of changes in consumer and producer surplus would be necessary, requiring modeling of supply and demand interaction in the commercial fishing or other relevant market.

Data and Resource Demands

The simple method relying on estimation of revenue changes has modest data and resource demands. Information on the quantity and price of market-based natural resources is generally available through state and federal resource management agencies. For example, commercial fishing landings and ex-vessel prices generally are available from the National Marine Fisheries Service. The data and resource demands associated with a full supply and demand model are much greater. Estimation of the demand curve requires data on consumption of the good at various price levels while estimation of the supply curve requires detailed information on production costs.

Application of Market Supply and Demand Models to Hydropower Dam Relicensing

As noted, commercial fishing represents an important market resource potentially affected by dam operation alternatives.

Many projects licensed by FERC are designed to supply water in addition to generating power. While irrigation and municipal water supplies could potentially be analyzed through market supply and demand models, the nature of water markets impedes such an approach. In much of the western U.S., water is marketed through a system of water rights. The holder of the right does not directly pay a price for the water and the benefit of current consumption by the water right holder generally exceeds the value of the right. This type of property rights arrangement does not yield the price and quantity data needed to construct a demand curve and estimate surplus changes. Even for end users such as households that face an explicit price, there is little price variability; for example, during droughts, water rationing rather than price increases are used to limit consumption.

Given the problems associated with demand estimation for water consumption, other approaches to valuing project-based water supplies are recommended. Later in this chapter we review replacement cost and factor income approaches that are applicable.

<u>Travel Cost Models</u>

Travel cost models are analytical tools frequently applied to value access to recreational opportunities, as well as to value changes in the quality and characteristics of these recreation opportunities. Basic travel cost models for a single site are based on the concept that the value of a recreation site can be estimated by analyzing the travel and time costs incurred by individuals visiting the site. These variable costs of travel serve as proxies for the "price" of recreational activity.[7]

A travel cost model typically examines the location from which visitors to a recreational site traveled. The analysis will first consider the number of trips taken to the site for a given travel distance. This essentially represents the quantity of the resource (i.e., trips) demanded at a given price (i.e., travel cost). Using data on multiple visitors to the site, the analyst can construct a demand curve of the sort discussed above. Finally, the analyst can estimate the consumer surplus associated with recreation at the site by estimating the area beneath the demand curve.

While model designs vary significantly, the product of a travel cost model is generally an estimate of the average consumer surplus enjoyed per individual. The consumer surplus estimate is an estimate of the willingness of users to pay for a resource over and above the travel costs they incur and the other costs associated with the experience (e.g., entrance fees). The findings are usually expressed as total consumer surplus per unit of recreation (e.g., a fishing trip, or a day of recreational boating) or per unit of time (e.g., per year).

Different model specifications can be used to value specific qualities of the resource and attributes of the recreational experience. To value these types of amenities, economists typically rely on a variant of the basic travel cost model referred to as a discrete choice or random utility model. Whereas basic travel cost models are most appropriate in analyzing the number of trips people make to a site, random utility models can be used to assess how people choose between multiple sites based on the qualities of the sites.[8] For example, a random utility model can be used to examine how differences in catch rates at different locations affect anglers' willingness to pay for recreational fishing. By statistically controlling for all factors affecting site visitation, the difference in trips attributable to differences in catch rates can be determined.

While single site models are still applicable in a variety of situations, multiple site travel cost and random utility models have become the state of the art. Multiple site models are preferred because of their ability to address how individuals choose among substitute sites, avoiding substitution biases that may occur with single-site models (i.e., overstatement of consumer surplus when improvements at one site simply attract people from another site without increasing overall activity and consumer surplus).

Data and Resource Demands

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[7] DOI, 1983, op cit., pp. 75-79.

[8] Freeman, 1993, op cit.

Travel cost approaches require data on site visitation, place of residence, and user characteristics (such as income). If the area around the dam is a park or other managed facility, the necessary data may be available from local, state or federal resource management agencies through user surveys. When the necessary data are available, the cost of implementing a travel cost study is relatively modest (e.g., $50,000 to $100,000). However, the analyst must often gather the required data through a survey of relevant groups such as anglers who fish at the site. More extensive regional surveys may be necessary when incorporating the effect of substitute resources on recreational or other choices. Studies requiring surveys generally cost at least $100,000, and can be greater depending upon the nature and scope of the survey.

Limitations of Travel Cost Models

Travel cost approaches are limited by the quality of the underlying behavioral data, including the availability of data on substitute recreation opportunities. In addition, travel cost approaches are limited in their ability to measure small changes in the quality of a site.[9] However, in cases where the change in services provided by a site is obvious (e.g., closure of a recreational fishery), and where sufficient data are available, these methods have the potential to provide highly defensible estimates of consumer surplus.

Application of Travel Cost Models to Hydropower Dam Relicensing

Travel cost models have several potential applications in the context of hydropower relicensing. Exhibit 5-6 summarizes some potential applications based on circumstances that commonly arise in EISs. First, EISs for facilities with reservoirs often attempt to incorporate qualitatively the value of reservoir-based recreational activity that would be lost if

USING TRAVEL COST METHODS TO ESTIMATE ECONOMIC LOSSES FROM REDUCED CATCH: AN ILLUSTRATION

Loomis, et al. (1986) considered the potential economic impact of several small-head hydropower dams on Henry's Fork, a tributary of the Snake River in Idaho. One component of the study was a travel cost model that estimated total trips per person as a function of angler characteristics (e.g., income), the availability of substitute sites, and site quality. Henry's Fork was one of 51 Idaho cold water fishing areas included in the model. Over 1,900 licensed anglers responded to a survey that mapped out the fishing areas and asked the respondents to record the number of visits to each site. Anglers were then re-contacted by phone and asked to provide information on travel costs and catch rates.

