Increasing Stream Flows to Sustain Salmon in the Northwest: An Economic and Policy Assessment

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Background and Acknowledgments

As we enter the new millennium, the citizens of Washington and Oregon face a number of important environmental challenges. For example, they know that a majority of streams fail to meet water quality standards and that many salmon stocks are listed as threatened or endangered regionwide. In addition, the recently published Oregon State of the Environment Report identified a number of areas where Oregonians can expect continued problems under current policies and programs including: poor water quality, especially in urban and agricultural areas, inadequate water supplies, loss of wetlands, degraded riparian areas, depleted fish stocks, invasion of exotic species, diminished biodiversity, and waste and toxic releases. Similar problems are sure to exist in Washington State.

These types of environmental issues threaten to constrain the economy and quality-of-life of communities throughout the Pacific Northwest. The public and decision makers want to take appropriate steps to resolve these problems, but often hesitate because they fear the economic consequences will be too severe.

In the spring of 1999, The Center for Watershed and Community Health (CWCH), a non-profit research institute affiliated with the Mark O. Hatfield School of Government at Portland State University, initiated a project to help decision makers throughout the region better understand the economic issues and facts associated with developing a more environmentally sustainable economy. The CWCH's aims is to provide accurate, objective, and easy-to-understand information about the potential costs and benefits associated with adopting practices and policies that can resolve pressing problems such as endangered salmon and lead to a more environmentally efficient economy. The CWCH has developed collaborative research partnerships with a number of academic institutions in Washington and Oregon, provides grants to a number of leading economists, and completes its own research, to accomplish this goal. This assessment is one in a series of reports to be produced as a result of this effort. The project is an integral part of PSU CWCH's focus on developing new, more effective and efficient approaches to environmental governance.

AUTHORSHIP

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EXECUTIVE SUMMARY

According to biologists, increasing streamflows in the Pacific Northwest is essential to restore and maintain the populations of salmon and other native fishes. Since agriculture is the principal source of surface water diversions, accounting for about 80 percent of the total for the region, any efforts to augment streamflow will necessarily concentrate on reducing irrigation diversions. The likely costs of any actions to protect salmon are a central public concern and an important policy consideration, and in this particular case, these costs will depend directly on the impact that reducing irrigation diversions will have on farm enterprises in the region.

This analysis appraises these costs and finds that they are likely to be modest if an efficient approach is taken to increasing streamflows. These estimates are based on evidence from market transactions for individual water rights, sales of irrigated farm land, and from a number of economic studies and cost estimation techniques. Our calculations indicate that the cost of water ranges from $1 to $25 per acre-foot, which, for a broadly based regional program to restore and maintain healthy fish populations, translates into annual costs of between 0.5 and 4.0 percent of the net farm income from all irrigated farms in the region, or between $1 and $10 per person in Washington, Oregon and Idaho.

The analysis cautions, however, that some actions aimed at restoring salmon may be excessively costly, largely ineffective, or both—for example if high value irrigation water is returned to the wrong streams at the wrong times. In addition, it should not be assumed that by simply introducing water markets among farmers, or by promoting adoption of improved irrigation technologies, that streamflows will increase or that salmon will benefit from these changes. For these or other measures to contribute to the restoration of salmon stocks, and to do so in a cost-effective way, will require creative institutional arrangements and attention to biological and economic information.

I. Introduction

In order to protect and restore the populations of wild salmon and other native fishes in the Pacific Northwest, including those actions required under the Endangered Species act, it is widely recognized by biologists and policymakers alike that significant changes will be required throughout the region. In addition to possible actions such as tighter harvest restrictions, dam breaching, and changes in the role of hatcheries, broad actions are anticipated to improve the freshwater habitats which play a key role in the spawning, rearing, and migration of salmon.

Streamflow is a key factor affecting the quality of salmon's freshwater habitat. Although the benefits to salmon for a specific increase in stream flows are difficult to assess precisely, biologists point to substantial scientific evidence that reductions in streamflows have contributed to the decline in salmon stocks throughout the region. Thus, a critical issue in the current policy setting will be how to maintain and increase stream flows in order to protect existing freshwater habitats and to restore those that have been degraded.

A central public concern and policy consideration will be the likely costs of actions to increase streamflows. Since agriculture is the principal source of surface water diversions, accounting for about 80 percent of the total for the region, any efforts to augment streamflow will necessarily concentrate on reducing irrigation diversions. Thus, the costs of any actions to protect salmon by increasing streamflows will depend directly on the impact on farm enterprises in the region of reducing irrigation water use.

The present analysis appraises the costs of increasing streamflows to restore and sustain salmon populations in the region, and also examines several policy considerations. The central questions being addressed can be framed as: 1) How costly will it be to reduce agricultural diversions of surface water at the times and in the locations where it will benefit salmon most? and 2) How best can we increase streamflows so that the maximum benefit to salmon and other fish can be achieved at the lowest cost? The issue of whether the costs should ultimately fall on farmers or tax payers are not addressed in the current analysis; these issues will eventually be addressed through legal and political processes at the local and national levels. The remainder of this paper is divided into three sections. In the next section, the cost of increasing streamflows estimated; section III discusses the potential benefits of increased stream flows for salmon; and section IV summarizes and raises policy considerations.

II. The Cost of Increasing Stream Flows

Since increased streamflows amounts to reducing the amount of water consumed in irrigated agriculture, the cost of increasing streamflow will equal the value of using water in agriculture. If competitive water markets existed, then the value of water could be easily inferred from the prices at which farmers buy and sell it. Unfortunately, water rights transactions between farmers are rare. This is due in part to the US prior appropriations system, combined with many state's restrictions on the transfer of water rights, which hinder the reallocation of water through the sale or transfer of water rights between locations and uses. Although there are serious ongoing efforts in many western states to overcome these obstacles in ways that will introduce more flexibility and efficiency in water allocation, progress has been slow. Moreover, in some parts of the region where water rights transfers have few restrictions, transfers may be impractical or impossible between distant basins or in the absence of conveyance infrastructure.

The estimates presented below include direct evidence of the value of water in agriculture, as well as estimates based on economic studies. Information about market purchases of water rights, or ones which involve water, will represent direct evidence of the value of water. Two forms of such evidence are described and presented below, market purchases of water rights to increase streamflows, and purchases and sales of agricultural land with associated water rights.

