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Cost–Effectiveness of Improved Irrigation Efficiency and Water Transactions for Instream Flow for Fish[1]

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Executive Summary

Irrigation is by far the largest consumptive use of diverted water in the Columbia Basin. Improved irrigation efficiency is often discussed as a way to conserve water to enhance instream flows and improve water quality for fish. The Council's Fish and Wildlife Program includes irrigation efficiency projects (e.g., piping projects, lining ditches, converting from surface to sprinkler application) with the objective of enhancing instream flows to benefit fish habitat and passage. Other water transactions projects aim to enhance fish habitat with payments to buy, lease or modify water rights, usually in the form of reduced diversions. Other projects combine water transactions and irrigation efficiency improvements. In some cases, instream flows are facilitated by reservoirs that allow water to be stored until needed by fish.

This report reviews the ways in which improved irrigation efficiency, farm-to-stream water transactions, and related agreements are used to increase instream flows to improve fish habitat and promote fish recovery in the Columbia River Basin. First, the semantics and hydrology of irrigation efficiency are discussed. Second, the report reviews general principles for how modifications in irrigation efficiency or diversions may improve instream flows for fish. Third, the report examines the experience with both water transactions projects and irrigation efficiency projects in recent years. In particular, eight subbasins are examined in detail as case studies to assess locational factors as they affect the roles and relative potential and cost-effectiveness of irrigation efficiency projects and water transactions projects. In addition, implications of improved irrigation efficiency for basin-wide electricity production and demand are discussed.

Irrigation efficiency, which is not related to economic efficiency, is defined as a ratio. For example, in the case of water conveyance, irrigation efficiency is the ratio of the amount of water delivered to a field divided by the amount of water initially diverted. In the case of irrigation application efficiency, it is the ratio of the amount of water used by the crop divided by the amount of water applied to the field. In some locations a portion of the water applied to a field but not used by the crop will return to a canal or stream and is re-used by other nearby irrigators. As a result, individual irrigation efficiency measures such as field or farm application efficiency may be significantly lower than overall irrigation efficiency at the district or watershed level.

Generally speaking, improved irrigation efficiency is achieved by the application of technology, information, capital, labor, or energy to reduce the amount of water that must be diverted or applied to accomplish a given purpose in terms of crop acreage and production. In some settings, increased irrigation efficiency may not increase streamflow because the amount of water consumed by the crop is unaffected and because the portion of diverted or applied water that is not consumed returns to the local hydrologic system as "return flows." Any reduction in water diverted because of irrigation efficiency may be diverted by someone else or offset by a reduction in the return flows. Indeed, the unconsumed share of diversion often provides important benefits for the local hydrologic system. Increasing irrigation efficiency can result in reduced water supply for other uses such as wells, necessitating additional diversion. Increased irrigation efficiency in one location can adversely affect habitat at some other time and place.

That said, the case studies reviewed for this report did not reveal any instances of substantial, unintended adverse consequences of irrigation efficiency projects.

There are many situations in which increasing irrigation efficiency can provide important fishery benefits. Irrigation efficiency can be used to reduce diversions just above a critical stream reach. Return flows downstream may be reduced, but often, not where or when needed by fish. Irrigation efficiency can improve water quality if return flows are degraded relative to the receiving water body; common problems associated with return flows include temperature, sediment, nutrients, metals, and pesticides. Finally, irrigation efficiency can help irrigators be more productive and economically efficient while at the same time improving local fish habitat conditions.

The potential for irrigation efficiency to increase instream flows is closely related to state laws and programs that:1) define conserved water and rights to its use, and 2) protect instream flows from other water users. Washington and Oregon have provisions for legally protecting instream water conserved by irrigation efficiency projects. In Oregon, the Allocation of Conserved Water Program requires some of the water saved by private efforts to be dedicated to instream flow, and all water saved using Fish and Wildlife Program (FWP) funds can be so dedicated. In Idaho, water users can place water made available by conservation into the Idaho Water Supply Bank, thereby protecting their right for future years. Measurement and protection of conserved water is now a milestone for BPA irrigation efficiency work elements in the FWP.

The eight case studies were chosen with a focus on evaluating the relative cost-effectiveness of irrigation efficiency projects compared to alternative approaches to improve instream flow to benefit fish populations. Details of each case study are included in the Appendix. Water transactions projects were observed in seven of the eight case studies (excluding Hood River). Documented irrigation efficiency projects have been completed in half of the basins (Yakima, Salmon Creek, Walla Walla, Deschutes, and Hood River). In general, most rivers have included multiple, complementary types of activities aimed at benefiting fish, including short- and long-term water rights leases, purchases of water rights, changes in point of diversions, stream restoration, improved fish passage, and diversion screening. Irrigation efficiency activities included on-farm changes in irrigation technology, but the majority of irrigation efficiency projects have involved piping to reduce seepage in water conveyance systems. Some projects combined irrigation efficiency with water transactions.

The characteristics and experiences in the eight basins studied vary enormously. For example:

- In the Hood River, irrigation efficiency improvements have been completed over the past 25 years by irrigation districts that saw financial gains from them; in the other basins most recorded irrigation efficiency projects involved Fish and Wildlife Program funding.
- In most water transactions projects, contracts stipulate a stated reduction in the amount of water diverted. On the Lemhi River, water transactions projects stipulated a minimum instream flow. Irrigators maintain the base flows throughout the season by monitoring stream gauges and reducing diversions when flows are low.

- Some case studies involved small tributaries (Rock Creek, a tributary to the Blackfoot River), others focused on larger main stems (Deschutes River).
- In the Deschutes River, the value of irrigation efficiency projects was enhanced by the relatively large distance between the river and irrigated areas.
- The number of irrigation efficiency projects over the past 10 years ranged from zero to thirty across case studies.
- The number of water transaction projects over the past 10 years ranged from zero to twenty-five.

Improved irrigation efficiency is certainly not a general or complete solution to habitat water supply problems, but it can help. To benefit fish cost-effectively, both irrigation efficiency and water transactions projects must achieve three things: first, diversions of instream flows are reduced; second, the resulting increased flows must remain instream over the desired river reach; and third, those increased flows must enhance fish populations. To increase stream flows from irrigation efficiency projects there must be an identified quantity of “conserved water” that reduces diversion and increases instream flow. Water transactions that stipulate reduced diversions do not require monitoring or assurances regarding the quantity or fate of saved water.

The case studies reveal that both irrigation efficiency projects and water transaction projects have been used successfully to achieve an increase in instream flow at times and in locations where the fish habitat is impaired. Costs for these improvements range widely among the projects sampled; many irrigation efficiency and water transactions projects undertaken in the past decade have achieved these instream-flow increases at costs below $50/AF. The FWP cost share of CBWTP transactions has been less than half of the total cost; however, this share varies by project and much of the non-FWP cost share is also a cost to the region.

Evidence from the case studies suggests, however, that under current conditions the potential for additional, low-cost irrigation efficiency projects may be limited. In those case study basins where hydrologic and other conditions make irrigation efficiency projects attractive (Hood River, Deschutes River, Walla Walla River), most of the opportunities for low-cost irrigation efficiency projects have already been undertaken, leaving limited scope for additional cost-effective improvements. Indeed, in the Deschutes River Basin where many irrigation efficiency projects have been completed, the cost per acre-foot of conserved water has been rising over the past decade. The costs of leases and purchases of water rights can also be expected to rise after the lowest cost opportunities have been exhausted.

Overall the evidence suggests that water transactions projects offer greater potential than irrigation efficiency projects. Water transactions contracts can be designed to assure conditions that will protect fish whereas irrigation efficiency alone may not be enough to protect fish in dry years. Water transactions generally allow water users to decide how to meet their contractual obligation at least cost. This decision may include irrigation efficiency, crop idling, deficit irrigation, internal water transfers, and other management to minimize net revenue losses. The locations where a water transactions contract may be possible, and where it will correspond to the need for improved fish habitat, appear to be less restricted than in the case of irrigation efficiency projects.

The analysis herein finds that targeted irrigation efficiency improvements to protect fish are unlikely to have much effect on regional power supply or demand, but other general trends may have more noticeable effects. The region continues to see changes in the types of irrigation technology being used. In recent years most of the change has involved conversion from gravity irrigation to pressurized sprinklers which increases the use of electricity for irrigation. In the future, higher energy costs could encourage conversions from high-pressure to low-pressure systems such as drip or trickle irrigation. Conversion to these systems is already occurring on some high-valued crop acreage.

Increased competition for water will encourage a closer look at the details of improved irrigation efficiency. While most of the unconsumed water returns to the local hydrologic system, some of it is also "lost" to local beneficial use. Such removals may include canal evaporation, ditch seepage transpired by undesirable plants, loss of sprinkler droplets evaporated or blown onto non-productive land, or percolation to degraded or unusable groundwater. If these losses can be reduced, they provide real gains in available water at the local level.

The Pacific Northwest has warmed about 1.0° C since 1900. Future warming is uncertain, but is projected to be 0.1-0.6° C/decade (ISAB 2007a). Warmer temperatures are expected to cause more precipitation to fall as rain rather than snow, shift the timing of snowmelt from f summer to spring, increase evapotranspiration, and increase water temperatures (ISAB 2007a). At the same time, demand for water for residential, irrigation, waste water assimilation, recreational, commercial, and industrial uses are all projected to increase with population growth in the Columbia River Basin (ISAB 2007b). Thus, future increases in the demand for water combined with a decline in supply will result in greater water scarcity. This trend should increase interest in irrigation efficiency and higher water prices may induce more water rights holders to participate in water transactions. Whether these trends will facilitate increases in instream flow is uncertain, and outcomes will likely differ by state due to differences in state laws for water transfers, conserved water and instream flow protection.

1.0 Introduction

Irrigation is by far the largest consumptive use of diverted water in the Columbia Basin, so it is not surprising that improved irrigation efficiency is often discussed as an approach to enhance instream flows and improve water quality for fish. The Council's Fish and Wildlife Program includes many projects with the common objective of enhancing instream flows to benefit fish habitat and passage. These projects include irrigation efficiency projects (IE projects) that improve conveyance infrastructure by piping or lining canals and ditches, or that aim to improve application efficiency by irrigation system improvements such as converting from surface to sprinkler application. Other Council projects are water transactions projects (WT projects) that buy, lease or modify water rights to reduce irrigation diversions and increase instream flows.

While IE projects may be motivated by a desire to alter streamflow to protect fish, these projects can also affect power demand and downstream hydropower supply and timing which might affect the basin-level cost-effectiveness of these projects.

This report is motivated by the following questions:

- What has been the experience within the region, in terms of success and cost, with projects to improve irrigation efficiency for the purpose of altering streamflow for the benefit of fish?
- What has been the experience within the region, in terms of success and cost, with projects that have leased, bought, or otherwise modified water rights to alter streamflow for the benefit of fish?
- What conclusions can be drawn about the cost-effectiveness of alternative ways of modifying instream flows for the benefit of fish?

The next section of this report investigates and reports on general principles and experience regarding irrigation efficiency and infrastructure improvements for enhancing instream flow and fish habitat. Hydrologic principles, state laws regarding protection of saved water, and relationships between electricity and irrigation efficiency are discussed. The following section summarizes the irrigation efficiency and water transaction programs in the region, most of which are supported by the Fish and Wildlife Program (FWP). Information on costs and the amount of water acquired is provided.

The fourth section summarizes several case studies where IE and WT projects have been implemented to improve water conditions for fish. Factors such as the needs of fish, hydrology, the nature of irrigated agriculture, the size of the basin, the position of the project in the watershed, and the ability to protect flow are found to influence project success. The case studies are presented in more detail in the appendices. The final section summarizes and to the extent possible lays out the implications for cost effectiveness of both irrigation efficiency and water transaction projects.

2.0 General Principles

While improvements in irrigation efficiency are generally thought of as desirable, the meaning and implications of irrigation efficiency are often poorly understood. We start with some definitions and principles since these are essential to understanding programs that aim to improve irrigation efficiency to benefit fish.