Loomis, et al. pooled the data and estimated a single recreational fishing demand curve for the region. The estimated equation measures changes in fishing trips (and associated consumer surplus) for changes in catch rates and other factors. Studies of similar dams revealed reductions in fish populations and catch rates of 50 to 75 percent. Loomis, et al. used this range of catch rate reductions to estimate the decrease in fishing trips to Henry's Fork and the total loss in consumer surplus associated with construction of the proposed dams. Specifically, the authors predicted an annual loss of $920,000 for a 50 percent reduction in fish catch and $1.36 million for a 70 percent reduction in fish catch.

Source: Loomis, John, Cindy Sorg, and Dennis Donnelly, "Economic Losses to Recreational Fisheries Due to Small-Head Hydro-Power Development: A Case Study of the Henry's Fork in Idaho," *Journal of Environmental Management*, Vol. 22, pp. 85-94, 1986.

[9] For a complete discussion of the limitations of travel cost methods, see Randall, Alan, "A Difficulty with the Travel Cost Method," *Land Economics*, 70(1), pp. 88-96, 1994.

the dam was removed or operated in a way that has extreme effects on reservoir depth. A more rigorous approach would be to develop estimates of willingness to pay associated with reservoir recreation through a travel cost study. Recreation at existing hydropower reservoirs is amenable to this type of analysis because the activity is ongoing and the reservoir represents a well defined resource that may charge entrance or usage fees to swimmers, boaters, and other groups.

For example, a reservoir may feature motorized boating opportunities. Boaters may register to use the available boat ramps. This registration may provide much of the key data necessary for a travel cost model (e.g., travel distance). Therefore, a travel cost study of boaters could be developed to estimate total net willingness to pay (i.e., consumer surplus) associated with current levels of boating at the reservoir.

Another relatively simple travel cost model might apply in instances where decisionmakers are considering tradeoffs between power generation and more frequent releases for use by whitewater enthusiasts. Using data from public or commercial outfitters, the analyst could gather information on the distance traveled to the site and rafter characteristics (e.g., rafting experience). More detailed data such as income levels and specific travel costs could be gathered through on-site interviews or a mail survey. Estimates of the average consumer surplus associated with each rafting trip could be estimated. This figure could then be used to estimate the value of increasing the number of trips through more frequent releases.

Exhibit 5-6

EXAMPLES OF POTENTIAL TRAVEL COST STUDIES TO SUPPORT RELICENSING DECISIONS

Service/ Resource to Be Valued	Example Scenario	Modeling Approach	Model Output
Reservoir recreation	A hydropower reservoir provides motorized boating opportunities that would be eliminated if the dam is removed.	Single-site travel cost model that estimates demand curve based on travel costs and park fees incurred by boaters.	Total annual consumer surplus lost by elimination of the reservoir.
Whitewater recreation	Whitewater rafting is currently rationed in a river reach below a hydropower plant. Estimate potential value of more frequent releases for rafting.	Single-site travel cost model to estimate current consumer surplus associated with existing rafting trips.	Per-trip consumer surplus for existing trips and total potential consumer surplus created through more frequent releases.
River-based recreational fishing quality	The dam reduces sediment loads causing loss of fish habitat, decreasing fish populations and lowering catch rates.	Random utility model incorporating similar substitute sites with higher catch rates.	Annual loss in consumer surplus associated with lower catch rates.

As noted, travel cost studies can be used to estimate the economic value of changes in resource quality that affect use of the resource. In the context of dam relicensing, an example would be alternatives that increase flows below a dam to enhance the downstream fishery. An improved fishery could have a variety of impacts on recreational use. For example, the improved fishery may create a change in catch rates that will attract new anglers. A travel cost (or random utility) model could be constructed to examine angler preferences across multiple fishing sites in a region, and statistical methods applied to estimate how trips to the river below the dam will change with a change in catch rates (see text box). This change in fishing activity would represent an increase in total consumer surplus.

Property Valuation Models

Property valuation models assess how proximity to various environmental amenities (e.g., a bathing beach) or disamenities (e.g., a hazardous waste site) influence the amount individuals are willing to pay for real property. It is well understood that a house will sell for more or less depending on the attributes of the neighborhood in which it is located. While there is some disagreement as to the magnitude of the effect, most economists would agree with the premise that long-term damage to environmental resources, such as reductions in the quality of a river or wetland, could act to reduce nearby property values. Thus, this method uses changes in property values as a proxy for changes in nearby resource values.

Two principal property valuation methods have been used in economic studies: the hedonic property valuation approach and the repeat sales approach. Hedonic property valuation involves the use of data on home characteristics for a range of homes in a given area at one point in time (e.g., data on lot size, number of bedrooms, or presence of a municipal landfill). Statistical regression analysis is used to determine the contribution of each factor to sale price. Hedonic analyses have been conducted at the house-level, using data on individual properties, and at the regional level, using data on average home characteristics across towns and counties.