Economic analyses can employ a number of different techniques to estimate the value of water. However, estimating the agricultural value of water in a precise way is a complicated task given the site-specific nature of the soils, hydrology, uses, timing, regulation, rights, and incentives surrounding agricultural water diversions. For example, differences in the water holding capacity of different soil types alone varies by a factor of 4, and the number of irrigations per season for major crops varies from 4 irrigations in the case of field corn on loam soils, to 10 irrigations for dry beans on sandy loam, to 51 irrigations for late potatoes on sand. Agro-climatic differences like these represent one of the reasons why the revenues generated from irrigation water use vary greatly across farms. Differences across locations in the revenues generated from water use are also affected by US and State water laws and the prior appropriations system which protects water rights based on a “first in time, first in right” basis. These water laws combined with the state-level restrictions on water transfers also contribute to differences in the value of water used on different parcels of land.

Nevertheless, estimation methods such as farm budget analysis, production function estimation, or detailed programming models are widely used to produce estimates of the incremental value of water. Given this range of sources and methods, there is a substantial basis on which to make some broad estimations of the cost of augmenting streamflows by reducing water consumption in agriculture. Each of these types of evidence is presented below.

A. Cost estimates based on market transactions

1. Transactions to acquire water rights for streamflow. Despite legal and other obstacles to active water markets among farmers, the acquisition of water rights for instream uses emerged in the early 1990s, including some federal and state agencies (such as the Bureau of Reclamation’s purchases in the Columbia River Basin), with more than 2.3 million acre-feet of water being acquired from 1990 to 1998 for instream uses (Landry 1998). Oregon Water Trust has pioneered the purchase of water rights by non-profit organizations seeking to improve streamflows for fish and recreation. In addition to the Oregon Water Trust there is now a Washington Water Trust and a pilot project in the State of Washington’s Department of Ecology. Also, traditional environmental organizations such as Environmental Defense Fund and the Nature Conservancy have participated in acquiring water for instream uses throughout the western US.

Since these activities involve actual transactions where farmers have sold water, it is reasonable to assume that these prices are equal to, or greater than, the value of the water to the farmer. However, the price paid may exceed the value of the water to the farmer if the transaction was not competitive (e.g., only one potential seller). In Table 1, we summarize the available data from both the Oregon and Washington Water Trusts. Looking at the data from Oregon, we see that the average (annualized) value of water based on purchases of water rights is $9 per acre-foot (af), which is lower than the average of $23/af for one-year leases. This higher cost for one-year leases is to be expected since a single year contract leaves the farmer and his equipment idle for a single year, whereas when the transaction is permanent, the farmer’s equipment could be sold. The transaction prices from Washington State are significantly higher, averaging $57/af. This may partly reflect purchases of water rights in popular recreational areas (e.g., on the Teanaway River) where vacation or “hobby” farms have recently pushed water rights prices above their direct value for producing agricultural crops.

2. Surrogate market analysis. Although there are no markets for water rights among farmers, there are markets for farm land, and water rights often accompany the purchase of land. If we had two identical pieces of farm land, one with a generous water right and one with a deficient water right, we might be able to infer the value of the water right based on the difference in the purchase prices for the two parcels of land. With information for a large number of sales of different parcels of land with different characteristics, there are sophisticated statistical techniques with which to discern the incremental value attributable to water rights. This general approach is widely used in economics for a range of goods or attributes for which prices are not available. We are fortunate that an excellent example of this kind of study was done in eastern Oregon to estimate the marginal value of water (as inferred from sales of farm land) in Mahleur County (Faux and Perry, 1999). The authors looked at data on land sales for 225 properties and found that land prices varied depending on both the water rights and the soil class. Their analysis was able to infer that the value of water per acre-foot per year ranged from $9 for land in the lowest soil class to $19 for the median soil class and $44 for the highest soil class.

The most striking observation at this point is the similarity in these estimates to the actual transactions of the Oregon Water Trust. The $9 estimate for the lowest soil class is identical to the average value for purchased water rights in Oregon. Because we would expect the Oregon Water Trust to look for bargains, we would not expect their costs to be at the high end of the range. However, if costs are higher for one-year leases, or if Oregon Water Trust is not able to always find the lowest priced water, then we would expect to see prices above the low end of the distribution. Indeed, the inferred value of $19 for the median soil class based on the surrogate market estimate is relatively close to the average one-year lease price of $23 from Oregon Water Trust’s purchases.

B. Estimates based on economic analyses

1. Crop and land use changes. The value of water in agriculture can also be estimated analytically using methods such as farm budgets, production functions, or optimization models. One approach is to represent the kinds of changes that farmers could be expected to make when water supplies are constrained and evaluate the changes in costs and revenues that would result. The analyst is sometimes required to decide the kinds of substitutions that would be made by the farmer, such as: a) converting from one irrigated crop to another, b) converting from an irrigated crop to a dryland crop, c) or removing some land from production. These adjustments are realistic to the extent that many farmers know how to ‘make due’ with less water since in many regions—and especially for junior water rights holders—they are sometimes faced with water shortages in low-flow years.

A large, detailed model of this kind, which represented only farm-level adjustments among crops and between alternative land uses, was developed to estimate the costs of augmenting streamflows by reducing irrigation diversions in the Upper Snake River Basin (USDA/ERS 1996). The study considers adjustments in 5 million irrigated acres in Southern Idaho and East-Central Oregon. The main crops affected are alfalfa hay, wheat, other hay, other small grains, dry beans, and sugarbeets. The estimates are indicative both of the value of water for farming in these regions and how the costs of augmenting streamflows rises with increases in the size of the reductions in irrigation diversions. The study found that the costs per acre-foot of water were \$20/af for a 14% reduction in baseline water diversions, \$24/af for a 20% reduction, and \$29 for a 29% reduction. If the model accurately reflects the choices faced by farmers, then these estimates should correspond to a one-time lease arrangement, where farmers will expect to return to ‘normal’ farming practices the following year. Once again, these estimated values correspond surprisingly closely to actual payments made by the Oregon Water Trust for one-year leases of irrigation water rights to augment streamflows. A second study of this kind, which looked at the potential for water markets in the Central Oregon Water District on the Deschutes River, produced similar estimates for leasing portions of water allotments (Turner and Perry 1997). For acquisitions of water of up to 30,000 af, the cost per acre-foot was estimated to range from \$5 to \$25.

2. Improving irrigation efficiency. Irrigation efficiency is defined as the ratio of the amount of water actually consumed by the crop to the total amount of water diverted (from surface or groundwater) for irrigation. Depending on the irrigation technology being used, a farmer may need to apply twice as much water to a field as is required by the plants being grown. The quantity of water that is not consumed by the plant will flow back to the stream, percolate down into the ground, or evaporate. It is generally assumed that water which percolates into the subsoil will eventually find its way back into the stream, but this may take hours, days, or years, depending on the soils, geology and the distance to the stream. Evaporation will vary as well depending on temperatures and humidity, but is often assumed to account for no more than 10 or 15 percent of the water applied.