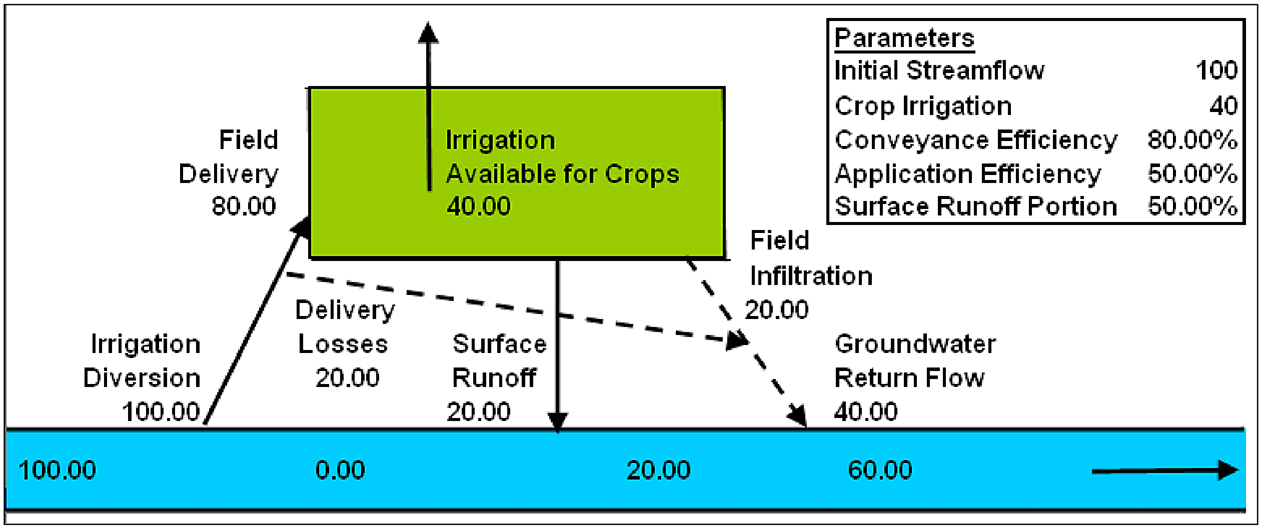
2.1 What is Irrigation Efficiency?

There are many possible definitions of irrigation efficiency, depending on the focus of interest. Economic efficiency is concerned with the quantities of different inputs used (water applied, labor, capital, technology) given existing input and crop prices. The engineering definition of irrigation efficiency, on the other hand, simply describes the share of water diverted or applied that eventually serves its intended purpose. We adopt this latter definition for the purposes of this paper.

2.1.1 Conveyance and application efficiency

The efficiency of water use by an irrigation project is often divided into two parts, the efficiency with which water is conveyed to the field and the efficiency with which that water is applied to the ground and made available for use by crops (Brouwer, 1999 and Howell, 2003). Conveyance efficiency is the proportion of diverted water that is delivered to the field. Application efficiency is the proportion of water applied to the field that is used by the crop. Figure 2.1 helps illustrate these concepts.

Figure 2.1: Simplified Schematic of an Irrigation System



Water is often delivered via an unlined canal in older irrigation projects, with significant infiltration losses to the underlying groundwater. The example in Figure 2.1 shows 100 acre feet (AF) diverted from the stream, and 80 AF delivered to the field – for an 80 percent conveyance efficiency. The 20 AF loss is shown as returning to the stream via downstream springs, presumably after a time interval determined by the hydrology of the underlying aquifer. In this example, the losses from a canal are not losses from the broader perspective of the watershed.[2]

The amount and type of conveyance "losses" depend on the type of conveyance system. Conveyance losses in unlined canals can be very high; especially if the canals traverse areas with gravel or sand substrate. Most losses from unlined canals typically percolate to groundwater, but some losses are water consumed by canal-side vegetation, and surface evaporation. Lining canals, usually with concrete, can eliminate almost all seepage but not surface evaporation. While it is quite expensive, practically all conveyance losses can be eliminated by replacing the canal with a pipeline.

Application efficiency is the portion of the water available at the field that is used by the crop on that field. Water is used for evapotranspiration, but water may also be used for leaching salts, applying fertilizer, or controlling temperature. Application losses include water that runs off the field on the surface (return flows), or water may percolate below the root zone where it cannot be used by the plants. Sometimes, percolation returns to surface water. Figure 2.1 shows water "lost" to both runoff and deep percolation eventually returning to the stream. Of the 80 AF applied to the field in the Figure 2.1 example, 40 AF is delivered to the crop root zone and consumed, for an application efficiency of 50 percent. The 40 AF in the soil root zone, along with any available precipitation, is consumed to satisfy the evapotranspiration needs of the crop.

In practice application efficiencies can vary widely. Older irrigation projects were often developed using gravity application methods, such as flood, furrow, or basin irrigation methods. The application efficiency for such systems can be high, but it is difficult to achieve greater than 60 percent under normal management practices. Sprinkler irrigation systems can be much more efficient. Well-managed hand moved and side-roll systems typically achieve 75 to 80 percent application efficiency while a well-managed low pressure center pivot system may be 85 to 90 percent efficient or even better. Precision application technologies such as drip irrigation can achieve 90 to 95 percent application efficiency, although cost and agronomic considerations currently restrict these systems to high valued crops such as fruits or vegetables (Howell, 2003).

2.1.2 Effects of irrigation efficiency changes

The numbers in Figure 2.1 were chosen to illustrate a common problem that develops on smaller streams when irrigation conflicts with the water flow and habitat needs of fish. The 80 percent conveyance efficiency is representative of an unlined canal. The 50 percent application efficiency is consistent with a surface irrigation system. In order to provide the 40 AF of water needed for the crops, all of the available water must be diverted from the stream. This leaves the stream completely dewatered. In this example, the surface runoff returns 20 AF to the river

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[2] The simplified irrigation schematics show water amounts as acre feet (AF), which one can think of as AF per year. One could alternatively have developed these figures with flow rates – cubic feet per second (cfs). Using cfs flows might be more relevant from the fish perspective. The water budget relationship holds equally for water volumes and flows. However, using flows would have introduced an important new variable – time. Time and time lags are very important in understanding the consequences of improved irrigation efficiency, especially in understanding the behavior of groundwater that infiltrates from leaky canals and from irrigated fields. The figures would have been much more complex if we had used cfs flows, and tried to illustrate the important time lag effects.

downstream with a relatively short time lag. The 40 AF of percolation losses from the canal and field also return, but with a time lag that depends on the characteristics of the regional aquifer. Once these return flows have rejoined the stream, the net stream depletion from irrigation is the 40 AF of water used by the crops, leaving an ongoing flow of 60 AF. These relationships follow the concept of a water budget – all of the water goes somewhere and can be accounted for. The effects of changes in efficiency are to change where the water goes and the timing of these flows.

Suppose this irrigation project improves its efficiency of water use, replacing the canal with a pipeline and installing sprinklers, with the results shown in Figure 2.2[3]. The improvements to irrigation infrastructure means that the 40 AF needed for the crops can be provided by diverting only 47 AF from the stream. The improved irrigation efficiency has solved the stream dewatering problem, since the flows below the diversion have increased from 0 to 53 AF. The return flows have been reduced to only 7 AF. The net irrigation depletion is still the 40 AF used by the crops, and the net downstream flow is still 60 AF. The water budget is still in balance, but more water stays in the stream and less water is routed to the field and through the aquifer.

Figure 2.2: Simplified Schematic with Improved Irrigation Efficiency

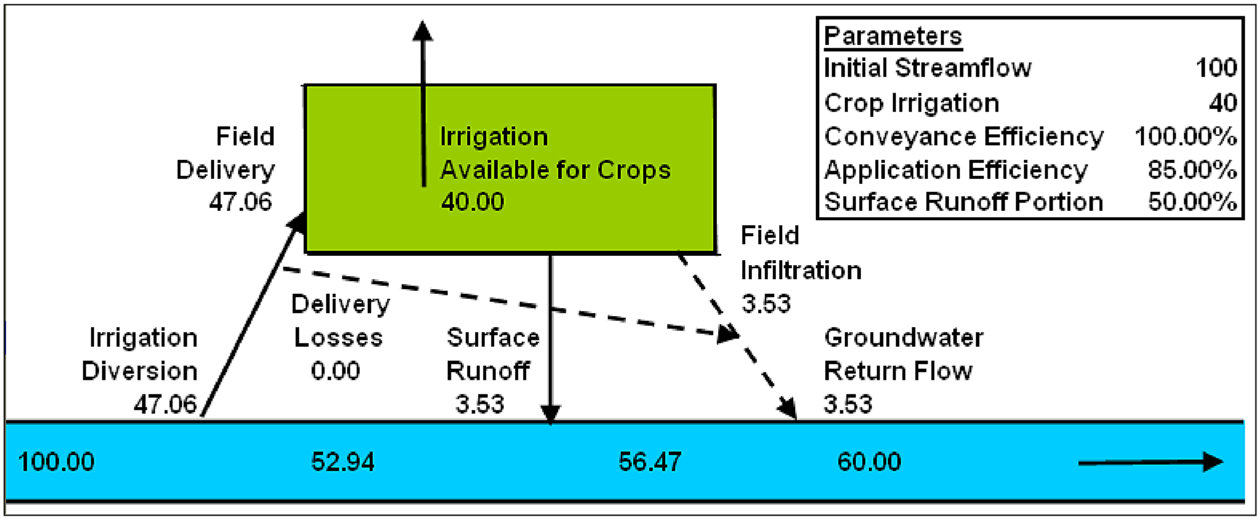

Figure 2.2 may not be the final answer, however. Water in the stream may be available to someone with land that could be irrigated. Suppose the irrigator in Figure 2.2 decides to take maximum advantage of the new more efficient irrigation technology and irrigates more land. It would be possible to more than double crop water use to 85 AF, again totally dewatering the stream as shown in Figure 2.3. Section 2.2 describes state laws that define conserved water and provide for protection of instream flows. However, what can happen if the conserved water is not provided and protected for instream flow?

For the stream, the situation is now even worse than in Figure 2.1. The improved irrigation efficiency has made possible an expansion of water use, again leaving the stream completely

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[3] The effects of irrigation infrastructure improvement and water conservation are addressed in a large number of publications. Two examples are Scheierling (2006) and Brinegar (2009).

dewatered, but also reducing the return flows. The net stream depletion from irrigation is now 85 AF. As a result of irrigation efficiency improvements the ongoing flow below the project has been reduced from 60 AF to 15 AF – potentially causing further problems for fish passage and rearing.

Figure 2.3: Simplified Schematic with Improved Efficiency and Expanded Crop Water Use

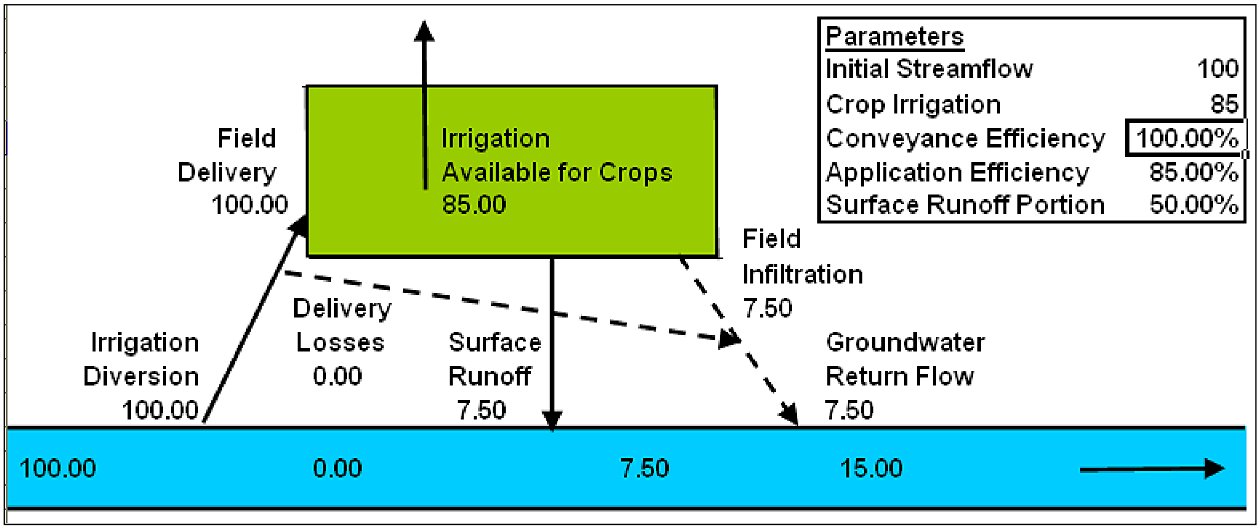

Figure 2.3 illustrates a significant issue that must be considered in any project that proposes improved irrigation efficiency as a way to improve streamflows for fish passage and habitat. More water available instream, may be taken and used by others and therefore it may need to be protected.