Repeat sale analysis, or panel data analysis, considers the relative rates of change in housing prices between affected and control (unaffected) areas. That is, these models follow a fixed sample of homes through time. For example, comparing the rates of home appreciation before and after an environmental change and between affected and unaffected areas would yield a measure of property value impacts. Repeat sale studies are particularly useful in cases where individual property characteristics data are not available.

Data and Resource Demands

On the one hand, property value models call for data that are often readily available from various sources. For example, housing attribute information may be available from county or municipal records and data on selling prices may be available from realtors or commercial data marketers. However, while data may be accessible, the amount of data that must be managed to obtain statistically meaningful results is great and will require an extensive commitment of resources to acquire, compile, and analyze. Overall, the cost of conducting a property value study begins at roughly $100,000 in cases where the analysis focuses on a single housing market with available data. Costs can be significantly higher when multiple markets must be considered (e.g., multiple cities along a river) or when data must be gathered from county or municipal paper files.

Limitations of Property Value Models

A fundamental advantage of the property valuation technique is that a change in property values can serve as a measure of many lost services (e.g., recreational, aesthetic) associated with a change in environmental quality. Further, the method is based on observable behavior in a market that is well understood. There are a number of limitations associated with this approach, however. The most significant limitations include:

- Given the large number of factors that determine home value, it is often difficult to disentangle the influence of various factors; for example, it may be difficult to separate the perceived health effects of hazardous chemical plant emissions from the visual and other aesthetic effects of the site.

- The ability of hedonic or repeat sales models to detect small changes in resource attributes is limited because a large number of factors act together to determine market price, some of which may correlate with the effect in question.

- Because property value models capture the full suite of values (e.g., recreational, aesthetic) associated with environmental changes, they may yield estimates that double count other benefits estimated for a site, such as lost recreation opportunities evaluated through travel cost methods.

Application of Property Value Models To Hydropower Dam Relicensing

Property value models have a relatively limited set of potential applications in the context of hydropower relicensing. The most likely use is examination of values associated with the presence of reservoirs behind dams. In many relicensing actions, FERC attempts to balance the interests of river restoration and reservoir management in choosing between project alternatives. Because reservoirs can be local recreational and aesthetic attractions, changes in reservoir characteristics such as water depth can potentially affect the value of properties on or near the reservoir.[10] In cases where dam removal is considered, elimination of the reservoir could have a

[10] See Khatri-Chhetri, J.B., and J.C. Hite, "Impact of Reservoir Levels on the Market Value of Lakeshore Properties," *Rivers*, Vol. 1, No. 2, 1990, pp. 138-147.

significant impact on local property values. Concern over the impact of reservoir management and effects on property values is evident in comments submitted to FERC as part of the relicensing process.[11]

Property value models could potentially be developed to estimate the economic value of reservoir resources to a community. One potential study design would involve developing a hedonic model that statistically contrasts the value of homes in a community near a reservoir with house values in a nearby community with no reservoir. Such a study would potentially help characterize the value of recreational, aesthetic and other amenities associated with the reservoir. If dam removal was among the alternatives under serious consideration, this type of property value study would allow FERC and other decisionmakers to contrast the costs of eliminating the reservoir with other benefits that would accrue as a result of river restoration.[12]

STATED PREFERENCE MODELS

Stated preference models represent another family of models designed to measure non-market benefits. At a basic level, these models involve asking individuals about the value they place on amenities such as natural resources, i.e., respondents "state" their values. Below, we focus on contingent valuation methods, the predominant type of stated preference technique; we then review emerging variants of stated preference models.

Contingent Valuation

The contingent valuation (CV) method uses survey techniques to directly elicit information on individuals' willingness to pay for goods that are not commonly traded in markets, such as natural resources and the services they provide. Components of this approach include creating a hypothetical market that provides survey respondents with a description of the good or service being valued; developing the institutional framework under which the good would be provided; creating a hypothetical payment vehicle; and providing respondents with an opportunity to express a value for the good or affected service. The analyst then compiles the survey data and applies statistical techniques to estimate average willingness to pay (i.e., consumer surplus) associated with the amenity under consideration. CV is versatile in that survey questions can be fashioned to elicit willingness to pay for specific amenities and resource

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[11] For example, see FERC, *Environmental Assessment for Hydropower License, Morris Sheppard Dam Water Power Project*, December 22, 1988; and FERC, *Final Environmental Impact Statement, North Georgia Hydroelectric Project*, FEIS-0098, June 1996.

[12] Very few studies of this sort have been developed, and those that exist are significantly outdated. See Vaughan, Claude M. and Don M. Soule, "Reservoir Effects on Property Values According to Location and Rural vs. Urban Use," *Water Resources Bulletin*, Vol. II, No. 6, December 1975; and Day, J.C., and J.R. Gilpin, "The Impact of Man-Made Lakes on Residential Property Values: A Case Study and Methodological Exploration," *Water Resources Research*, Vol. 10, No. 1, February 1974.

characteristics, e.g., willingness to pay for increased visibility in the area of a scenic vista. In this way, CV allows greater latitude than revealed preference approaches that require markets which directly or indirectly yield information on the values people hold for an environmental amenity.

CV can be used to estimate both use and non-use (intrinsic) values associated with natural resources. Relevant applications for estimating use values include studies of recreational and aesthetic improvements. For example, Johnson and Adams (1988) used CV to assess anglers' willingness to pay for changes in fish populations and catch rates.[13] Respondents were given changes in steelhead population and asked to state their new expected catch rates. Respondents then specified their willingness to pay for these improved catch rates.