In the Northwest, the most common irrigation system used is surface irrigation, also called flood or furrow irrigation, which is the least efficient, with irrigation efficiencies between 32% and 57% depending on the crop. A wide range of improvements in technology and management can raise irrigation efficiency, as depicted in Table 2. Changes in labor use can reduce runoff losses and raise irrigation efficiency by 5%; pump-back and gated pipes can further raise irrigation efficiency to between 52% and 77%. Automatic multi-set systems can do even better, achieving irrigation efficiencies from 77% to 92%. Sprinkler system irrigation efficiencies range from 60% to 75%. Conveyance efficiencies (typically canals for transporting water) of 70 to 80 % are common in the Northwest; some are as low as 20 % for unlined canals. Overall efficiencies including conveyance and irrigation average less than 50 % and, in some cases, less than 20 % (Butcher et al. 1988).

While irrigation efficiency is an important factor affecting streamflows, it has sometimes been assumed that promoting improved irrigation efficiency in agriculture will result in less water being diverted from the stream, and hence more water left for fish or other uses. Consistent with this perception, several western states have passed legislation encouraging farmers to invest in improved on-farm irrigation technology (Huffington and Whittlesey undated). The reality is more complicated, however, since improved irrigation efficiency will also reduce return flows.

Assume a farmer diverts 400 af with an irrigation efficiency of 40 percent. This means that his consumptive use is 160 af, and assuming 10 percent is irretrievably lost to evaporation or deep percolation, we can expect that 200 af ends up as return flow into the river. What happens if this farmer adopts improved irrigation technology that raises irrigation efficiency to 70 percent, if the stream diversion is lowered from 400 to 350 af? On the face of it, this would appear to be good for salmon because it leaves an additional 50 af in the stream. With a higher irrigation efficiency, however, the consumptive use is now 245 af, and with 10 percent (35 af) still irretrievably lost, the return flow is only 70 af. Adding 70 af to the 50 that is no longer diverted, implies a lower stream flow of 120 instead of the 200 that occurred before the adoption of the new technology. In general it is quite possible that investment in irrigation efficiency can substantially reduce streamflows, depending on what changes the farmer may make in his farming practices, and depending on how other irrigators downstream may respond to changes in the availability of stream flows at different times.

It is also important to recognize that improved irrigation efficiency does not necessarily mean more economic efficiency or higher net revenues. It may be that for some crops, especially low value crops, the cost of improved irrigation technology is high compared to the increased revenues that it will generate for the farmer (for example, if it enabled him to increase yields, or switch to a higher value crop). There are two essential points to be made here. First, a technology which raises irrigation efficiency may not raise economic efficiency, it may lower profits for the farmer if the cost of the technology outweighs the gains to the farmer. Second, neither promoting irrigation efficiency nor promoting economic efficiency will necessarily improve the stream flow situation for salmon, especially in settings where surface water is already over-appropriated via existing senior and junior right holders.

Although an increase in irrigation efficiency cannot be assumed to increase streamflows, streamflow could be increased in this way if the reduction in water diversion is greater than the reduction in return flow resulting from the increased irrigation efficiency. Arrangements could certainly be made with a particular irrigator to ensure that streamflow increased, in which case we want to evaluate the cost of increasing streamflows in this manner. The costs of improved irrigation efficiency will be primarily the capital costs of the new irrigation technology and their associated maintenance costs. The benefits to the farmer may include labor savings, energy savings, and the elimination of costs associated with previous irrigation technology (e.g., earth moving equipment used in flood irrigation). Bear in mind that for this to be attractive to the farmer, the benefits to him or her must outweigh the costs. In this case, however, the potential reduction in the amount of water diverted for a given level of consumptive use will not represent a benefit to the farmer since he does not pay a fee per unit of water used, and he will not generally benefit from leaving the water instream.

To estimate the cost of increasing streamflows by improving irrigation efficiency, we need to know the net irrigation requirements for the crops grown (a crop's consumptive use minus the water naturally supplied by rainfall). For crops in the Northwest these range widely. For example, in central Washington the range is estimated to be from 15 to 29 acre-inches per acre. Taking a value of 24 acre-inches per acre, we can calculate that for surface irrigation with an irrigation efficiency of 50%, 4 af of applied water are required to achieve the 2 af requirement. Adoption of sprinkler irrigation (with an irrigation efficiency of 75%) could lower the necessary applied water by 1.33 af. The annualized cost of the investment for sprinklers ranges from \$300 to \$600 per acre in Oregon.[1] For a 6 percent interest rate, this translates into annualized costs of \$18-26 per year, or \$14 to \$27 per acre-foot per year. Other factors may affect these costs, such as accompanying changes in energy use, labor, etc.; and estimates will differ for other kinds of irrigation investments. For example, an analysis of the economics of alternative irrigation systems in Kittitas Valley Washington (Hoffman and Willett 1999) compare grated pipe irrigation with wheel-line, center pivot and linear move techniques. Comparing the costs of these technologies with the improved irrigation efficiencies, the cost per acre-foot of 'saved' water ranges from \$40 for center pivot to \$61 for linear move. As a means of increasing streamflows, these cost estimates are in the intermediate to high range compared to those cited above.

Once again, however, one cannot assume that farmers will divert less water when irrigation efficiency improves; they may change the crops they grow or other practices so that the amount of water applied stays the same, but the consumptive use increases. Indeed, low irrigation efficiency may be good for fish since return flow is wasted water for the farmer, but it mostly represents water that ends up back in the stream either on the surface or through aquifers, but delayed by hours, months, or perhaps years depending on the soils and geology. If return flows occur over a period of months, much of the water returns to the stream in seasons when achieving minimum streamflow is not critical. In this situation, reducing irrigation diversions when streamflows are critical to salmon survival and reproduction will have a larger positive impact because the concurrent reduction in return flows will be slight, making the net effect on streamflow larger. Even though the total annual streamflows may be unaffected in this case, the seasonal distribution of streamflow will be enhanced by raising flows during months when it may be beneficial to salmon, while at the same time reducing streamflows during other, non-critical months.

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[1] K. Delano, Soil and Water Conservation Office, John Day, Oregon; personal communication, July 2000.

Another side benefit may be a reduction in non-point pollution. To the extent that inefficient irrigation and large return flows are responsible for bringing chemical- and fertilizer-laden water back into the stream, improved irrigation efficiency may improve water quality even if it can not be assumed to increase water quantity. If it does both, then the increased stream flow will also dilute the (lower) levels of pollution even further.