In the Figure 2.3 example, the irrigator who installed the more efficient irrigation system was the one who irrigated more land and used more water. However, one needs to think more broadly in terms of what could happen both up and down the stream where there might be other potential water users who might make use of water left instream by irrigation efficiency improvements. For example, since the stream in Figure 2.2 is no longer totally dewatered below the point of diversion, this looks like available water supply for some other adjacent irrigator to divert for crop irrigation. The result would be about the same as in Figure 2.3. The improved irrigation efficiency leaves more water instream, which is appropriated by someone else, increasing water consumptive use and potentially again dewatering a portion of the stream and decreasing downstream flows to the detriment of fish.

Another possible example might involve an upstream junior appropriator with an inadequate water supply. The irrigator in Figure 2.2 has the senior (earlier) water right, so his or her flow is protected against the upstream junior water right holder who must let enough water pass by the upstream diversion to satisfy the senior 100 AF right. When the senior puts in the pipeline and sprinkler system, this leaves more water in the stream in excess of diversion needs. The junior irrigator may be free to divert more water at the upstream diversion, so long as enough water is released through the upstream diversion to satisfy the 47 AF needs of the senior appropriator.

The consequences here could be even worse than in Figure 2.3. The streamflows above the Figure 2.2 appropriator could be reduced to 47 AF, a segment of the stream could again be dewatered, and the downstream flows could be reduced to as little as the 7 AF return flow from the senior irrigator – all of which could be very bad for fish.

This discussion highlights the importance of considering the ability to protect conserved water. Monitoring may be required to ensure that protected flows remain instream and are not diverted by junior appropriators.

Several conclusions can be stated:

- Improved irrigation efficiency may not make much more water available as in-stream flow.[4] It may just change the route followed by the water and the timing of these flows.
- The effects of irrigation efficiency improvements depend critically on the layout of the stream or basin and the characteristics of the underlying groundwater.
- Improvements in irrigation efficiency can actually be damaging to fish passage and rearing needs unless flow improvements can be protected from diversion by other water users.
- State laws that allow instream flows to be protected are critical to use of conserved water for fish. Section 2.2 describes these laws.

2.1.3 Other changes to irrigation practices to enhance streamflows for fish

Changes in irrigation infrastructure or management that improve irrigation efficiency are one way to leave more water in streams to help fish passage and habitat. There are also other diversion structure modifications that might accomplish the same goal.

All of the water in the stream was diverted in the Figure 2.1 example leaving a dewatered barrier to fish passage. Downstream the stream was reconstituted by surface and groundwater return flows. Moving the diversion to below the point where the surface return flows enter the stream, would have a positive effect. Presumably the original diversion was located to allow for gravity diversion of the water into the canal and gravity flow along the canal. Moving the diversion point downstream would require moving the water uphill to the field. This could be accomplished with pumps and a pipeline. Figure 2.4 assumes that pumps and a pipeline were installed, but the farmer continues to use the inefficient gravity irrigation system. Changing the point of diversion has solved the dewatering problem in this example.

The streamflow improvement would have been even greater if it were possible to move the diversion point to a location below where the groundwater returns. The streamflow improvement would also be larger if the farmer installed sprinklers, since this could significantly reduce the volume of water diverted.

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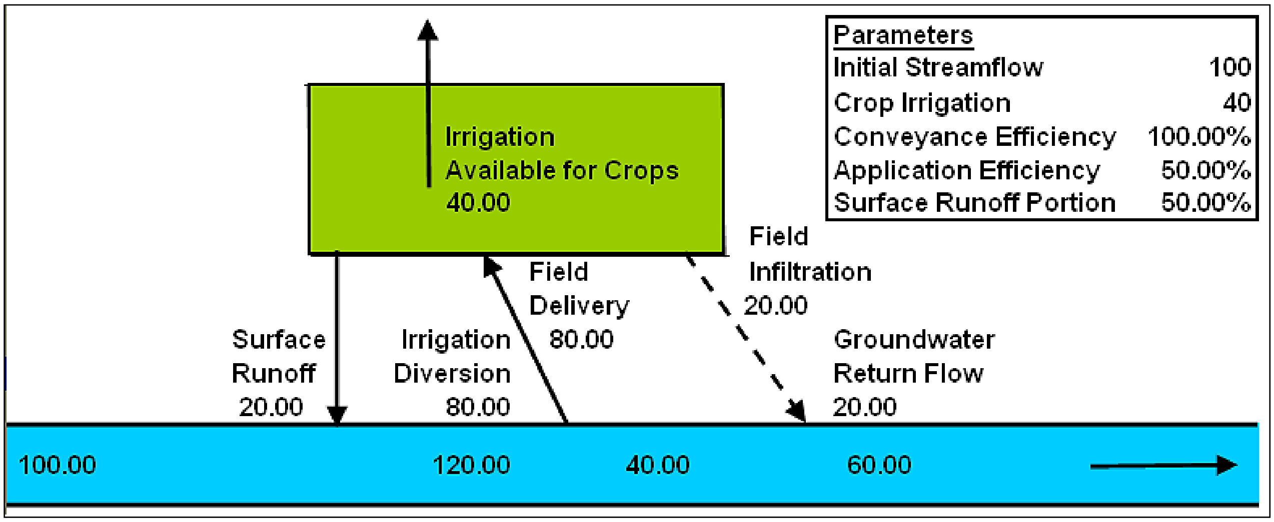
[4] Sometimes, conveyance or application losses are evaporated. Irrigation efficiency improvements can reduce these losses thereby increasing total water supply.

Figure 2.4: Simplified Schematic with a Change in the Point of Diversion



2.1.4 Aquifers and the Surface Water – Groundwater Link

If a river basin has irrigation, it almost certainly has some kind of underlying groundwater or aquifer. In the Figure 2.1 example, infiltration from the leaky canal and from the irrigated field percolated to the aquifer where it flowed with a time lag to springs and eventually back to the stream. What happened on the surface and what happened to groundwater were linked.

Aquifers range from small local aquifers underlying mountain streams to the huge aquifers that underlie much of the Columbia Basin and southern Idaho's Snake River Plain. In most cases there are a number of links between surface water and groundwater (Taylor, 2010). Aquifers are recharged by precipitation, overlying streams and irrigation, and they lose water to groundwater pumping and seepage to lower aquifers and rivers. The water table is well below the riverbed in some reaches so water seeps from the "losing" river to recharge the aquifer. In other reaches the water table may be above the streambed so water flows as springs back to the "gaining" river.

Groundwater hydrology of a basin can be very complex and very case-specific. These surface-aquifer links can have a very important influence on the impact of irrigation infrastructure projects. For example, some small basin aquifers are recharged by percolation from inefficient irrigation and that water is released as cool inflow exactly when needed for late season salmon passage. In other cases the return flows travel overland and heat up, causing a substantial water quality problem for fish.

The important conclusion is that the hydrologic conditions underlying each basin and each project are case specific. Therefore, it is important to have available case-specific information to help understand the full effects of a proposed irrigation efficiency or infrastructure project or water transaction proposal.

2.1.5 Irrecoverable Water

The discussion above suggests that irrigation efficiency often has little effect on the total amount of water used but the timing and location of flows can be very much affected. Regional differences mean that the changed timing and location can have very different implications for fish depending on location. In some cases irrigation efficiency improvements will be able to reduce the amount of water that is irrecoverable.

Irrecoverable water is water that is not utilized by crops but is also transferred beyond the local basin boundary. Examples of irrecoverable water include

- surface water evaporation from reservoirs or canals
- ditch or canal seepage transpired by undesirable plants
- evaporation from wetted areas that are not cropland
- loss of sprinkler droplets evaporated in the air or blown onto non-productive land
- percolation to degraded and unusable groundwater

If irrecoverable water can be reduced by increased irrigation efficiency it could represent real gains to the local water supply. However, such losses are typically a small share of total diverted water and can be costly to eliminate. In the future, economic factors such as water or energy costs could encourage conversions that are intended to reduce irrecoverable water; for example, conversion from lined canals to piped conveyance or use of drip systems that provide water directly to plant roots. The potential for real water savings from reducing irrecoverable losses is very site-specific, so applied research may be required in a local context to better understand the fate of diverted and applied water.

2.2 State Laws to Protect Conserved Water and Instream Flow

The prior appropriation doctrine was not originally designed to protect conserved water or water provided for instream flow. Under prior appropriation, water made available instream by conservation can be diverted by existing appropriators or it might be deemed available for a new appropriation. Where conserved water cannot be claimed, dedicated to instream flow and protected, IE projects can be successful only where the water is protected by the physical layout of water users and the basin.

Until recently, instream flow was not recognized as a beneficial use in most states. Now, all four States involved in this study have some legal mechanism whereby conserved water can be used and protected for instream flow. However, the degree of protection of conserved water and instream flow from subsequent appropriation and diversion varies across the four member states of the Council.

2.2.1 Idaho

A water right can be established in Idaho only by appropriation, and once established, it can be lost if it is not used. However, water users can place water made available by conservation into the Idaho Water Supply Bank, thereby protecting their right for future years. The use of “rental pool” water for instream flow in specific bodies of water, such as the Lemhi Water Bank, is allowed. Also, the use of the Idaho Water Supply Bank rights for instream flow is allowed (Boyd 2003; IDWR 2003).

The Upper Snake Basin water bank allows willing irrigators in the upper Snake River basin to rent some or all of their irrigation water through a water bank for salmon flow augmentation downstream in the lower Snake River. Reclamation pays for the water, up to 427,000 AF annually.

The Idaho Water Resources Board (IWRB) may apply to the Department of Water Resources (IDWR) for an appropriation of water for a range of instream uses. These actions concern only unappropriated water and carry a priority date of the application. Approval of an application requires that the appropriated instream flow be in the public interest, not interfere with existing water rights and be capable of being maintained.

2.2.2 Montana

A water user who implements a water-saving method in Montana may retain the right to the salvaged water for a beneficial use, including instream flow. Salvaged water includes seepage, wastewater, or deep percolation water. The saved water may be used by the appropriator, moved to other lands, leased, or sold after implementing a water-saving method, but only after proving lack of adverse effect to other water rights. A salvage water application must include a report documenting the volume of water that is being saved by the proposed water saving method.

Montana has five mechanisms for the protection of instream flow. The Montana Fish and Game Commission may appropriate unappropriated waters on 12 “blue ribbon” streams to maintain instream flows for the preservation of fish and wildlife habitat. The priority dates of these “Murphy rights” are 1970 or 1971. With Department of Natural Resources and Conservation (DNRC) approval, an appropriation right may be temporarily changed to maintain instream flow to benefit fishery resources. All or a portion of a water right may be leased to the Montana Department of Fish, Wildlife, and Parks, leased to another party interested in holding the right for the fishery, or converted to an instream use without a lease. The temporarily changed appropriation has the same priority date as the existing water right. Water reservations may be granted to public entities for future beneficial uses or to maintain minimum stream flows or quality of water. Some river basins are closed to certain types of new water appropriations. In addition, several compacts with Indian tribes and federal agencies have closed some sources of water to new appropriations (Boyd 2003; MDNRC 2003; MDNRC et al. 2009).

2.2.3 Oregon

Oregon has a unique Allocation of Conserved Water Program (ACWP) that allows a water user who conserves water to use a portion of the conserved water on additional lands, lease or sell the water, or dedicate the water to instream use (OWRD 2011). The enabling statute defines conservation as "the reduction of the amount of water diverted to satisfy an existing beneficial use achieved either by improving the technology or method for diverting, transporting, applying or recovering the water or by implementing other approved conservation measures." Without ACWP, water users who improved their irrigation efficiency would not be allowed to use the conserved water to meet new needs; instead any unused water would remain in the stream and be available for the next appropriator.

ACWP first requires conserved water to be used to mitigate any harm to other water users. Then, the ACWP generally allows the user to claim up to 75 percent of the conserved water for new uses, and the State obtains at least 25 percent for instream use. If the investment of public funds is used for the irrigation efficiency improvement, the water user can agree to have all of the conserved water go instream. In practice, the percentage of water retained by the user can be capped by the percentage of investment by the user. Thus, if the entire project is publicly funded, all of the conserved water may be transferred instream.

Three new water right certificates are issued: one with the original priority date reflecting the reduced quantity of diversion, and two for the applicant´s and State's share of the conserved water. The priority dates for these certificates are either the same as the original right, or slightly junior, for example, by one day.