Economists also frequently apply CV to estimate non-use values for natural resources. As discussed earlier, individuals may value the existence and quality of a resource even if they do not use the resource. For example, a number of studies have used CV to characterize non-use value associated with the preservation of wild and scenic rivers (see Chapter 6). Empirical studies have demonstrated that non-use values associated with resources are often significant and can exceed use values.[14] Currently, CV is the only established method for measuring such values, although other techniques are growing in acceptance (see below).

Data and Resource Demands

The development of a full-scale CV study generally involves several stages. These steps include the following:

- **Focus Groups**: The researcher can use focus group discussions to better understand public perceptions of the resource in question and to refine their description of the commodity to be valued.

- **Survey Development**: The survey instrument must be carefully structured to yield meaningful responses. In particular, the commodity to be valued must be clearly described and the appropriate payment mechanism (e.g., increased federal taxes) established. The researcher must also choose the format for the bidding; for example, a dichotomous choice format asks respondents to "vote" yes or no for various payment levels suggested by the survey or interviewer. The preliminary survey instrument should be pretested, preferably in a one-on-one setting. It is also prudent to conduct pilot field tests of the instrument.

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[13] Johnson, Neal S., and Richard M. Adams, "Benefits of Increased Streamflow: The Case of the John Day River Steelhead Fishery," *Water Resources Research*, Vol. 24, No. 11, pp. 1839-1846, November 1988.

[14] Harpman, David A., et al., "Nonuse Economic Value: Emerging Policy Analysis Tool," *Rivers*, Vol. 4, No. 4, pp. 280-291, 1994.

- **Survey Implementation**: Implementing the final survey involves selection of a sample frame that is representative of the population holding values for the resource and that will ensure statistically valid results. CV studies have used mail, phone, and face-to-face survey approaches, the choice of which is influenced by the nature of the commodity and the survey population, as well as by the study budget. The survey may also require follow-up contact with the respondents to clarify or supplement initial responses.

- **Data Analysis**: Finally, the researcher must analyze the data obtained from the pilot and final surveys. This typically involves application of sophisticated statistical methods to estimate average willingness to pay and quantitatively characterize other survey results.

This multi-step process is designed to reduce biases that may be created by a poorly designed or administered survey.[15]

The detailed procedures associated with a CV survey and analysis require a significant commitment of resources. Costs are sensitive to factors such as the survey sample size, the complexities of constructing a representative sample for the population in question, the type of survey instrument (i.e., mail survey or phone survey), the extent of pre-testing, the nature of the data analysis, and other factors. A phone survey with simple sampling procedures, limited pre-testing, and simple data analysis can be accomplished for roughly $100,000 to $200,000. A mail survey that examines various regional and national subgroups and requires extensive pretesting, phone follow up, and data analysis can cost as much as $1 million.

In practice, the investment made in CV surveys is usually proportional to the resource values in question, i.e., complex and costly surveys are done only to support major resource management decisions or litigation cases. In most cases, quick and rough CV surveys are not advisable because the inherent biases may be difficult to identify and correct. For this reason, screening analyses like those described in Chapter 6 are essential before making the investment of time and resources required by a CV.

Contingent valuation surveys generally require a minimum of one year to complete, with many studies significantly longer in duration. Furthermore, studies of physical and biological impacts associated with the dam may not be available until later in the EIS process. Because the survey will likely incorporate physical and biological impacts as part of the good to be valued, the EIS schedule may leave little time for completion of the CV study. Therefore, the manager of the EIS process may need to delay release of the draft EIS or allow final results of the CV

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[15] For more detail on the process of developing and implementing a contingent valuation survey, see Mitchell, Robert Cameron, and Richard T. Carson, *Using Surveys to Value Public Goods: The Contingent Valuation Method*, Resources for the Future, Washington, DC, 1989.

study to be added to the final EIS, with the draft EIS reporting only a description of the study methodology.[16]

Limitations of Contingent Valuation

The advantage of the CV method is that it can be used to capture the full range of values associated with a resource. In addition, because this method relies on stated values rather than observed behavior, it is the only method available for many service flows. Most notably, CV offers the unique advantage of allowing valuation of prospective resource services not yet experienced; this is useful in the case of dam management where changes may restore river conditions long absent in the area (e.g., anadromous fish runs, non-use values for wild and scenic rivers).

However, the reliability and validity of this method has been the subject of much controversy.[17] Some economists express particular concern about the ability of the method to provide meaningful estimates of non-use values for public goods.[18] The debate primarily focuses on whether respondents can provide reliable estimates of the value of these types of goods, given that the public has little or no experience with purchasing such goods. Specific criticisms include, but are not limited to, the following:

- For a variety of reasons, respondents' stated intentions may not equal true willingness to pay. Observers have noted that respondents may not carefully consider personal budget constraints when stating willingness to pay. In particular, CV surveys suggest that individuals value a vast array of environmental commodities; total bids across all these commodities could quickly exceed personal income, casting doubt on the validity of the individual study results.[19]

- Likewise, individuals' bids may be affected by the "warm glow" of giving. That is, bids may reflect individuals' interest in contributing to a worthy cause rather than their true value for the resource in question.

[16] Harpman, 1994, op cit.