3. Idling land and deficit irrigation. One can also calculate the lost revenues if farmers simply left some of their land idle, or if water were simply cut off at some point during the growing season, recognizing that this would adversely affect crop yields. This approach ignores the various substitutions among crops and other inputs that farmers would likely make in anticipation of a water shortage; so these estimates, while simpler to compute, will tend to overstate the actual costs that farmers would incur for prearranged contracts to increase streamflows.

The cost of augmenting streamflows by simply curtailing farm production on a given piece of land could be calculated by taking the revenues normally received from the particular farming activity and subtracting the input costs such as seed, fertilizer, labor, equipment, etc. This would reflect an 'average' value of the water that would have been applied on an acre of land. This may indeed be a low cost way to augment streamflows in some locations where farming is only marginally profitable, but in many cases this will represent a costly way to help salmon. Estimates for Washington State of the average value of water in agriculture range from $20/af for hops and alfalfa, $62/af for corn, $104/af for wheat, $156/af for pears and $172/af apples (Gibbons 1986).[2]

The costs of augmenting streamflows assuming "deficit irrigation," (giving a given plant insufficient water for it to grow normally) will also likely produce high estimates of the cost if they are calculated by assuming that the supply of water is simply cut-off at some point during the growing season. With advance warning, farmers would typically alter other timing and cropping decisions in order to minimize their losses, such as planting drought-resistant crops, planting a smaller area, etc. Estimates for reducing water applications by 10 percent compared to the desired level range from $120/af for wheat to $565/af for potatoes in Washington State (Gibbons 1986).[2]

4. Contingent contracts. Acquiring water to increase stream flows in *all* years will frequently be unnecessary if: a) the bulk of the benefits to salmon come from maintaining a minimum streamflow during critical months, and b) the critical minimum streamflow is currently being achieved in some, and perhaps most, years. This situation exists for many rivers in the region, where the critical issue is maintaining streamflow above specific levels in low-flow years (and during the lowest-flow months) because of the effect of streamflow on water temperatures (and other factors) which can be lethal to fish.

Providing additional streamflows in those critical years will be less costly than providing additional water in all years—including years when streamflow may be adequate. Given both the desirability and the lower cost of ensuring streamflows in low flow years, "contingent contracts"

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[2] All prices adjusted to current (2000) dollars.

have been studied and even attempted in which farmers agree to apply less water to their fields in low flow years in exchange for a payment. This mechanism has great potential for reducing the cost of protecting populations of salmon and other fish, especially where portions of available water could be acquired on a contingent basis. For example, in the Snake River basin, contingent water contracts which required farmers to release stored water supplies (stored in reservoirs) in low flow years during periods critical to smolt migration could provide substantial quantities of water at a modest cost and without significantly affecting the agricultural base in the area (Willis et al. 1998). It is estimated that the costs for contracts covering 50% of total stored water would range from $0/af for farms with efficient irrigation technologies (so that their reserves exceed their requirements) to no more than $3.91/af for surface irrigators. Even for contracts covering 100% of total stored reserves, costs ranged from $3 to $14 per acre-foot.

In locations where stored water reserves are not available, low cost contracts of this kind may not be feasible. However, there are other circumstances in which low cost contingent contracts may be feasible. For example, in Mahleur County, Oregon, evidence from land prices for junior water rights suggest that interruptible water rights may not be costly in areas where high value crops (onions and potatoes) cannot be grown every year on the same parcel of land because of soil-borne disease problems. These high value crops are rotated with low value crops such as hay or wheat on portions of land each year. When water is in short supply (or if a contingent contract were in force), these low profit crops could either be deficit irrigated or not planted at all in order to conserve water for the other fields with cash crops (Faux and Parry 1999). The evidence from Mahleur County suggests that uncertain water supplies of this kind do not impose significant costs on farmers. Thus, these two cases represent examples where contingent arrangements for protecting streamflows during low flow years can be achieved at very low cost.

5. <u>Ancillary benefits</u>. If augmenting streamflows can produce benefits other than to fish, then the ‘net’ cost of protecting salmon habitat may be even lower. One type of ancillary benefit mentioned above is the likelihood that improved irrigation efficiency may increase streamflows and also reduce non-point water pollution because of the reduction in return flows. Both effects should be taken into account in assessing the net cost of augmenting streamflows in this manner.

Another potentially valuable ancillary benefit of augmenting streamflows is the generation of hydroelectric power. Combining the idea of a contingent market with that of ancillary benefits, water in the upper Snake River basin could be shifted from irrigation to streamflow to assist passage of migrating juvenile salmon during periods of droughts. The costs of diverting water away from Idaho farmers are estimated to be about $2.50/af. However, the additional power that could be produced with such a water market has been estimated to be between $5/af and $6.59/af (Hamilton and Whittlesey 1992). Changes in the price of power will affect these estimates, and current power values are somewhat lower than those estimated in 1992. However, they may still outweigh the foregone farm income, even with current forecasts for future electricity prices. A rough estimate would put the additional power benefits at between 1/3rd and 2/3rds as high as estimated by Hamilton and Whittlesey in 1992, making the result somewhere between a net cost of $1/af and a net benefit of $1/af.

C. Synthesis

Overall, the evidence suggests that increasing and maintaining minimum streamflows and restoring salmon populations can oftentimes be relatively inexpensive if low cost opportunities are taken advantage of, especially when the circumstances make contingent contracts appropriate or where ancillary benefits are possible. However, in locations such as those where high value orchard crops are grown, or for large increases in streamflows, the costs may be substantially higher.

Table 3 summarizes cost estimates derived from, or applied to, four streamflow augmentation actions in different river systems in the region: the Snake River, the John Day River, the Walla Walla River, and the Deschutes River. Based on the rivers, methods, and contractual arrangements represented in this sample, the evidence suggests that the bulk of the cost-per-acre-foot of water estimates vary between $1 and $25 per acre-foot. To place these estimates in perspective, we compare the annual total cost of the proposed actions to the annual net farm income for all irrigated acres in each of the affected regions. Doing this allows us to answer the question: If the costs of streamflow augmentation were incurred entirely by irrigated farms in each region, how costly would it be in relation to their net farm income? This calculation takes into account the consumptive use of water per acre (typically between 1.5 to 3 af), net farm income per irrigated acre, and the average annual reduction in consumptive use of water per irrigated acre that would be required to achieve the desired streamflow goal (a fraction of an acre-foot per acre). The calculations for these four case studies indicate costs ranging from 0.5 percent to 4 percent of net farm income among irrigated enterprises in the affected region.