Oregon has at least six mechanisms for the protection of instream flow: permanent conversion of a water right, long-term leases, short-term leases, split-season leases, conversion of a supplemental groundwater right, and the ACWP. Both temporary and permanent conversion of water rights is allowed for the protection of instream flow. Regulations are implemented through the Oregon Water Resources Department (OWRD). Instream water rights are held in trust for the public by the OWRD and are specified for a particular stream reach. The seniority of the right is retained (Boyd 2003; OWRD 2003).

Oregon allows split season leasing for up to five years. Under split season water transaction, a water user can use the early season water when it has the most value for growing alfalfa or hay, and then leave late season water instream instead of irrigating when it is often more important for fish migration and spawning. The split season can make good sense for the farmer from an economic standpoint since the agricultural production yield per unit of water can be much higher in the early season than in the late season.

2.2.4 Washington

The water associated with a water right in Washington must be used to protect it or it can be lost unless the circumstances fall under one of the exemptions for relinquishment. The Washington State Legislature enacted the Trust Water Rights Program (TWRP) in 1991 to "develop and test the means to facilitate the voluntary transfer of water and water rights, including conserved water and to provide water for presently unmet and emerging needs (WDOE 2011)" Trust water rights leased or donated are exempt from relinquishment. The TWRP may acquire water rights on a temporary or permanent basis.. The "trust water right" is held by the State through the Department of Ecology (WDOE) and retains the priority date of original right. The conveyor may specify the use to be in-stream flow. Approval of a water right conversion to in-stream flow is dependent on WDOE's finding that water is available, existing water rights will not be impaired, and the use is beneficial and in the public interest (Boyd 2003; WDOE 2003).

2.3 Power Implications of Irrigation Efficiency

Electricity demand and hydroelectricity production can both be affected by improved irrigation efficiency. Irrigation efficiency can affect hydropower production by changing downstream hydrology and irrigation conveyance and application conversions can directly affect electricity demands.

2.3.1 Effects on Hydropower Production

Hydropower generation provides about two thirds of the power in the Pacific Northwest. To the extent that IE or WT projects change streamflow, they can affect hydropower generation. There are a number of caveats to this:

- Many of the projects that are the focus of this report are small and located in the upper tributaries, so their effects on hydropower generation will often be too small to be noticed.
- If the project or transaction does not change the acreage and consumptive water use by crops, there is little or no effect on average downstream power generation. Such a project only changes the routing and timing of water flows. The change in flow timing could affect the value of the power generated, but such changes are expected to be very small.
- In some cases water diverted for irrigation bypasses one or more hydropower dams even though return flows eventually rejoin the river downstream. Improving irrigation efficiency in such cases can increase hydropower generation.

In cases where irrigation efficiency improvements or water transactions actually do result in more water at downstream hydropower dams, the amount of power and its value can be approximated using the numbers in Table 2.1.

2.3.2 Effects on Hydropower Demand

Many of the irrigation infrastructure and water transaction projects that are the focus of this report involve replacing gravity diversions with pipelines. Conversions to pipelines can provide all or part of the pressure needed for pressurized water service. Such projects may encourage the replacement of gravity application systems with sprinklers, but electricity demand may not be increased.

Irrigators often replace gravity irrigation systems with sprinklers or drip for economic or agronomic reasons. If pressurized service is not provided by gravity, a pump is required. The electricity required for pumps to pressurize sprinklers is approximately 1.5 kwh for each foot of pressure for each acre foot of water used. For example, Table 2.2 shows that a 130 acre center pivot sprinkler with no pump lift and 25 feet of pressure that applies 3 feet of water per year will require about 49,914 kwh of power per year for pressurization alone (Hamilton and Whittlesey, 1986). Twenty-five feet of pressure at the nozzle might require 88 feet at the pump to overcome some lift and friction loss in addition to the sprinkler pressure.

Table 2.1: Approximate Value of Columbia-Snake Basin Water for Hydropower Production at Various Possible Electricity Prices, $/AF

	Developed Head[1]	Cumulative Head	Cumulative KwH / AF[2]	Cumulative Hydropower Value $/AF[3] Price, $/kWh					
				$.05	$.10	$.20	$.30	$.40	$.50
Lower Columbia									
Bonneville	59	59	51	2.57	5.13	10.27	15.40	20.53	25.67
The Dalles		142	124	6.18	12.35	24.71	37.06	49.42	61.77
John Day	100	242	211	10.53	21.05	42.11	63.16	84.22	105.27
McNary	74	316	275	13.75	27.49	54.98	82.48	109.97	137.46
Upper Columbia									
Priest Rapids	77	393	342	17.10	34.19	68.38	102.57	136.76	170.96
Wanapum	77	470	409	20.45	40.89	81.78	122.67	163.56	204.45
Rock Island	34	504	438	21.92	43.85	87.70	131.54	175.39	219.24
Rocky Reach	87	591	514	25.71	51.42	102.83	154.25	205.67	257.09
Wells	67	658	572	28.62	57.25	114.49	171.74	228.98	286.23
Chief Joseph	167	825	718	35.89	71.78	143.55	215.33	287.10	358.88
Grand Coulee	342	1167	1015	50.76	101.53	203.06	304.59	406.12	507.65
Upper Snake									
Ice Harbor	98	414	360	18.01	36.02	72.04	108.05	144.07	180.09
Lower	100	514	447	22.36	44.72	89.44	134.15	178.87	223.59
Little Goose	98	612	532	26.62	53.24	106.49	159.73	212.98	266.22
Lower Granite	98	710	618	30.89	61.77	123.54	185.31	247.08	308.85
Hells Canyon	210	920	800	40.02	80.04	160.08	240.12	320.16	400.20
Oxbow	120	1040	905	45.24	90.48	180.96	271.44	361.92	452.40
Brownlee	272	1312	1141	57.07	114.14	228.29	342.43	456.58	570.72
Swan Falls	24	1336	1162	58.12	116.23	232.46	348.70	464.93	581.16
C.J. Strike	88	1424	1239	61.94	123.89	247.78	371.66	495.55	619.44
Bliss	70	1494	1300	64.99	129.98	259.96	389.93	519.91	649.89
Lower Salmon	59	1553	1351	67.56	135.11	270.22	405.33	540.44	675.56
Upper Salmon	46	1599	1391	69.56	139.11	278.23	417.34	556.45	695.57
Upper Salmon	37	1636	1423	71.17	142.33	284.66	427.00	569.33	711.66
Shoshone Falls	214	1850	1610	80.48	160.95	321.90	482.85	643.80	804.75
Twin Falls	147	1997	1737	86.87	173.74	347.48	521.22	694.96	868.70
Minidoka	48	2045	1779	88.96	177.92	355.83	533.75	711.66	889.58
American Falls	49	2094	1822	91.09	182.18	364.36	546.53	728.71	910.89
Palisades[4]									

Footnotes:

[1] These are relatively old figures on developed head. Subsequent remodels at Swan Falls and American Falls may have increased their developed heads, with corresponding increases in hydropower value.

[2] These hydropower amounts are based on the rough rule of thumb that an acre foot of water falling through a foot of developed head generates about 0.87 kilowatt-hours of electricity. This assumes that the power plants have capacity to handle the changed flow. In the long run, of course, capacity can be changed.

[3] These values refer to the total value of power that an acre foot of water above the specified dam could generate if routed through all downstream turbines.

[4] Palisades dam has additional hydropower potential. There is only a small amount of irrigation diversion above Palisades, so this dam is ignored.

Source: This table is derived from a table in JR Hamilton and NK Whittlesey, "Energy and the Limited Water Resource: Competition and Conservation", chapter 12 in NK Whittlesey, Ed, Energy and Water Management in Western Irrigated Agriculture, Westview Press, 1986.

Table 2.2: Example of Power Used by a Sprinkler System

	Units	Amount
Operating pressure at sprinkler nozzles	Feet	25
/ Pounds per square inch per foot	Psi/ft	0.4336
= Sprinkler pressure head	Feet	57.66
+ List and friction loss	Feet	30
= Total dynamic head	Feet	87.66
* Electricity/AF at 70% pump efficiency	kwh/af/ft	1.46
= Electricity per acre foot	kwh	128
* Water use per acre	Af	3
= Electricity used per acre	Kwh	384
* Acres irrigated	Acres	130
= Total Electricity used	kwh	49,914

At the regional level, improved irrigation efficiency might have significant effects on electricity demand. Data on electricity use by irrigation and types of irrigation systems are available at the State level through the USDA's Farm and Ranch Irrigation Survey (USDA, 2011, 2006). Table 2.3 presents estimates of 2008 irrigated acreage and water applications per acre by methods of water distribution in Idaho, Oregon, and Washington. Sprinkler systems appear to be the most common type of irrigation in the region, followed by gravity systems. Drip/trickle or other similar systems are still a small fraction of systems used in the region.

Table 2.3: Irrigated acreage and water application per acre, by methods of water distribution and states, 2008, and Pacific Northwest total 2008 and 2003

State	*All Systems*		*Gravity*		*Sprinkler*		Drip/*Trickle*	
	Irrigated Acres (1000)	Water Use (AF/A)	Irrigated Acres (1000)	Water Use (AF/A)	Irrigated Acres (1000)	Water Use (AF/A)	Irrigated Acres (1000)	Water Use (AF/A)
Idaho	3,320	1.9	797	2.1	2,599	1.8	23	1.6
Oregon	1,759	1.9	669	1.9	1,080	1.6	81	1.9
Washington	1,676	2.3	200	2.5	1,379	2.1	138	1.9
PNW, 2008[1]	6,856		1,767		5,301		243	
PNW, 2003	6,680		1,940		4,656		116	
USA 2008	54,930	1.7	22,017	2.2	30,877	1.2	3,756	1.1

1. The Pacific Northwest region

Data source: The 2008 Farm and Ranch Irrigation Survey, the Census of Agriculture, U.S. Department of Agriculture.

A comparison with the 2003 survey shows some trends related to irrigation technology and energy use in the Pacific Northwest. For the "Pacific Northwest Region," irrigated acreage was estimated to increase from 6.68 million acres in 2003 to 6.86 million acres in 2008. The acreage using gravity irrigation declined from 1.940 to 1.767 million acres, and acreage using sprinklers increased from 4.656 million to over 5.3 million. The acreage using drip, trickle or low-flow doubled, but is still a small share of all acreage.

The Farm and Ranch irrigation survey also reports numbers of irrigation pumps and cost of electricity use. In 2003, 27,700 farms in the region used 62,700 irrigation pumps of all types. In 2008, 30,800 farms used 70,600 pumps, an increase of more than 12 percent in 5 years. Region-wide, the number of electrical irrigation pumps increased from 60,800 to 68,100 and reported electricity expenses increased from $200 million to $254 million. More analysis would be required to see how much of the recent expense increase is due to the increased number of pumps, electricity price increases, and possibly, increased average electricity use per pump.

These data suggest a continuing conversion to pressurized irrigation systems with commensurate increase in electricity use and pumping costs. This trend may not continue indefinitely. Conversion from high-pressure sprinklers to low-pressure systems that may use less water could eventually result in a decrease in irrigation electricity use as compared to recent conditions.

Appendix I provides a discussion of BPA’s 2001 Voluntary Energy Load Reduction Program. This program was used to reduce electricity use required to pump water to the Columbia Basin Project and to leave more water in the Columbia River to benefit hydropower production and fish. With the high electricity prices that year, payments of $330 per acre for crop idling may have been well worth the cost.

3.0 Costs of Irrigation Efficiency and Water Transaction Programs

This section describes the Fish and Wildlife Program (FWP) project types and level of effort taken to increase instream flows by cooperative projects with water users. The two types of projects commonly used are 1) payments for irrigation infrastructure to increase efficiency (IE) projects, and 2) water transactions (WT) projects.

3.1 BPA Irrigation Efficiency Projects

The Bonneville Power Administration (BPA), as a part of its Fish and Wildlife Program (FWP) funds a large number of irrigation efficiency (IE) projects intended to help fish. Table 3.1 shows that between 2004 and 2011 BPA spent over $10 million on pipelines and nearly $4 million assisting farmers to install sprinklers. (These figures have not been adjusted for inflation.) Most FWP costs have been incurred in the Walla Walla, Hood and Salmon River subbasins. Other payments to landowners include drilling of wells, installation of flow gages, modified diversion facilities and screening, and payments for water transactions.