[17] For a comprehensive critique of CV, see Diamond, Peter and Jerry Hausman, *Contingent Valuation: A Critical Assessment*, North Holland Press, 1993.

[18] Many economists that question the use of CV for estimating non-use values accept the method for estimating use values.

[19] Arrow, Kenneth, et al., *Report of the NOAA Panel on Contingent Valuation*, January 1993.

- Respondents may be able to express values for clearly understood commodities, but may be unable to express values for more abstract or unfamiliar commodities (e.g., groundwater quality).

- Individuals may have difficulty understanding the scale of the resource they are being asked to value.[20] For example, rather than focusing on a specific river reach that would be affected by dam removal, the respondents may offer bids that reflect their willingness to pay for healthy rivers in general.

Due to the importance of the CV method in many natural resource damage assessments, a panel of eminent economists was convened by the National Oceanic and Atmospheric Administration (NOAA) to evaluate whether it should be applied to estimate lost passive use values for the purposes of damage assessment. The panel concluded that "contingent valuation studies can produce estimates reliable enough to be the starting point of a judicial process of damage assessment, including lost passive-use values," provided that a number of conditions are met in the design, implementation, and interpretation of the CV survey [(58 FR 4601-4614)].

Application of Contingent Valuation to Hydropower Dam Relicensing

Contingent valuation methods are well-suited to a variety of non-power benefits associated with dam relicensing. Exhibit 5-7 reviews examples of how CV may be applicable. First, CV could be used to assess aesthetic values that individuals hold for resources affected by the dam. For instance, diversions and bypasses at the dam may reduce flows to scenic waterfalls. A contingent valuation survey could be used to gauge individuals' willingness to pay to view the falls at different flow levels. One survey approach would be to present respondents with photographs of the falls at various flow levels; the photos would serve as the basis for their willingness to pay bids. The accompanying statistical analysis could then estimate the total consumer surplus for all visitors to the falls. Additional survey questions could be used to estimate the increase in the number of visits to the falls at higher flow levels, an added dimension of the overall societal willingness to pay for the resource. One of the case studies presented in Chapter 7 provides a detailed review of a survey that used such an approach.

Numerous studies have used CV to value improved availability and quality of recreational fishing.[21] One type of study potentially relevant to hydropower relicensing would involve surveying anglers regarding their willingness to pay for improved recreational fishing experiences, e.g., higher catch rates. For example, past studies have asked anglers at a specific site or geographic region to specify their typical daily catch rates; these studies then asked how much more the individual would be willing to pay to double his or her catch rate. This type of

[20] See 58 FR, Preamble, Section III (Response to Comments), Subpart S (Nonuse Values and CVM), July 22, 1993.

[21] See Chapter 6 of this report for a review of these studies.

CV survey may be appropriate when evaluating licensing alternatives that call for expansion of fish habitat (e.g., through flow increases) or reduced entrainment.

Exhibit 5-7

EXAMPLES OF POTENTIAL CONTINGENT VALUATION STUDIES TO SUPPORT RELICENSING DECISIONS

Service/ Resource to Be Valued	Example Scenario	Modeling Approach	Model Output
Aesthetic value of scenic waterfall	Reduced flows below the dam diminish the aesthetic qualities (e.g., sight, sound, spray) of a scenic waterfall in a recreational area.	Survey could present respondents with photographs of the falls at various flow levels and elicit willingness to pay for viewing different flows.	Estimates of individual willingness to pay for flow increases and changes in the number of trips to the falls; estimate of total potential consumer surplus from flow increases.
Improved recreational fishing quality	Dam affects sediment levels, dissolved oxygen, and water temperature, reducing fish habitat and reproduction.	Survey anglers using the river regarding their willingness to pay for increased catch rates and/or increased fish size.	Average per-angler consumer surplus increase associated with increased catch/size; estimate of total increase in consumer surplus across all anglers.
Total value associated with dam removal	Removal of dam on an otherwise free-flowing river would restore anadromous fish population and other aspects of the natural ecosystem.	Survey different categories of households (i.e., regional, statewide, national) regarding willingness to pay for dam removal.	Average per-household willingness to pay for removal of the dam; total regional, state, and national willingness to pay for dam removal.
Intrinsic value of endangered species	Change in dam operations would expand habitat for an endangered fish species.	Survey households regarding willingness to pay to protect the endangered species.	Per-household and total willingness to pay for protection of the endangered species.

As noted, CV is the only established method for assessing non-use or intrinsic values for resources. For instance, CV could be used to estimate the general public's willingness to pay for removal of a dam and restoration of key ecosystem components such as anadromous fisheries. This type of study would yield an estimate of total value, i.e., use and non-use value. Such a survey must be carefully structured to convey to the respondent the complex mix of services that would be gained (e.g., ecological functions) and lost (e.g., cheap power). Furthermore, the sample design for such a study must be carefully crafted. A small dam on a minor river may have only local or regional significance, suggesting that only the nearby population would hold values for the resource and therefore be included in the survey. In contrast, a major dam on a well-known river may have national significance, calling for a much larger surveyed population.

☞ The case study chapter in this report reviews a recent CV study estimating the total value of removing two dams on Washington's Elwah River.

Researchers also have used CV approaches to estimate non-use values associated with preservation of threatened or endangered wildlife species. In the context of hydropower relicensing, such a study may be useful if dam operations deplete habitat for key instream species.