The kinds of increases in streamflow and minimum streamflow targets evaluated in the studies detailed above range from very large scale augmentation schemes on the Snake River, to a small-scale plan for assuring August streamflows of 60 cubic feet per second (cfs). The mitigation measures characterized in these studies are ones which have been considered to be desirable in each of the specific river basins examined. Thus, they are likely to be representative of the kinds of measures needed to restore stream habitat to levels consistent with protecting and restoring fish populations. (Indeed, they may overstate the average need for increased streamflow to the extent that they were selected to represent a basin with severe streamflow problems.) If we assume that actions similar to those represented in these four examples are needed in all irrigated basins, we can extrapolate the costs of restoring streamflows in the region as a whole.

Based on figures for net farm income per acre equal to $310 in Washington, $230 in Oregon, and $190 in Idaho, and with the cost estimates in Table 3 as a percent of net farm income, we can compute an estimate for the total cost in each state and the region based on the total number of irrigated acres. These estimates are shown in Table 4 as ranging from $2.2 million in Oregon when the cost is assumed to be 0.5% of net farm income, to $26 million in Idaho when the cost is assumed to be 4% of net farm income. To place these numbers in perspective, if these costs were born by the region's tax payers, they would amount to only a tiny fraction of personal income, ranging from 3/1000ths of a percent to 1/40th of one percent, or between about $1 and $10 per person per year.

III. The Impact of Increased Streamflows on Salmon

There is substantial evidence of the high value placed on protecting and improving freshwater habitats for fish populations. For example, several studies for western and southwestern states have estimated the value of increasing streamflow for fishing and other recreational uses ranging from $16 to $86 per acre-foot, or for the economic value of improved streamflows to enhance salmon populations in northern California (between $33 to $53 per acre-foot)(Colby 1989). The benefits of increased streamflows will depend both on the value to society of increasing fish populations, and on the effectiveness of increased streamflows on increasing fish populations. The effect on the populations of salmon and other fishes of augmenting stream flows will vary enormously by location and timing.

A key factor affecting the survival of salmon in their freshwater habitats is water temperature. Stream temperature can affect salmon directly by reaching lethal levels, or indirectly by reducing reproductive rates or offspring survival. Higher stream temperatures can also lead to a greater prevalence of bacteria, reduced resistance to these bacteria among fishes, and lower levels of dissolved oxygen. In general, cold water species such as salmon confront increased stress levels, greater susceptibility to disease, and increased competition with warm water species (Beschta et al. 1987). Some evidence suggests that mortality of salmon smolts from predator fish also rises significantly at higher water temperatures; and low streamflows can reduce the available area for spawning, or leave eggs dry that were laid when water levels were higher. In the case of the Snake and Columbia Rivers, low streamflow is believed to raise the mortality of ocean-bound juvenile salmon as they move slowly through the ponds created by a series of dams. The relationship between low streamflows and high water temperature is generally more pronounced during summer months when air temperatures and exposure to sunlight are highest. However, the contribution of additional streamflows to improved salmon habitat can vary greatly from location to location, month to month, and year to year, for a given river. Figures 1 and 2 illustrate the variability of streamflows at different locations on the same river, and for different years and different months.

The benefits of increased streamflow will differ by species, and differ seasonally given differences in the potential benefits for protecting eggs, smolts and adult fish. Augmenting stream flows at the wrong time in the wrong place could actually be harmful to salmon, or have no effect. The benefits of increased streamflows may also depend on the presence of complementary conditions which also affect habitat quality and stream temperature such as riparian vegetation (Wu, Boggess and Adams, 2000). Among other factors, the effect of increased streamflows on salmon survival will depend on how water temperature will be affected, and whether water temperatures are currently close to the threshold levels where survival and reproduction are seriously threatened. If water temperatures are well above these threshold levels, then lowering water temperatures by one or two degrees will have no impact on salmon survival. Similarly, if water temperatures are well below these threshold levels, additional water may also have no impact on salmon populations (Wu, Adams and Boggess, 2000).

It is therefore essential that the benefit side of the equation be carefully considered at the same time as the cost side. Buying low priced water at the wrong time in the wrong place may appear to be a bargain, but if it has no positive effect on salmon it will represent a cost without a benefit. Publicly funded programs which seek to increase streamflows in an “across-the-board” fashion, or ones which seek to spread funds evenly across jurisdictions due to political equity considerations, may produce outcomes in which a majority of actions were futile because water temperatures were either too low or too high to have the desired effect, or where other conditions in a given stream were more limiting factors on salmon survival than was streamflow.

IV. Summary and Policy Considerations

Based on data from market transactions and numerous economics studies, the costs of increasing streamflows by reducing irrigation diversions are estimated to range between $1 and $25 per acre-foot of water if an efficient approach is taken. In the context of a broadly based regional program to restore and maintain healthy fish populations, these values translate into annual total costs of between 0.5 and 4.0 percent of the net farm income for all irrigated farms in the region, or between $1 and $10 per person. If some of these costs were paid with federal funds, the costs to residents of the region would be lower.

A central question affecting both the costs and the effectiveness of any program to increase streamflows, is how such changes would be implemented. In this regard there is significant misunderstanding, for example, regarding the effectiveness of either improved irrigation technology or the consequences of eliminating regulatory obstacles to water markets. In the case of irrigation technology, innovations at the farm level may be an important part of a program to increase streamflows, but adoption of advanced irrigation technologies will not achieve the desired result by themselves. In fact, raising ‘irrigation efficiency’ could actually lead to a reduction in streamflows.

With regard to water markets, simply eliminating the impediments in the current system of irrigation water rights so that water right holders may freely buy and sell water in markets is unlikely to directly benefit salmon. These changes would promote economic efficiency and a reallocation of water such that water that is currently in low-value uses could be sold to farmers with potential higher value uses. But while this would improve economic efficiency of water use, it would not necessarily result in more water left in stream. Indeed, in the absence of other changes in the rules governing water allocation, freer water markets could be expected to broaden the range of valuable uses of water in agriculture, thereby leaving less water in streams.

To achieve the desired increases in streamflows in a cost-effective way, an approach is needed that takes account of: a) the benefits to salmon and other fishes of increases in streamflows across different times, locations, and for a range of scenarios for fluctuations in year-to-year conditions; b) the presence or absence of confounding or complementary ancillary factors which may raise or lower the expected benefits from a specific streamflow increase; and c) differences in the marginal cost of reduced irrigation diversions for different rivers, times of the year, and under a variety of lease, purchase, and contingent contracts.

In essence, the fish need a broker. They need an agent to search for the best deals, to find those transactions with the highest benefit per dollar spent. Such a broker will need to identify which rivers will benefit most from streamflow increases, and how much additional water is optimal (in which months, years, and reaches). In addition, the cost to agriculture of augmenting flows for each location and time must be compared to the benefits so that scarce resources can be allocated to streams, months, and years where the fish-benefit per dollar spent is highest. Success will require assembling detailed scientific and economic information, and finding creative arrangements, agreements, and contracts that take advantage of settings where currently low value water uses coincide with high potential benefits to salmon and other fishes.