IE projects are often popular with irrigators. The projects provide irrigators with a financial incentive to adopt technology or practices that they may be already inclined to adopt. The improved technology or practices often improve irrigation management, increase yields, and reduce energy and labor costs. It should be noted that the cost figures in Table 3.1 do not include any costs paid, or benefits received, by irrigators.

3.2 Columbia Basin Water Transactions Program

Water transactions can take a variety of forms. In most cases irrigators agree to reduce diversions when necessary to leave more water in the stream. They might agree to reduce diversions during the particular critical time periods when the fish need the water. The agreements might require land idling in dry years, but improvements to irrigation systems might be used to reduce diversions in most years. That is, irrigation improvements and water transactions are not substitutes and they may be complementary.

Table 3.1: BPA Spending on Pipelines and Sprinklers 10/1/2004 to 2/15/2011, Nominal Dollars

	Install Pipeline		Install Sprinklers	
	Number of Projects	Work Element Budget	Number of Projects	Work Element Budget
Yakima	20	401,560	11	630,695
Walla Walla	9	2,531,373	9	229,500
Umatilla	1	3,000	2	30,000
Tucannon			3	113,858
Sanpoil			3	70,312
Salmon	8	414,281	18	2,328,720
Okanogan			7	204,940
Methow	4	359,261		
Kootenai	2	18,692		
John Day	23	1,451,932	2	115,000
Hood	5	4,757,027		
Flathead	1	30,000		
Entiat			3	48,148
Deschutes	5	61,642		
Clearwater			1	335
Totals	78	10,028,768	59	3,771,508

Source: BPA's Pisces database, 2010

The Columbia Basin Water Transactions Program (CBWTP) is a partnership between Bonneville Power Administration (BPA) and the National Fish and Wildlife Foundation, a non-profit organization dedicated to preserving and restoring native wildlife species and their habitat. The majority of funding is provided by BPA through the Fish and Wildlife Program. The CBWTP was created in 2002 in response to Action 151 of the 2000 Biological Opinion for the Federal

Columbia River Power System (USFWS 2000) and the Council's 2000 Fish and Wildlife Program (2000).

The CBWTP currently supports 11 non-governmental organizations and state agencies, known as qualified local entities (QLEs), who acquire water for the purpose of enhancing instream flow. QLEs can submit proposals for funding at any time; proposals are evaluated using criteria approved by the Independent Scientific Review Panel (ISRP).

Table 3.2 provides data on the amount and cost of water purchased through the CBWTP based on data provided by the NFWF (NFWF 2011). The amount of water provided by CBWTP purchases increased in the 2008 through 2011 period as compared to the 2003 through 2007 period. The amount of purchases increased in some sub-basins, but declined in a few. A series of purchases for groundwater mitigation ended in the late 2000s in the Deschutes basin. Prices paid were updated to 2010 dollars (adjusted for inflation using a common base) using the GNP implicit price deflator and based on the transaction year as provided by the database. After adjusting for inflation, the CBWTP has spent about $27.18 million in FWP and other funds for temporary and permanent transactions.

Table 3.2: Water provided by CBWTP transactions, average 2003 through 2007 and 2008 through 2011, and total cost paid for water in 2010 dollars

Subbasin	Average AF provided 2003-2007	Average AF provided 2008-2011	Total cost paid for water, million 2010 dollars
Yakima	4,630	8,901	$3.067
Willamette	8,909	8,995	$0.283
Walla Walla	549	980	$0.502
Umatilla	215	828	$0.196
Salmon	4,152	8,938	$4.690
Okanogan	140	971	$0.950
Methow	648	3,814	$1.490
John Day	1,642	4,280	$1.405
Grande Ronde	1,422	2,037	$1.427
Flathead	705	163	$0.116
Fifteenmile	379	775	$0.034
Deschutes	23,102	22,508	$10.344
Clark Fork	5,407	3,131	$0.377
Blackfoot	7,797	8,070	$0.483
Bitterroot	8,860	11,511	$1.816
TOTAL	68,555	85,900	$27.179

Table 3.3 shows the cost per AF for water acquired and used through 2011 and share of total cost paid by the CBWTP. Average unit cost is a useful measure, but calculation of a cost per unit water is complicated by permanent transactions because the denominator is infinite. Therefore, the unit cost is calculated as cost per unit of water acquired through 2011.

These results are estimates for a variety of reasons; some leases are paid in advance, others each year, some acquisitions provide a minimum flow that requires no action in wet years, and some part of costs may be unreported. Therefore, the unit costs should be taken as a rough estimate.

The estimated cost per AF provided varies among subbasins. The average was about $19 per AF. The lowest price ($1.72) was obtained in the Willamette basin. This price is heavily influenced by one permanent transaction that paid $180,000 for 8,672 AF. The highest price ($92.43) was in the Grande Ronde basin. This price is heavily influenced by a series of purchases on the Lostine River that cost around $90 per AF.

The cost per AF of obtaining water by transactions might be compared to costs of obtaining water directly by irrigation improvements. However, the water costs in Table 3.3 include some minimum flow agreements in which water users must do little or nothing to provide an agreed-on flow level. The unit costs required to meet the terms of a water acquisition are not always comparable to the unit costs of conservation.

The last column of Table 3.3 shows that 43 percent of the total cash cost of purchases in which the CBWTP participated was paid by CBWTP funds. Other large shares were provided by landowners, states, tribes, NGOs, the Pacific Coast Salmon Recovery Fund, and other federal funds. Water transactions often involve some payment to the irrigator, but some involve charitable donations with tax advantages to the seller and many have involved funding from a variety of sources.

An external review of the CBWTP (Hardner and Gullison 2007) noted that its strengths include its "ability to strategically coordinate different stakeholder groups (e.g. government regulators and non-governmental organizations) working on common issues, the ability to act as an interface between small grantees and large donors, the ability to foster learning among grantees working on similar issues, and the ability to achieve economies of scale in capacity building."

It is important to recognize the synergy between water transactions and irrigation efficiency.

- Water transactions focus on the "ends" – the transfer of water to instream flow. Idling some land or improving irrigation efficiency may be the "means" used to release the water needed to satisfy a transaction commitment.

- Irrigation infrastructure projects focus on the "means" – improving irrigation efficiency so that the saved water can be used instream. For this water to serve the "end" of being useful to fish it must be moved or traded to increase instream flow when needed and, in most cases, it must be protected from diversion or appropriation.

Table 3.3: Water provided by CBWTP expenditures through 2011, cost per AF in 2010 dollars, and CBWTP cost share

Subbasin	Total AF acquired and used through 2011	Total cost paid for water acquired and used through 2011, million 2010 dollars	Cost per AF acquired and used through 2011, 2010 dollars[1]	CBWTP (FWP) cost share
Yakima	58,754	$1.138	$19.38	40.9%
Willamette	80,521	$0.138	$1.72	85.9%
Walla Walla	6,663	$0.152	$22.85	80.6%
Umatilla	4,387	$0.077	$17.55	100.0%
Salmon	56,508	$1.758	$31.11	40.1%
Okanogan	4,583	$0.359	$78.27	46.8%
Methow	18,494	$0.685	$37.03	54.2%
John Day	25,332	$0.552	$21.79	37.1%
Grande Ronde	15,258	$1.410	$92.43	91.3%
Flathead	4,176	$0.126	$30.13	100.0%
Fifteenmile	4,994	$0.037	$7.36	99.6%
Deschutes	205,541	$5.163	$25.12	30.0%
Clark Fork	39,559	$0.360	$9.09	100.0%
Blackfoot	71,267	$0.328	$4.60	45.3%
Bitterroot	90,341	$0.658	$7.28	50.2%
TOTAL	686,378	$12.941	$18.85	43.4%

[1] First, for each transaction, the quantity of water purchased and provided for instream flow through 2011 was calculated. For permanent transactions, the cost per AF was estimated as a real discount rate of five percent times the 2010 one-time cost paid, divided by annual AF provided. For temporary transactions, the cost per AF was calculated as the annual payment required to pay off the cost in 2010 dollars at 5 percent interest over the period of the lease. Then, for every transaction, the cost per AF can be multiplied by the amount of AF acquired and used through 2011 and summed over acquisitions in the sub-basin to obtain the “Total cost paid for water received through 2011.” Then, this total cost paid can be divided by total water acquired and used through 2011 to obtain the cost per AF of water acquired and used through 2011.

Where protection under state law is weak, increased instream flows are sometimes protected by the physical layout of the basin. In other cases, where state law allows, the instream flows can be protected by laws designed specifically for this purpose. State laws regarding the protection of instream flows were discussed in Section 2.2.

There are several concerns about the ability of water transactions to acquire more water in the future.

One is the "low hanging fruit issue" -- have past transactions exhausted the supply of landowners willing to transact? The concern is that past CBWTP transactions may have used up all the likely sellers willing to forego irrigated farming. These people are likely to be

- marginal farming operations
- in need of a respite because of illness or other opportunities
- people with a hobby farm or a horse pasture they are willing to give up irrigating
- people with the income to make use of charitable donation deductions
- people with a strong concern for environmental issues

If the supply of such potential sellers has been used up, then future transactions may be harder to arrange.

Another concern is that high crop prices and urban competition for water will increase the price farmers require to sell water for instream use. The rising value of water for both crop production and urban use means that farmers will demand higher prices to sell or lease their water. If water transactions costs increase, IE projects may be more attractive in the future.

On the other hand, changes in State laws to facilitate transfers could increase water transactions. In Idaho and Montana, water transactions may be limited by constraints or costs required under State laws. In these states and Washington, split-season leases may not be possible. Oregon law facilitates transactions, but even there, extending the split season option to permanently put water instream could have beneficial implications for water users and fish. More generally, laws that more clearly define conserved water and provide for better protection of dedicated instream flow might provide impetus for more transactions.

3.3 Other Programs

While BPA is the single largest funding source for both irrigation efficiency and water transaction projects for fish in the Pacific Northwest, it is not the only funding entity. Over 50 percent of the cost of CBWTP transactions have been paid by sources other than BPA. Other major funding sources have included:

- State agencies such as the Washington Department of Ecology, Montana Fish, Wildlife and Parks, and the Oregon Department of Fish and Wildlife
- Federal agencies and funds such as the Pacific Coast Salmon Recovery Fund, the U.S. Fish and Wildlife Service, the Bureau of Reclamation and the Natural Resources Conservation Service

- Non-CBWTP funds from foundations and non-profits
- Landowners and private individuals
- Tribal entities such as the Yakima Nation, the Spirit Mountain Community and the Colville Tribe
- Energy companies such as Pacificorp and Northwestern Energy

A single water transaction often involves a number of cooperating participants. The qualified local entities develop a water transaction, and the CBWTP serves as facilitator in the review and implementation of the transaction. BPA often funds transaction costs and costs for the water right through the CBWTP process. Other NGOs may also provide part of the money needed to pay for the water right transaction.

In many cases, a water user retains title to the water right, and the legal use of the water right is transferred instream for the duration of the water transaction in accordance with state water agency processes. In some permanent water transactions, a land or water trust assumes title to the water right, or title is transferred to a state agency along with the ongoing management and enforcement obligation.

Water transactions have made the most of limited Fish and Wildlife Program funds by including a number of cooperating stakeholders. BPA money channeled through CBWTP has often been matched with other agency and NGO money. These other funds have provided for more acquisition than would be possible using CBWTP funds alone..

The United States Department of Agriculture (USDA) is a major source of funds for irrigation infrastructure improvements nationwide. The USDA Environmental Quality Incentives Program (EQIP):

> "… provides support for projects that conserve and improve water quality, use irrigation water efficiently, mitigate the effects of drought and climate change and take other actions that benefit water resources. NRCS enters into partnership agreements with federally recognized Indian Tribes, state and local units of government, agricultural and forestland associations, and nongovernmental organizations to help landowners plan and implement conservation practices in designated project areas." (USDA, 2011)

The USDA has not been an important contributor to CBWTP water transactions; however, it has been and will continue to be important for support of irrigation efficiency projects that have multiple benefits, including fish and wildlife.

4.0 Case Studies

Eight case studies were undertaken to investigate and compare the use of IE and WT projects in the region. The case studies were chosen to represent the diversity of conditions in the region. Projects were chosen from each of the four states, and from small and large basins. The case studies are discussed in detail in the appendices to this report.