USING CONTINGENT VALUATION TO ESTIMATE WILLINGNESS TO PAY FOR WHITEWATER RECREATION: ILLUSTRATION

To support the relicensing of the Ayers Island hydroelectric project on the Pemigewasset River in New Hampshire, Duffield (1993) prepared a contingent valuation study examining whitewater rafting values. The objective of the study was to assess willingness to pay for whitewater boating under several dam management alternatives, ranging from continuation of existing peaking power operation to conversion to run-of-river operation in the summer months. Each alternative had different implications for instream flow levels.

Through a phone survey, boaters identified their preferred flow level and were asked to state their willingness to pay for various changes in flows. Respondents were also asked how their level of boating activity would change under the flows for each management alternative. The estimated value per trip ranged from roughly $28 to $41 ($1993). Combining this information with estimates of boating activity, the author estimated aggregate annual consumer surplus ranging from about $10,000 to $111,000, depending upon the management alternative.

Source: Duffield, John, *The Economic Value of Whitewater Boating on the Bristol Stretch of the Pemigewasset River*, prepared for Public Service of New Hampshire, August, 1993.

Other Stated Preference Approaches

Contingent valuation is by far the most widely used stated preference technique. In recent years, another stated preference methodology -- attribute-based stated choice modeling or conjoint analysis -- has been applied to non-market valuation. While this family of models is somewhat complex, it is an emerging technique and therefore worth describing briefly.

Conjoint analysis is related to contingent valuation in that it relies on the respondent making a choice regarding a hypothetical situation. However, with the conjoint method, individuals are presented with several suites of options having various amenities and prices. The method elicits estimates of marginal willingness to pay based on how the respondent ranks, rates, or constructs equivalent sets of alternatives. For example, Adamowicz et al. used thirteen attributes to create hypothetical recreational fishing scenarios.[22] Some of the attributes used in their scenarios were distance to the site, site terrain, average size of fish caught at the site, catch rate, fish species found at the site, water quality, water flow, and presence of motor boats. These attributes were combined into various choice sets between which respondents choose. The responses were then combined with actual site choice data in a standard random utility framework. The stated preference data give additional insight into the welfare contribution of the different site attributes by improving the statistical efficiency of the estimation process and allowing consideration of changes and site conditions not experienced at actual sites.

Conjoint analysis can also be applied to the estimation of non-use values, although there have been few applications to date. The analysis asks respondents to choose between alternative scenarios where relevant attributes are varied. Attributes include both physical changes and the

[22] Adamowicz, Wictor, et al., "Combining Revealed Preference and Stated Preference Methods for Valuing Environmental Amenities," *Journal of Environmental Economics and Management*, Vol. 26, No. 3, pp. 271-292, 1994.

individual's cost of obtaining the change (e.g, an environmental improvement). The data can then be analyzed in a random-utility fashion. One advantage of conjoint analysis is that it allows consideration of benefits for a continuum of attribute changes whereas traditional contingent valuation studies generally focus on a single change. For example, a conjoint model could potentially be used to value a range of river flow levels rather than a single alternative.

In the context of both recreational choice and non-use value estimation, conjoint analysis may prove to be very useful in the analysis of FERC relicensing alternatives. Although promising, the properties of the resulting benefit estimates are not as well understood as the estimates obtained from more established stated preference techniques.[23]

METHODS FOR VALUING PROJECT SERVICES

As noted, hydropower projects may provide services other than power. For example, a reservoir that is part of a development may create a reliable source of water for agricultural, municipal, or industrial use. Such services may not vary significantly between relicensing alternatives incorporating different environmental measures and so may have only limited influence on the net benefit estimates. However, when considering dam removal or major changes in dam operation, it is important that FWS staff and other participants in the relicensing process consider the value of such services. Below, we discuss two approaches -- averted cost methods and the factor income method -- potentially useful in assessing the value of such project services.

Added or Averted Cost Approach

Under added and averted cost methods, the cost of producing a good or service is considered in comparison to the cost of providing the good or service through some alternative means. As we have reviewed, the current FERC approach to valuing power benefits represents an averted cost approach. That is, if power can be produced at the dam at a cost lower than that achieved at the next best alternative, then the difference in cost represents the net economic benefits associated with the dam; i.e., the added cost of power generation at the alternative source is an avoided cost.

This same thinking can be applied to a variety of other resource valuation problems. In particular, added or averted cost methods may be applicable when considering the infrastructure services that dams provide, unrelated to power generation. The following are notable examples:

- Dams often provide flood control by tempering the seasonal flow changes of free-flowing rivers. In some instances, if the dam did not exist,

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[23] For a discussion of the consistency and reliability of conjoint estimates, see Smith, V.K., "Pricing What is Priceless: A Status Report on Non-Market Valuation of Environmental Resources," in *The International Yearbook of Environmental and Resource Economics 1997/1998: A Survey of Current Issues*, edited by H. Folmeer and T. Tietenberg, 1997.

construction of other flood controls (e.g., levees) would have been necessary. Likewise, if the dam is removed, these controls may be needed. Therefore, the flood control services provided by the dam can be valued on the basis of the avoided flood control expenditures.

- Dams may reduce and stabilize flows on a river making it navigable for commercial vessels; this avoids potentially higher costs associated with alternative transportation.