Achieving satisfactory results at low cost will necessarily require innovative individuals and organizations acting on behalf of salmon. A "hands off" or across-the-board approach will necessarily produce higher costs and lower benefits than a "hands on" approach which looks for "best buys" on behalf of salmon. Encouragingly, actions with many of these characteristics are already being taken in the past few years by organizations such as Oregon Water Trust and Washington Water Trust, and by the Bureau of Reclamation and Washington Department of Ecology. The Oregon Water Trust has built an encouraging record by being the first organization of its kind to initiate purchases of irrigation water rights for instream uses in the region. Indeed, the bulk of existing evidence on market transactions for instream water purchases, listed in Table 1, comes from the Oregon Water Trust. Their lead is now being followed by the Washington Water Trust, and recently by the Washington State Department of Ecology.

A threat to the potential success of government programs aimed and achieving these goals comes from competing interests and political pressures. Pressures to spread funds evenly across Congressional Districts, or to allocate funds based on criteria other than maximizing the benefit to salmon, would severely diminish the effectiveness of the program. Evidence of how such pressures to spread funds to achieve "political equity" can be wasteful are found in other federal programs aimed at improving riparian habitats (see Wu, Boggess, and Adams 2000). This evidence highlights the caution that inappropriate approaches to increase streamflows may prove highly costly or ineffective. Thus, policy makers must guard against approaches such as across-the-board water right cutbacks or purchases, or subsidies for adoption of improved irrigation efficiency, if those actions are not carefully chosen and implemented so that they actually result in increased streamflows in the locations and times where they will benefit salmon most.

Nevertheless, government policies and initiatives will be needed for any large-scale program. Several observations can be made about specific directions these might take which could contribute to their success. First, there is a clear need for additional biological information and data analysis to determine just how much water is needed in which streams, during which months, and in which years. One such program involves compiling information on the health and potential for improvements at the sub-basin level by the Oregon Water Resources Department. State and local water authorities need to monitor water diversions and changes in consumptive use if streamflow protections are put in place. The allocation or reallocation of water and water rights needs to focus on actual consumptive use, rather than statutory rights or diversions, in order to avoid changes which may appear to be increasing streamflows when in fact they do not (Huffaker and Whittlesey, undated).

Second, while it should be noted that facilitating water markets will not directly address streamflow problems, the exchange of water among farmers could be beneficial in several ways. Markets would promote the efficient distribution of water, raise the average (and total) value of water use in agriculture, which would in turn be beneficial to farm incomes. Thus, in the face of long-term, or across-the-board, reductions in irrigation water rights, improvements in the allocative efficiency of water would help to maintain average profits among irrigated farms. Also, a well-developed market for irrigation water might help create the institutional mechanisms and information needed to facilitate water contracts for instream use.

Third, in order to lower the costs of increasing streamflows, the ease with which ancillary benefits such as hydropower generation could be taken advantage of needs enhancement. Accomplishing this will likely require legislation to remove hindrances from water transfers, especially between Idaho irrigators and instream uses.

And finally, it should be recognized that irrigators are among those in the region who want to protect salmon and other fish instream. This is evidenced by a significant number of voluntary water rights contributions that have been made to the Oregon Water Trust. Giving recognition to farm enterprises which made voluntary contributions, or who have participated in other stream enhancement projects, will likely encourage participation in these efforts.

Table 1. Recent water rights transactions to augment streamflows

Oregon locations	Current use	Contract type	Consumptive use (af/year)	Price paid	Cost/af*
Rogue River, Sucker Creek	Fallow	purchase	67.80	$ 8,800	$ 7.79
Rogue River, Sucker Creek	Fallow	purchase	107.62	$ 13,627	$ 7.60
Rogue River, Sucker Creek	Fallow	purchase	57.47	$ 8,138	$ 8.50
Deschutes River, Squaw Creek	Pasture	purchase	417.19	$ 42,900	$ 6.17
Deschutes River, Squaw Creek	Pasture	purchase	308.08	$ 44,352	$ 8.64
Deschutes River, Squaw Creek	Pasture	purchase	48.14	$ 7,425	$ 9.25
Deschutes River, Squaw Creek	Pasture	purchase	8.46	$ 870	$ 6.17
Deschutes River, Squaw Creek	Pasture	purchase	96.27	$ 13,860	$ 8.64
Rogue River Little Butte Creek	Hay	purchase	173.95	$ 20,000	$ 6.90
Hood River, Fifteenmile Creek	Wheat	purchase	71.76	$ 26,307	$ 22.00
				Average:	**$ 9.16**
Deschutes River, Buck Hollow Creek	Hay	one-year lease	196.80	$ 6,630	$33.69
Deschutes River, Buck Hollow Creek	Hay	one-year lease	196.80	$ 6,630	$33.69
Deschutes River, Buck Hollow Creek	Hay	one-year lease	196.80	$ 6,630	$33.69
Grande Ronde River, Crow Creek	Hay	one-year lease	194.00	$ 1,600	$8.25
Umatilla River, E. Birch Creek	Hay	one-year lease	238.50	$ 2,500	$10.48
Deschutes River, Trout Creek	Hay	one-year lease	1135.50	$ 23,843	$21.00
Deschutes River, Trout Creek	Hay	one-year lease	270.00	$ 4,680	$17.33
John Day River, Hay Creek	Hay	one-year lease	248.80	$ 14,500	$58.28
Rogue River, S.F. Little Butte Creek	NA	one-year lease	83.34	$ 1,438	$17.25
Deschutes River, Buck Hollow Creek	Hay	one-year lease	196.80	$ 6,630	$33.69
Grande Ronde River, Crow Creek	Hay	one-year lease	197.70	$ 5,272	$26.67
Deschutes River, Tygh Creek	Pasture	one-year lease	94.50	$ 945	$10.00
Rogue River, S.F. Little Butte Creek	NA	one-year lease	83.34	$ 1,438	$17.25
Grande Ronde River, Crow Creek	Hay	one-year lease	197.70	$ 5,136	$25.98
Deschutes River, Tygh Creek	Pasture	one-year lease	94.50	$ 945	$10.00
Rogue River, S.F. Little Butte Creek	NA	one-year lease	83.34	$ 1,438	$17.25
Umatilla River, Couse Creek	Wheat/Pea	one-year lease	1065.9	$ 23,800	$22.33
Deschutes River, Buck Hollow Creek	Hay	one-year lease	196.80	$ 5,000	$25.41
Grande Ronde River, Crow Creek	Hay	one-year lease	197.70	$ 5,136	$25.98
Rogue River, S.F. Little Butte Creek	NA	one-year lease	83.34	$ 1,438	$17.25
Umatilla River, Couse Creek	Wheat/Pea	one-year lease	1065.9	$ 23,800	$22.33
Umatilla River, Couse Creek	Wheat/Pea	one-year lease	1065.9	$ 23,800	$22.33
				Average:	**$23.19**
Washington locations					
Teanaway River, Kittitas county	na	purchase	302	$300,000	$59.60
Teanaway River, Kittitas county	na	purchase	121	$160,000	$79.34
Big Creek, Kittitas County	na	purchase	113	$150,000	$79.65
Methow River, Chelan County	na	one-year lease	2 af/acre-year	$100	$50.00
Walla Walla River	na	purchase	2 af/acre-year	$1,800	$54.00
Yakima River (pending)	na	purchase	2.25	$1,000	$26.67
Yakima River (pending)	na	purchase	2.25	$2,000	$53.33
				Average:	**$57.51**