The eight case studies are:

- Lemhi River
- Yakima Sub-Basin
- Salmon Creek
- The Upper Grande Ronde Basin
- Walla Walla Basin
- Deschutes River Basin
- Hood River Basin
- Blackfoot Sub-Basin

Projects involving water transactions were observed in seven of the eight case studies (excluding Hood River). Documented IE projects have been completed in half of the basins (Salmon Creek, Walla Walla, Deschutes, and Hood River). In general there have been multiple types of activities aimed at benefiting fish, including short- and long-term water rights leases, purchases of water rights, changes in point of diversions, stream restoration, improved fish passage and canal screening. Irrigation efficiency activities included on-farm changes in irrigation technology but the majority of IE projects have involved piping to reduce seepage in water conveyance systems. Some projects combined irrigation efficiency with water transactions.

To benefit fish cost-effectively, both IE and WT projects must achieve three things: first, diversions of instream flows are reduced; second, the resulting increased flows must remain instream over the desired river reach; and third, those increased flows must improve fish habitat in ways that enhance fish populations. Most of the emphasis for economic comparisons involves the first component, increasing instream flows cost-effectively. To increase stream flows from IE projects there must be an increase in a quantity of “conserved water” that increases streamflow as a result of reduced diversion. In the case of WT projects, water is simply left instream rather than using it to irrigate crops.

Table 4.1 provides a summary comparison of the median costs of IE and WT projects by basin. Because IE projects tend to contribute to instream flows in a permanent or long-term way, it is most appropriate to compare their cost to the cost of long-term or permanent transactions where possible. Because of lower transaction costs per acre-foot, the cost per acre foot tends to be lower for multi-year leases than for one-year leases. For this reason the comparisons presented in Table 4.1 are between IE projects and multi-year WT projects.

The largest numbers of IE projects were observed in the Deschutes and Walla Walla Basins: 30 projects have been completed in the Deschutes; 21 on the Walla Walla. These two basins also provide the largest sample of cost estimates for IE projects. From Table 4.1, the median cost of increasing instream flow with conserved water in the Deschutes River was $41/AF/year; the range was $6 to $159. This compares to a median cost of $25/AF for WT projects in the same basin. Sufficient information was available to compute costs per acre-foot for 5 of the 21 projects in the Walla Walla basin. For these the median cost was $23/AF with a range of $5 to $37. This compares to a median cost of $27/AF for multi-year WT projects in the same basin. In Salmon Creek, WA, one IE project was documented to have increased streamflow at a cost of $42 based on a 50 year lease. This compares to one nine-year WT project in Salmon Creek where the cost was $91/AF/year.[5] Additional evidence of the cost of water transactions come from the other case studies. In the Yakima basin, the available data indicate 25 multi-year projects with a median cost of $26/AF. In the Upper Grand Ronde basin, the median among 5 projects was $33; for the Blackfoot basin the median was $15 among seven projects. Table 4.1 provides additional details.

The Table 4.1 costs, with the exception of those for Hood River, are the costs borne by ratepayer, taxpayer and federal funds , including the BPA and the QLEs acting on behalf of several funding agencies. We have not, however, included the costs borne by irrigation districts or their members, nor have we included other sources of funding, or other indirect benefits accruing to irrigators. It is reasonable to assume, however, that the QLEs work to minimize their costs per acre-foot and that the irrigators would take account of any additional costs, or benefits, borne by them when deciding to accept the terms offered by the QLE. If this is the case on average, then the costs used in the current analysis may reasonably reflect the social cost of the increased instream flows made possible by these IE and WT projects. Still, in some cases there may have been additional benefits to irrigators that are not reflected in our accounting of these costs. Similarly there may be costs that were paid to irrigators by other non-governmental organizations and some of these additional costs may have been omitted from the accounting presented here. There is no strong evidence, however, that on balance these omissions will have had the effect of biasing the results reported here in one direction versus the other.

The evidence suggests that both IE and WT efforts can be relatively low cost ways to increase streamflow. Despite seeing similar ranges of cost/AF for both IE and WT projects, there is evidence that the potential for continued or expanded efforts to protect or enhance fish habitat based on IE projects is limited. Among those basins where many IE projects have occurred in the past decade or longer, observers suggest that few additional opportunities may exist for cost-effective IE gains. When the major canals prone to seepage are piped, alternatives may be few to make comparable streamflow improvements at relatively low cost. Indeed, in the Deschutes basin there is evidence of rising cost per acre-foot among projects undertaken in the past decade (see Appendix Figure F2). In the Hood River basin there have been significant efforts to improve irrigation efficiency, sometimes with a net financial gain to the irrigators, but irrigation district representatives indicate that few additional IE projects are likely to be undertaken in the future.

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[5] The data for these case studies were obtained from a range of sources. Each case study made use of the BPA Fish and Wildlife Program's comprehensive database (PISCES) for data on water transactions projects, as well as data from the Columbia Basin Water Transaction Program. In the Deschutes basin, additional data was provided by the Deschutes River Conservancy; and in the Walla Walla basin from the Walla Walla Basin Watershed Council. For the Hood River, detailed information was provided by the Farmers Irrigation District and the East Fork Irrigation District.

Table 4.1: Summary of Case Study Findings

	Irrigation Efficiency Projects			Water Transactions Projects		
		Cost/af/year ($2010)			Cost/af/year ($2010)	
Location	Sample types	Median	Range	Sample types	Median	Range
Upper Salmon/Lemhi, ID	Combined IE, WT	>$5	--	8 permanent	$38	$34-38
Yakima River, WA	2 completed	$82	$46 - 118	25 multi-year	$39	$9 - 72
Salmon Creek, WA	1 ex ante est. 2001	$42	--	One 9-year project	$91	$40 - 91
Upper Grande Ronde, OR	None reported	--	--	5 multi-year	$33	$14 - 155
Walla Walla Basin, OR	5 projects	$23	$5 - 37	10 multi-year	$27	$10 - 37
Deschutes River, OR	30 projects	$41	$6 - 159	18 multi-year	$25	$7 - 52
Hood River, OR	Multiple projects	< $0 [1]	NA	No information	--	--
Blackfoot River, MT	None reported	--	--	7 multi-year	$15	$1.6 - 33

Note: Costs are total reported costs including BPA and all other outside sources.

[1] Negative cost reflects the many self-financed IE projects undertaken by irrigation districts in this basis that generated revenues or cost-savings such as increased hydropower production and sales; no non-local funds were required.

Have IE and WT projects effectively increased streamflows in the locations and at times where there are need to improve fish habitat? And have those improvements contributed to restoration or protection of fish populations at risk? There is evidence from these case studies that in locations where river reaches were completely or nearly dewatered in mid-summer periods, the restoration of instream flows has improved habitat which in turn has likely benefited fish. In the Walla Walla basin, a reach of the mainstem that had previously become completely dewatered in mid-summer is now flowing during those periods (see Appendix Figure E4).

Low flows in the midsection of the Deschutes River have been significantly increased in summer. The increases owing to IE projects have increased flows by 85 cfs, or more than doubling the previous mid-summer, mid-section flows. In the Lemhi, redd counts have increased from single digits in the 1990s to 106 in 2009 and 126 in 2010, owning to multiple actions including IE and WT projects. Among these actions, 2010 flow data indicate that the projects undertaken here have avoided the dewatering that had caused serious damage to salmon runs in previous years.

In the Hood River basin, by contrast, the substantial numbers of IE projects initiated by the irrigation districts led primarily to increased water use on-farm and increased hydropower revenues. Some of the change related to these infrastructure improvements also benefits streamflows and fish habitat, but no documentation for these benefits was available.

These case studies were selected to include at least one basin from each state and where efforts were undertaken to improve fish habitat (rather than as a random sample). As a result, some of the evidence collected may represent situations that are somewhat unique, but overall appear to present a valuable picture of recent experiences. For example, in the Hood River the topography and the nature of agricultural production, which includes high-value tree fruits, is likely uncharacteristic of most other sub-basins and these factors help give rise to numerous self-financed IE projects that required no outside funding. In the middle Deschutes River, the geography of the river and the significant distance between the main irrigated areas and the mainstem of the river limit the concerns that a) improved irrigation efficiency and reduced diversions might simply be offset by reduced return flows, and b) that improved instream flows might result in other irrigators diverting more water immediately downstream from the diversions affected by the IE projects. In the case of the Walla Walla River, the presence of a completely dewatered segment of the mainstem in July left little doubt that efforts to augment instream flows could have immediate benefits to fish.

5.0 Implications and Conclusions about Cost Effectiveness

This report has examined the potential benefits to fish from increased irrigation efficiency in the Columbia River Basin. Projects aimed at improving irrigation efficiency have been undertaken alongside many other projects involving water transactions. In some cases, these two approaches to increase streamflows to benefit fish have been combined. Outside sources of funds have been used to finance improved irrigation efficiency in most IE projects as a way to create the "conserved water" for augmenting instream flows. In WT projects, irrigation water has been bought directly to transfer to instream uses, normally by reduced diversion. Many projects of both kinds have been undertaken in the Columbia River Basin over the past 15 years, and the evidence suggests that both can achieve increases in instream flow at reasonably low costs (below $50 per AF per year). These costs vary widely across projects and basins. Not all of the basins studied in detail provided evidence of the potential for improving irrigation efficiency to benefit fish. Indeed, in two of the eight basins examined no evidence of IE projects was found, whereas all basins had undertaken numerous WT projects. Other actions benefiting fish were also observed, including changes in a point of diversion for irrigation and installing fish screens on a canal.

Clearly, the most efficient approach for a given basin depends on the unique characteristics of that basin, including the flow or water quality problem to be addressed, local surface and groundwater hydrology, water conveyance and storage infrastructure, cropping patterns, state water rights laws, and land ownership patterns. These factors largely determine the ability to acquire, protect and manage water when needed.

Both approaches have particular advantages. Irrigation efficiency can play an important role in a package of water supply improvements and can often be implemented without any reductions in the acreage irrigated. IE projects can reduce both water diversions and return flows. These changes may have important water quality implications.

One of the important features of irrigation efficiency, as opposed to water transactions where some of the water is obtained by idling irrigated land, is that agricultural production is not decreased. Rather, improved irrigation efficiency tends to maintain or even increase production by improving water application rates or increasing crop yields and, sometimes, by increasing crop acreage. Piping of irrigation conveyance can provide the benefit of pressurized water for on-farm systems.

Improvements in irrigation efficiency have limited effects on the quantity of downstream power production, primarily because consumptive use is little affected. On the other hand, widespread conversion from gravity to pressurized sprinkler systems appears to be increasing power demand in the region. Use of low-pressure efficient systems could limit these effects in the future.

WT projects have outnumbered IE projects in the last decade as a method of providing water for fish. One advantage of water transactions is that they are better able to augment and assure streamflows in low flow years in which fish are most vulnerable. Water transactions can result in an entire package of actions, including irrigation efficiency, to enhance conditions for fish. The qualified entities who conduct transactions are able to provide the entire array of services required to purchase, manage, protect and monitor water transactions. The presence of NGO and other public and private funds reflects public interest in this method of improving native fish populations.

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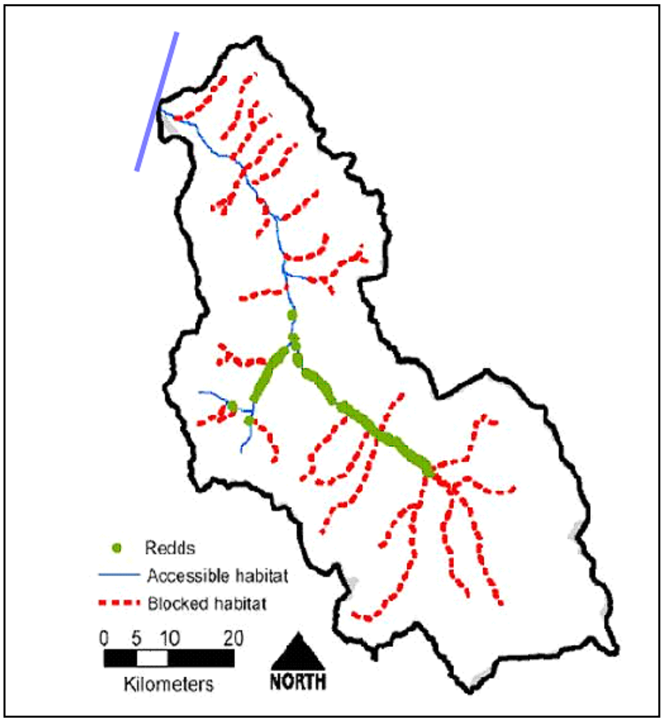
Appendix A: Lemhi River, Idaho

Background

The Lemhi River is a tributary of the Upper Salmon River in Idaho. The Upper Salmon River and its tributaries including the Lemhi were once prime spawning areas for salmon and other anadromous and resident fish. Early irrigation development on the Lemhi relied on a number of push-up dams to divert water and also diverted the flow of several smaller side streams for irrigation.