- As noted, reservoirs created by dams may allow more cost-effective water withdrawals for municipal and agricultural use. The cost of delivering water from an alternative source can be used to reflect the value of water supplied by the project.[24]

A good example of how avoided cost methods can be applied in assessing project services is provided in the Bureau of Reclamation's (BOR) assessment of the Kingsley Dam in Nebraska.[25] One component of this analysis involved valuing the reliable supply of cooling water that the project furnished to a nearby coal-fired power generation facility. The study estimated the avoided cost of the least-cost alternative for cooling the plant in the absence of the Kingsley Dam project. Without the project, the natural flow diversions to the reservoir would be insufficient to meet water needs at the plant. BOR considered both the costs of retrofitting a closed cooling system and the costs of pumping groundwater and using it as a replacement for surface water. BOR estimated the 30-year present value of the cooling system option to be about $148 million while the analogous estimated cost of pumping groundwater was estimated to be about $68 million. Therefore, BOR valued the cooling water supply at $68 million.

Replacement power effects represent another example of averted-cost benefits potentially provided by dams. When considering the economic advantages of hydropower sources, FERC currently incorporates the avoided cost of pollution control at combustion-based replacement sources. As we have described earlier, it may be more appropriate to consider the externalities imposed by emissions from combustion plants. Most studies of emissions externalities focus on the costs imposed by these emissions (e.g., health care costs, costs of cleaning soiled surfaces). Therefore, a benefit of a given hydropower project may be avoidance of these costs around combustion replacement sources.

The data and resources required for an avoided cost study are diverse and highly case-specific. For example, the avoided cost of replacing flood control services provided by the hydropower project with other engineered solutions will depend on numerous hydrological,

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[24] For a more detailed discussion of water supply benefit evaluation procedures, see DOI, 1983, op cit., pp. 20-25.

[25] Davis, Rob M., et al., *Economic and Financial Analysis: Federal Energy Regulatory Commission Projects No. 1417 and No. 1835*, Economics Group, Technical Service Center, U.S. Bureau of Reclamation, August 1996.

geographic, and demographic factors in the vicinity of the river. It is beyond the scope of this report to review methods for evaluating such costs. However, when dam removal is under consideration, participants in the relicensing process should be aware that many of the non-power benefits discussed throughout this report will need to be weighed against potentially significant secondary infrastructure services provided by hydropower projects.

Factor Income Approach

Under the factor income approach, the services provided by a resource are viewed as inputs to the production of a service or commodity sold in the market. This approach is based on the economic concept of a production function; that is, inputs such as natural resources are combined to produce a good or service sold in the market. Changes in the cost of acquiring these inputs can affect profit realized by the producer of the final good or service, and this loss can be used to value the resource in question.

In the context of hydropower relicensing, the factor income approach is most applicable for valuing irrigation water supplies. Irrigation water from the project can be treated as an input in the production of crops. The water's contribution to farming net income (profit) represents the value of the irrigation water.

This approach was used by BOR to value irrigation water supplies from the Kingsley Dam in Nebraska.[26] The analysis was based on Department of Agriculture crop budgets reflecting productivity and profitability of corn farming with and without irrigation water. Based on water application rates, BOR translated differences in net income per acre to differences in net income per acre foot of water used. The analysis estimated a value of $8.29 per acre foot of water, with total annual supplies (95,500 acre feet) valued at $791,700.

[26] Davis, Rob M., et al., 1996, Ibid.

THE MARGINAL VALUE OF INSTREAM FLOW: A SPECIAL APPLICATION OF PRIMARY METHODS

Hydropower facilities, particularly peaking power dams, frequently alter the amount and timing of water flows below the dam. Water may be impounded behind the dam to be released at times when power generation is most economically advantageous. Impounded water may also be routed to consumptive uses such as irrigation and municipal water supply. Furthermore, water may be diverted around portions of rivers (called bypass reaches) and returned to the river far downstream. Depletion of instream flow can affect both ecological conditions in the river (e.g., reduction of fish habitat) as well as human uses such as rafting and aesthetic enjoyment. Many EISs focus on the need to manage the hydropower facility in a way that satisfies the licensee while preserving or restoring the various instream services the river provides.

Economists have developed studies that consider instream flow as a resource to be efficiently allocated between competing uses. As with other economic resources, efficient use means allocating the resource to the highest-value applications. Therefore, these studies generally examine the value of instream flow for commercial uses such as power generation and agriculture relative to value in non-market uses such as recreation and aesthetics.

Marginal Value Concept

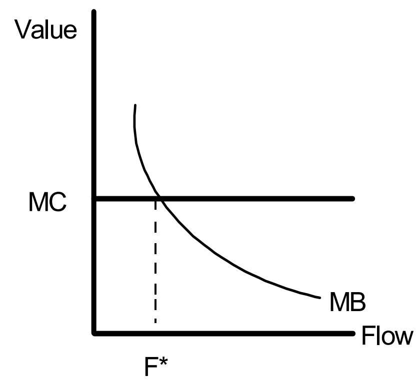
Many of the studies of instream flow seek to estimate the marginal value of water for the alternative use under consideration and compare this marginal value to an ongoing use of the river flow (e.g., power generation). The concept of marginal value refers to the last unit of an economic good that is consumed. For example, the marginal benefit of one more acre-foot of water added to river flow is equal to what the user (e.g., a recreational rafting enthusiast) is willing to pay for the additional unit of water.