* Assumes an 6% discount rate to compute annualized cost of permanent acquisitions. Oregon data is from Oregon Water Trust; Washington data is from Washington Water Trust.

Table 2. Technologies with Potential for Improving Irrigation Efficiency

	Potential for Improving Irrigation Efficiency		
Structural technologies	High	Moderate	Low
Diversions			
Flow measurement		X	
On/off control	X		
Flow adjustment		X	
Repairing leaks			X
Conveyance			
Lining canals	X		
Control vegetation		X	
Canal replacement w/ pipeline	X		
Canal reservoirs	X		
Farm reservoirs	X		
Repair leaks			X
Automated gates, centralized or computer assisted control		X	
Application			
Sprinkler:			
Change sprinkler type		X	
Change sprinkler mounting		X	
Installing basins	X		
Minimize pressure variation		X	
Change sprinkler/lateral spacing		X	
Trickle			
Change emission device			X
Installing basins			X
Shading/burying laterals			X
Controlling system clogging			X
Surface (flood, furrow)			
Tailwater recovery	X		
Cutback irrigation		X	
Cablegation		X	
Surge flow		X	
Land smoothing			X
Management technologies			
Irrigation scheduling	X		
Deficit irrigation		X	

Source: Butcher, L.B.R. et al., 1988. Review of potential for improving water use efficiency in Washington irrigated agriculture. State of Washington, Water Research Center, Pullman, Washington.

Table 3. Estimated Cost to Increase Streamflow in Specific Northwest River Basins

		Total Cost	
Basin and Proposed Action	**Cost per acre-foot**	**In dollars**	**As percent of net farm income in the affected region**
Upper Snake River (1)			
+ 1.13 million acre-feet (maf) annually	$26.00	$28m	6.0%
+ 2 maf from stored water contracts in driest 25% of years	$0.00 to $3.00	$2m	0.50%
+ 1.8 maf from irrigation "interruption markets" 15% of years, max. 50% reduced diversion	-$1.00 to +$1.00	+/- $1.8m	+/- 0.45%
John Day River above North Fork (2)			
August streamflow raised from 20 cfs to 60 cfs annually by:			
- Taking land out of production	$10 to $40	$6,000 - 25,000	1.2 - 5.0%
- Improved irrigation technology	$14 to $27	$8,700 - 16,700	1.7 - 3.3%
- Cropping substitution	$10 to $20	$6,000 - 12,400	1.2 - 2.5%
Walla Walla River Basin (3)			
Combinations of restricted diversions, storage, lining, and water markets to meet June stream flow goal of 75 cfs 95 % of the time	NA	$142,000 - 200,000	1.2 - 2.3%
Deschutes River Basin (4)			
+ 30,000 af to raise summer stream flow from 30 cfs to 250 cfs by:			
- fixed annual water lease contracts	$5 - 25	$375,000	3.60%
- variable water lease contracts	$5 - 15	$225,000	2.20%

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(1) From USDA (1996), Willis, Caldas, Frasier, Whittlesey and Hamilton (1998), Hamilton and Whittlesey (1992).

(2) Based on Faux and Perry (1999), Oregon Water Trust data, USDA (1996), and K. Delano, Soil and Water Conservation Office, John Day, Oregon (personal communication, July 2000).

(3) From Willis and Whittlesey (1998).

(4) Based on Turner and Perry (1997).

Table 4. Estimated cost of streamflow augmentation in the Pacific Northwest

When cost as a percent of net farm income is:	Oregon	Washington	Idaho	Entire region
		Annual cost		
0.50%	$2,241,050	$2,642,789	$3,318,810	$8,202,648
1%	$4,482,100	$5,285,578	$6,637,620	$16,405,297
2%	$8,964,199	$10,571,155	$13,275,239	$32,810,594
4%	$17,928,399	$21,142,310	$26,550,478	$65,621,187
		As % of state personal income		
0.50%	0.003%	0.002%	0.012%	0.003%
1%	0.005%	0.003%	0.024%	0.006%
2%	0.011%	0.006%	0.049%	0.012%
4%	0.021%	0.013%	0.098%	0.024%
		Dollars per person per year		
0.50%	$0.68	$0.46	$2.70	$1.19
1%	$1.37	$0.93	$5.39	$2.37
2%	$2.73	$1.86	$10.78	$4.74
4%	$5.46	$3.72	$21.57	$9.48

Source: Estimates of cost as percent of net farm income derived from information presented in Table 3.