The lower Lemhi was blocked by a small power dam from the 1920s to the 1930s, completely blocking salmon passage except for occasional high flow periods when some water was bypassed. Some remnant populations were maintained by fishermen who caught salmon below the dam and released them above. The power dam was removed in 1938, and some population recovery was observed (Idaho Soil Conservation Commission, 1995). However the push-up dams remained as physical barriers to migration of both juvenile and adult salmonids. The diversion of side streams for irrigation so they no longer connected to the main Lemhi, except in extreme high flow events, cut off large portions of prime salmon habitat.

Figure A1: Map of Lemhi River Basin



By the mid 1990s there were 37,000 irrigated acres in the basin, mostly irrigated hay and pasture. At that time about 20 percent of the land was sprinkler irrigated and 80 percent flood irrigated. Irrigation efficiency averaged 25 to 30 percent and ranged from 10 to 60 percent (Idaho Soil Conservation Commission, 1995). Several segments of the lower Lemhi were sometimes completely dewatered by irrigation diversions when natural flows were low in late summer – totally blocking salmon passage to and from favorable salmon spawning areas in the upper reaches of the Lemhi. The map in figure A1 shows the situation in the basin at the end of the 1990s.

The local aquifer also plays an important role in streamflow:

"The ground water – surface water interplay and the temporal nature of irrigation demands also lend complexity to the Lemhi River system. During high flows in the spring runoff period, irrigators along the main Lemhi and tributary streams open their diversions to fill their canals and soak their fields. Irrigation water causes ground-water levels to rise seasonally. It is widely believed that this shallow ground water storage is slowly released back to the Lemhi River which sustains stream flows later in the irrigation season. This scenario is also evident on some tributary streams where flood irrigation of upper fields in the early season is thought to benefit lower fields (near the valley floor) as water percolates downslope through the shallow subsurface". (DHI, 2006, page 2)

As the salmon runs began to collapse in the 1960s and 70s, concern increased at the federal, state and local level. By 1995 these concerns had coalesced into a Model Watershed Plan for the Lemhi, Pahsimeroi, and East Fork of the Salmon River (Idaho Soil Conservation Commission, 1995, and Strong, 2003). The plan encouraged a number of voluntary actions including consolidation of push-up dams into permanent diversion structures with fish passage provisions, improvements in irrigation practices, installation of fish screens, and the beginnings of a program to reconnect tributary streams.

The Salmon Subbasin Management Plan recognized the problems of the Lemhi Basin:

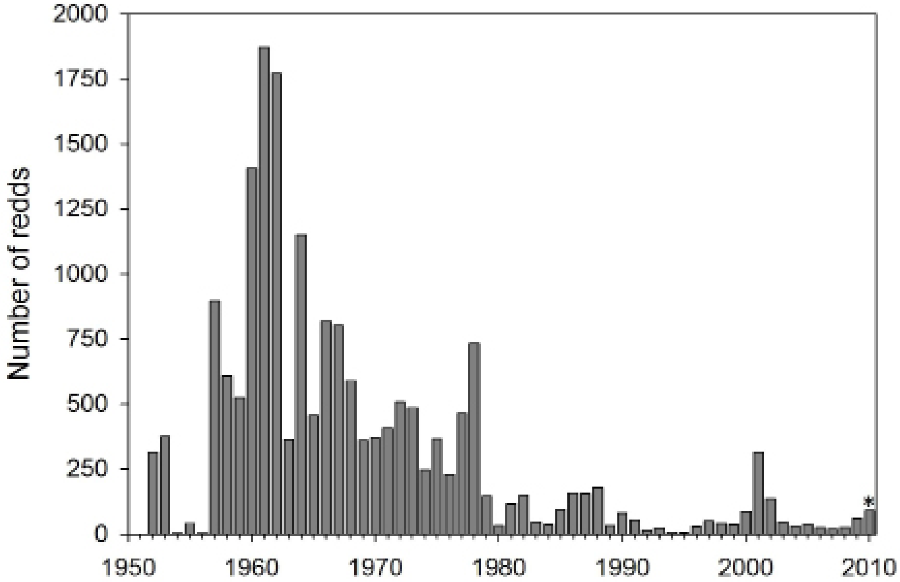
Lemhi River—Mouth to Agency Creek

> Problem 35: The hydrologic regime (peak flows, base flows, flow timing) and connectivity of most Lemhi tributaries has been altered by irrigation withdrawals. Only 7% of all tributaries remain connected to the mainstem. These changes limit resident and anadromous populations' access to potentially available habitat and delay anadromous smolt and adult migration in the lower reaches of the mainstem Lemhi, which may contribute to increased mortality rates, although no evidence has been offered to date.
>
> Aquatic Objective 35A: Rehabilitate natural hydrographs in key anadromous and resident tributaries to ensure adequate base flows are available in lower, mainstem reaches.
>
> Aquatic Objective 35B: Provided that there is adequate funding, personnel, and landowner participation, reconnect a minimum of one tributary every three years that are currently defined as partially or seasonally inaccessible to anadromous and/or resident focal species.
>
> (NPCC, Salmon Subbasin Management Plan, May 2005, pages 66 and 67)

The precipitous declines of Lemhi River salmon numbers in the 1960s and 70s (shown in figure A2) caused strong local as well as national concern. Salmon redd counts dropped to single digits in the 1990s. The need for aggressive local action was apparent when these events were followed by ESA listings in the 1990s. The Upper Salmon Basin Watershed Program was organized in 1992 as a local, state, and federal partnership. The program focuses on participation by local landowners voluntarily working to protect and restore streams for both salmon and resident fish while balancing the needs of the local irrigated agriculture.

The focus of this case study is on the lower end of the Lemhi River, the area a few miles above the point within the city of Salmon, Idaho where the Lemhi joins the Salmon River. This is the river reach that is sometimes dewatered when adult salmon would migrate upstream and when juveniles would migrate downstream. An irrigation diversion point referred to as the L6 diversion (7.4 miles above the confluence with the Salmon River) serves 13 irrigators organized as Water District 74.

Figure A2. Lemhi River Annual aerial redd counts (1952-2010)



Source: Steve Stuebner, "Salmon River ranchers restore salmon streams in Upper Salmon Basin to provide homes for fish", Upper Salmon Basin Watershed Program, 2010.
(The * was not explained, but presumably indicates preliminary data)

Water Transactions and Irrigation Efficiency

A large number of projects have addressed the problems of the Upper Salmon Basin. Table 3.1 noted that between October 2004 and February 2011 BPA spent $414,000 on 8 pipeline projects and $2,329,000 on 18 sprinkler projects in the upper Salmon Basin. Some of these were for infrastructure improvements in the Lemhi portion of the Salmon Basin.

Action on the Lemhi required cooperation between local interests, the Idaho Water Board, the Idaho Legislature, the Columbia Basin Water Transactions Program (CBWTP), and others. In 2001 the Idaho Legislature created the Lemhi River Water Bank. This step was necessary because, although Idaho has had a long history of water banking, the existing Idaho banks have not allowed an irrigator to put water into the bank and direct that that water be used for fish flows. The Lemhi bank was created as an exception to that rule – Lemhi irrigators were allowed to designate that water go to the bank and be assured it would be used for fish. The Idaho Water Transactions Program was created in 2003 within the offices of the Idaho Water Board to oversee this program. The Water Transactions Program became a Qualified Local Entity of the Columbia Basin Water Transactions Program.

Lemhi water transactions started in 2004. The first transaction was an agreement by Water District 74 to limit water diversions at diversion L6 to maintain flows of 35 cfs between May 15th and June 30th of 2004. Exactly how this flow target was to be met was the responsibility of the District 74 Board using the Lemhi Water Bank to funnel water from cooperating irrigators to the river. In fact farmers and the district chose a mixture of irrigation efficiency improvements and foregone irrigation to achieve compliance. This initial one year split-season transaction was funded by $14,130 from the CBWTP.

Compliance was to be assured by the National Marine Fisheries Service (NMFS) and the Idaho Department of Water Resources using the USGS gage a mile below the L6 diversion.

A maximum of 3,193 acre feet of water would have been needed to meet the 35 cfs flow targets between May 15th and June 30th under conditions where the river would otherwise have been dewatered. Because higher flows were expected, at least part of the time, the actual amount needed to achieve the minimum flow was expected to be less. If all of the water had been needed, the cost per acre-foot would have been $5.10 per acre-foot (2010$). Since not all the water was expected to be needed, the expected cost per acre-foot delivered would have been higher.

This initial one year transaction served as a confidence builder. It was followed by a succession of one year agreements. In 2005 there were two one year agreements, an early season one covering an expanded period from March 15th to June 30th, joined by a late season agreement for the period from July 1st to November 15th. The early season agreement assured flows of at least 35cfs 80 percent of the time and flows of at least 25 cfs for the remainder. The late season agreement assured flows of at least 25 cfs for the period. The agreement provided that the cooperating irrigators would be paid as much as $68,960 for the early season and as much as $184,600 for the late season, although actual payment would be based on the actual amount that had to be delivered to meet the flow targets. The costs were funded 25 percent by CBWTP and 75 percent by the Pacific Coast Salmon Recovery Fund (PCSRF). An additional $34,000 in project transaction costs was also split 25/75 (Columbia Basin Water Transactions Program).

Given the experience of 2004 and the longer period covered in 2005 including the low flow period of late summer, the cost per acre-foot would be expected to be higher. A maximum of 12,591 acre feet could have been required at a total cost of $287,560, or $22.84 (2005$) per acre-foot.

2006, 2007 and 2008 saw similar annual agreements, at least 35cfs 80 percent of the time and at least 25 cfs the remainder of the time between March 15th and June 30th and at least 25 cfs between July 1st and November 15th. The 2006 agreement cost $184,600 and the 2007 agreement cost $80,200 and the 2008 agreement cost $34,000, again split 25/75 by CBWTP and PCSRF.

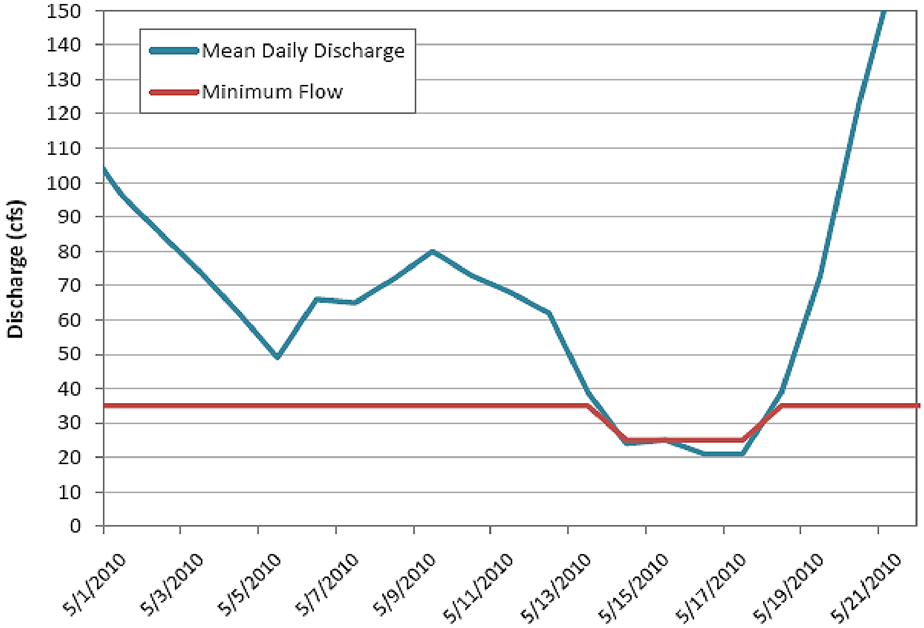
The 2007 agreement had an interesting new wrinkle. The City of Salmon Golf Course had been one of the water users diverting irrigation water at diversion L6. Agreements with BPA allowed the golf course to change its point of diversion. BPA Fish Accords money was used to install pipelines, sprinklers, and most importantly to install wells diverting irrigation water from the alluvial aquifer along the main Salmon River rather than the Lemhi. This assured that 3.5 cfs of the flow needed at diversion L6 was provided by the golf course, and only 32 cfs had to be acquired from other irrigators.