Economic theory suggests that a resource is efficiently allocated when the marginal benefit of supplying the good is equal to the marginal cost. Placed in the context of hydropower and river flow, this means that competing uses of river flow should be balanced to equalize the marginal benefit of the water for generating power and the marginal benefit of the water for other uses. For example, the marginal benefit of an acre-foot of water for downstream recreation can be compared to the value of the power (measured as the avoided cost of replacement power) that is given up by using one less acre-foot of water to generate power at the dam. Other studies of the value of instream flow have examined consumptive uses such as irrigation withdrawals and compared the commercial value of these withdrawals to alternative downstream uses.

Exhibit 5-8 illustrates the potential relationship between flow and value in competing uses of streamflow. As shown, the marginal benefit of increased flow for alternative uses is initially high, demonstrating a strong willingness to pay for increased flow when streamflows are very low. The marginal value of increased flow is positive across a range of flows, although this marginal value decreases at higher flow levels; e.g., rafters may value increased flow, but additions to larger base flows are less and less valuable. Most studies compare this marginal benefit to a marginal cost that equals the price or value of the water in its current use (e.g., the value of the unit of water if it is used to generate power). This marginal cost is depicted as a flat line in the graph. The point where the marginal benefit of increased streamflow equals the marginal cost (shown as F*) is the economically efficient flow because at greater flow levels, the cost of flow exceeds the benefits.

Exhibit 5-8

COMPARISON OF MARGINAL BENEFIT AND MARGINAL COST OF INCREASED STREAMFLOW



Application to Hydropower Relicensing

In the context of hydropower relicensing, marginal analysis of instream flow is useful for contrasting the value that recreational river users place on flow relative to the marginal value of water for producing power. Much of the economics literature focuses specifically on balancing hydropower and consumptive uses with recreational uses of streamflow. While a variety of flow valuation approaches exist, the most common techniques are built on the contingent valuation methodology discussed above.[27] The studies survey recreationalists regarding their willingness to pay for river uses, treating willingness to pay as a function of stream flow. Several different survey approaches have been used. For example, some studies elicit individuals' stated willingness to pay for flows that they actually experienced at the site and then compare these

[27] For a review of instream flow valuation approaches, see Brown, Thomas C., et al., "Addressing the Direct Effects of Streamflow on Recreation: A Literature Review," *Water Resources Bulletin*, Vol. 27, No. 6, pp. 979-989, December 1992.

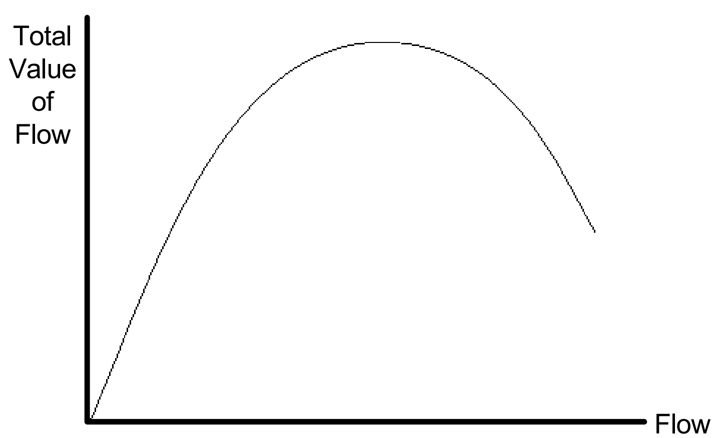
responses to infer the value of different flow levels. Other studies displayed photographs of the river under various flow conditions while others used verbal descriptions to obtain estimates of willingness to pay.

Most of the instream flow studies find an "inverted-U" relationship between flow and the recreational value under consideration. This relationship is illustrated by the curve in Exhibit 5-9. Consistent with the marginal benefit concept reviewed above, the economic value of increased river flow initially rises as flows increase. However, in the case of recreation, flows beyond a certain point are actually detrimental to the recreational activity. Therefore, marginal benefits decrease beyond some optimum flow.

In cases where competition for instream flow is a major issue, marginal benefit studies may provide a means for identifying dam operation alternatives that maximize social welfare. Using the contingent valuation or travel cost methods described above, original research could be conducted to estimate the value of instream flow to local river users. Major uses in the study area could be targeted; for example, existing studies have derived the value of instream flow on the basis of willingness to pay on the part of anglers, rafters, viewers of scenic waterfalls, and other users. These marginal benefits of increasing flow could be compared to the marginal costs of increasing flow. In most cases, these costs would include the value of the power generation given up to supplement river flows.

Exhibit 5-9

RELATIONSHIP BETWEEN INSTREAM FLOW AND RECREATIONAL VALUES



In addition, the marginal value of instream flow could also be used to evaluate the cost-effectiveness of other attributes of dam operation. For example, in arid western states, mitigation measures sought by resource management officials often include water conservation actions designed to reduce evaporation losses occurring when water is delivered to irrigation and other uses. The cost of conservation measures could be contrasted with the marginal value of the water for instream uses to evaluate the cost-effectiveness of the measures.

Data and Resource Demands

Estimation of instream flow benefits essentially entails customized application of contingent valuation or travel cost methods reviewed earlier. Therefore, the data and resource demands are the same as those discussed above. In Chapter 6, we review secondary methods for benefits estimation; included is a discussion of how results from previous studies of instream flow benefits could be applied in basic screening analyses to compare marginal benefits and costs of increasing instream flow.