Figure 1. Monthly average stream flows, John Day River

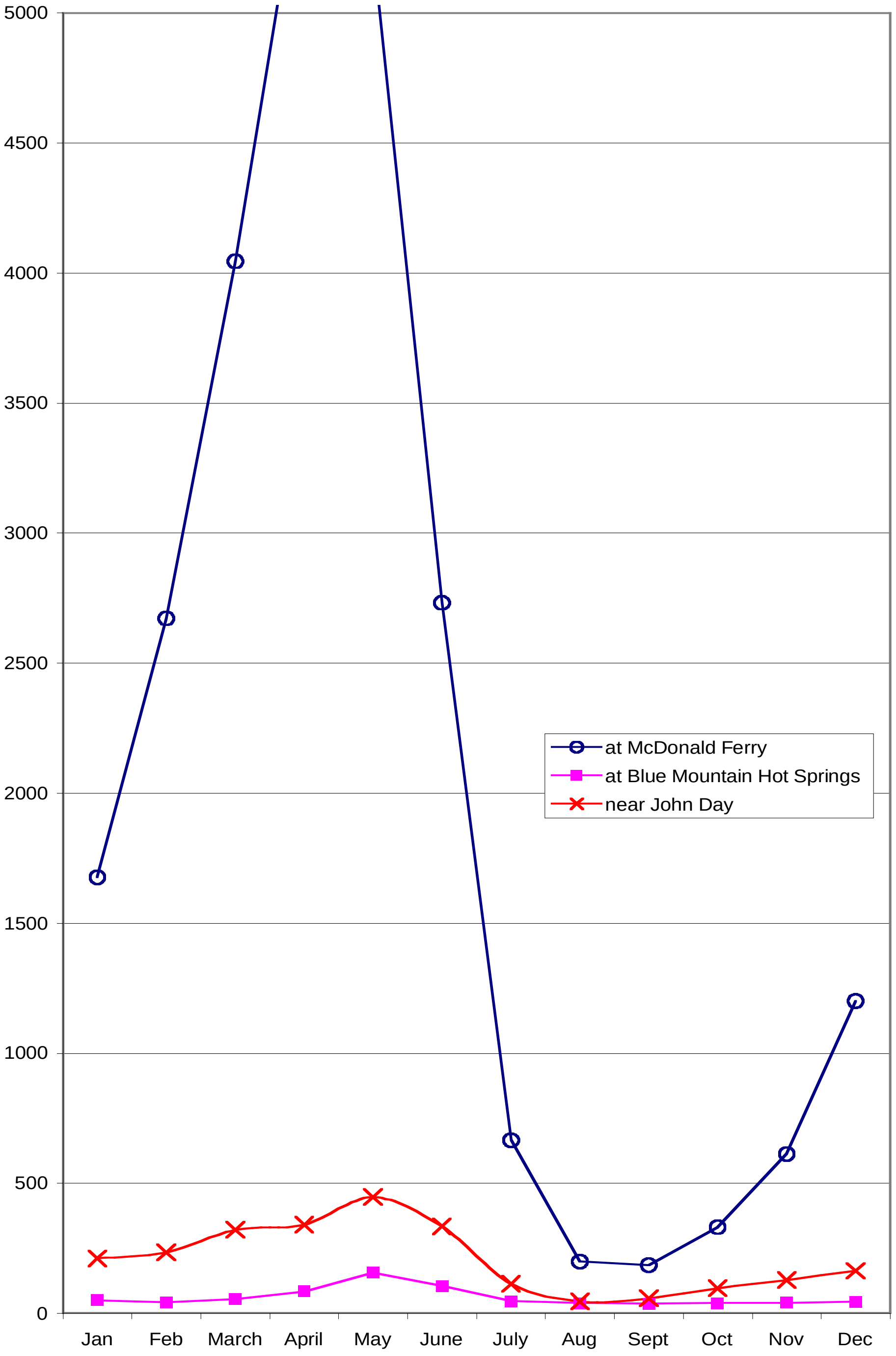
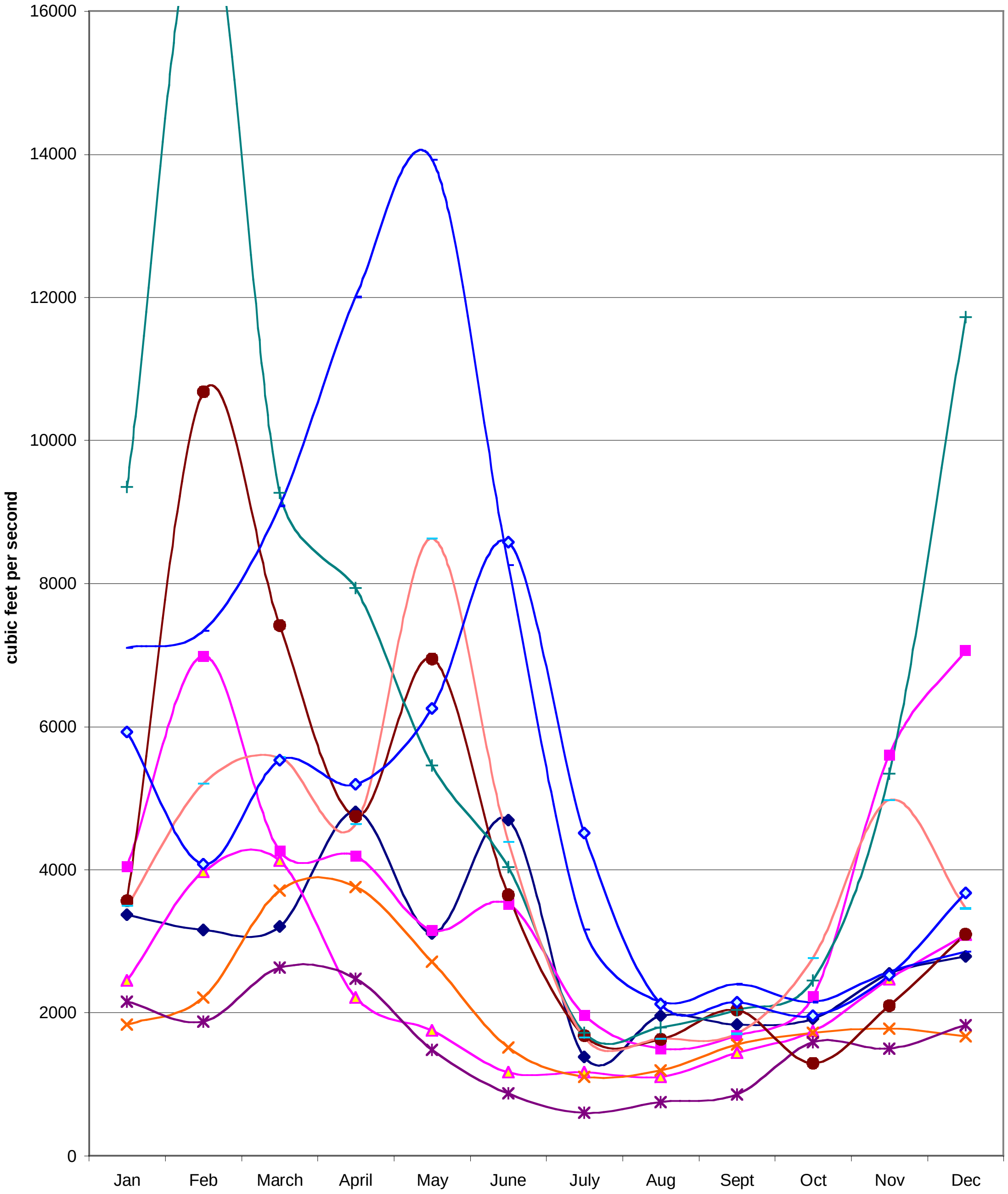


**Figure 2. Annual variation in monthly stream flow,
Yakima river at Kiona (1990-1999)**



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