The year 2008 marked the last annual agreement. In 2009 the parties reached the Lemhi Conservation Agreement. This included a Memorandum of Agreement with Water District 74 to permanently meet the 35/25/25 cfs flow targets, and started the process of reaching permanent agreements with the individual irrigators using conservation easements to assure the flows. Agreements made in 2009 paid seven irrigators a total of $1,200,000 to assure 14 cfs of the flow obligation. While CBWTP participated in crafting the agreements, the costs of acquiring the conservation easements was split 72/28 between the Pacific Coast Salmon Recovery Fund and the BPA Fish Accords. Agreements made in 2010 assured the rest of the required flow.

The cost of these permanent transactions is included in the cost summary in Table 4.1. Again, the water quantities covered by the transactions are the maximum amount that could be needed to achieve the minimum flow in a worst case dry year, but the actual water needed in any particular year will usually be less.

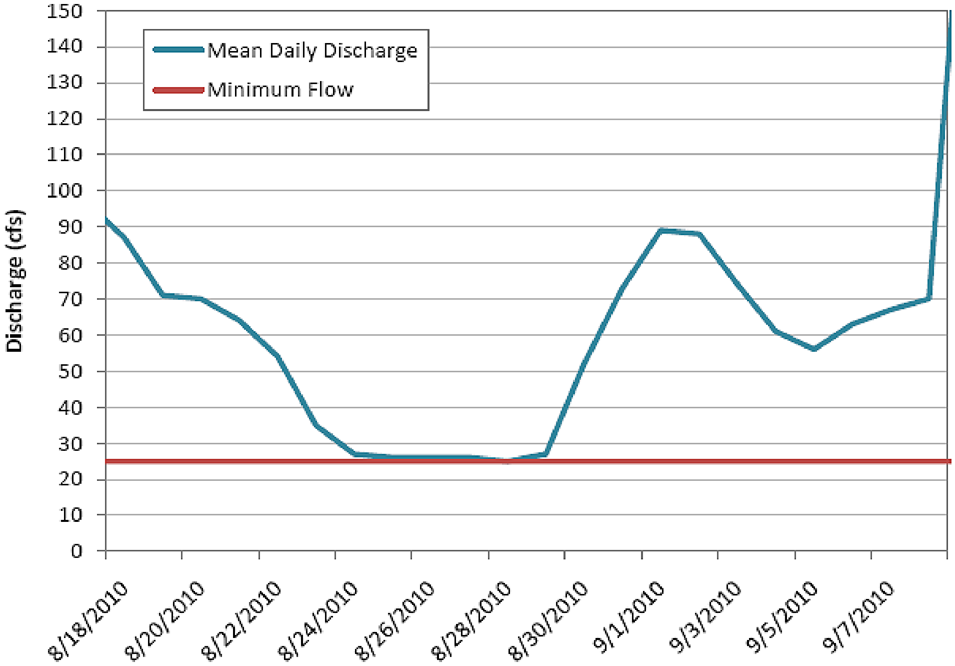
The Idaho Department of Water Resources Water Transaction Program has the ongoing responsibility of monitoring compliance with the terms of these agreements. Figures A3 and A4 show that these transactions achieved their stated purpose of maintaining a minimum flow in the lower reaches of the Lemhi River during the critical mid-May and late August time periods. At least in 2010 they avoided the dewatering that frequently caused serious damage to salmon runs in earlier years.

Figure A3: **Lemhi River mean daily flow at L5, May 1-22, 2010 during the first period of regulation.**



Source: Idaho Water Transaction Program 2010 Monitoring and Evaluation Report, page 30.

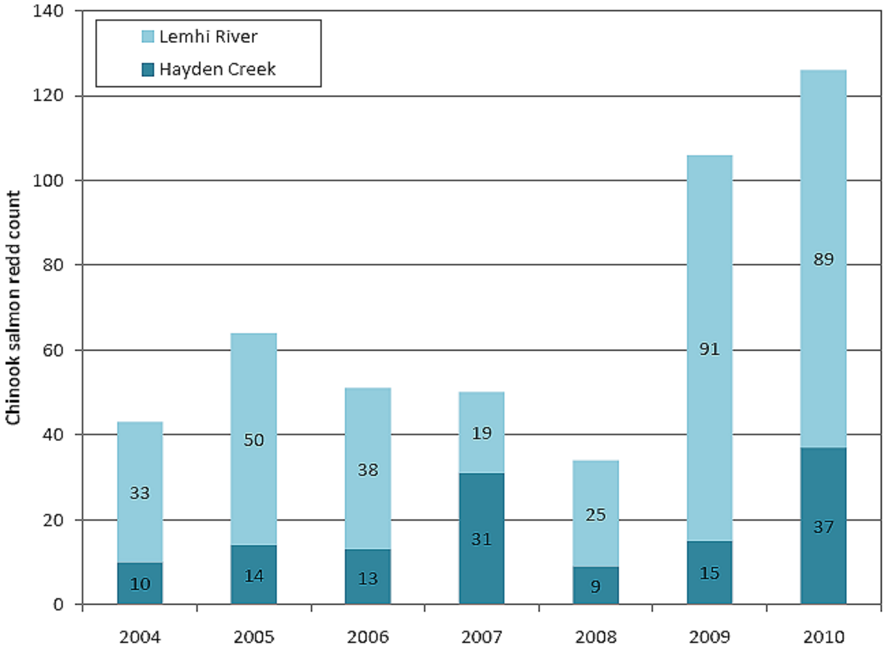
Figure A4: Lemhi River mean daily flow at L5, August 18 to September 8, 2010 during the second period of regulation.



Source: Idaho Water Transaction Program 2010 Monitoring and Evaluation Report, page 31.

More important, these transactions, along with a number of other fish-motivated actions in the upper Lemhi basin, appear to be having an effect on salmon numbers. From single digits in the mid 1990s, the number of salmon redds above the previously dewatered stream segment increased to 106 in 2009 and 126 in 2010 (see Figure A5).

Figure A5: Lemhi River and Hayden Creek Chinook salmon redds 2004-2010



Source: Idaho Water Transaction Program 2010 Monitoring and Evaluation Report, page 32.

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Appendix B: Yakima Sub-Basin

Background

The Yakima sub-basin encompasses just over 6,100 square miles. The mainstem Yakima River drains southeastward from the Cascades to the Columbia River. The basin contains a variety of aquatic habitats: the large mainstem Yakima; tributaries Cle Elum, Teanaway, and Naches rivers; and many smaller tributaries such as the Little Naches River, and Taneum and Manastash creeks. In the upper reaches there are six major reservoirs (Keechelus, Kachess, Cle Elum, Rimrock, Bumping, and Clear Lakes) which store about 1.07 million acre-feet (see Figure B1). Operation of the reservoirs has fundamentally altered the historic river hydrograph, reducing mainstem river flows in the winter and spring, and raising flows during the summer and fall. Also, the reservoirs reduce flow during flood events which has significant hydrological and biological effects. Both the historic and modified river flows vary widely among years as the sub-basin precipitation ranges widely from 7 to 100 inches per year.

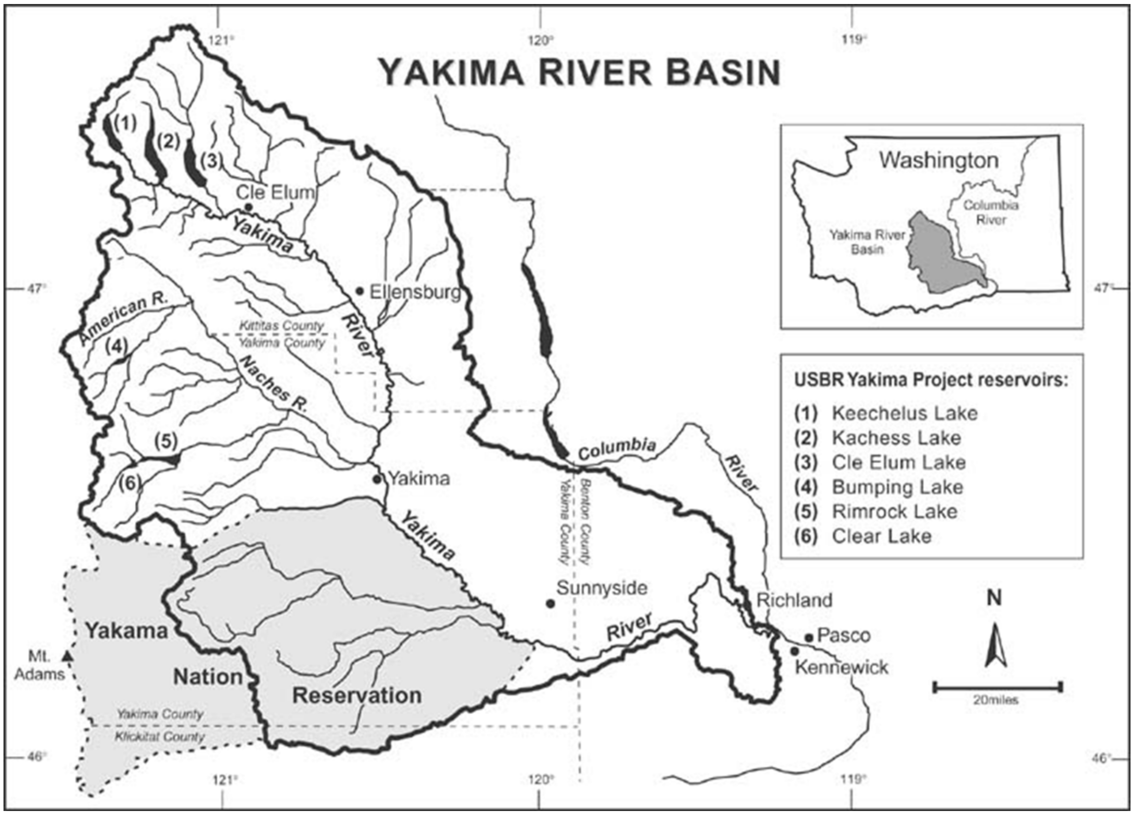
The basin's population of 81,000 is projected to increase about 45 percent by 2020, mostly expected to occur in the cities and communities along the river corridor and floodplains from the city of Cle Elum downstream to the confluence with the Columbia River. This will continue to put localized pressure on natural resources. There will be increased conversion of land and water resources to use for housing, roads, agriculture, industry, commercial development, recreation, energy, and related infrastructure, all of which will increase pressure on fish and wildlife habitat.

The Yakima Subbasin Fish and Wildlife Planning Board guided the planning process for the development of the 2004 *Yakima Subbasin Plan* (YSP). The Mission of the Board is to: "Restore sustainable and harvestable populations of salmon, steelhead, and other at-risk species through collaborative, economically sensitive efforts, combined resources, and wise resource management of the Yakima Basin."

The anadromous fish species historically migrating to the Yakima basin dropped significantly in abundance after the development of dams and irrigation water withdrawals. According to the YSP (Chap. 1 pp32-34) sockeye and summer Chinook were extirpated entirely by 2001, coho and steelhead runs were reduced by 97%, fall Chinook by 95% and spring Chinook by 92%.

The strategies adopted to protect and restore endangered anadromous species include land or water rights purchases, transfers, easements, and exchanges. Restoration strategies are used for locations where conditions limit the productivity or abundance of a focal species or focal habitat. Among the Guiding Principles enunciated in the plan is No.6 which reflects a cost effectiveness agenda. "That the costs of plan actions be estimated in relation to benefits. Alternatives that achieve the benefits relative to costs are preferred. Costs of habitat/species restoration should be mitigated and distributed equitably."

Figure B1. Yakima Sub-basin (Manastash Creek is just west of Ellensburg).



A major objective of the Sub-basin Plan for aquatic habitats is to alter the impact of irrigation withdrawals by reducing or eliminating operational spill to tributaries during migration periods, increasing irrigation efficiency, relocating or consolidating existing structures, replacing or rebuilding existing diversion dams, moving or consolidating diversions, and providing pump screens to landowners. (p.12) A Key Finding in the YSP, and associated Management Strategies, notes that altered flows of water, sediment and water temperature changes (mostly summer increases) severely reduce the quantity and quality of aquatic habitats. The Plan contains objectives to replicate basin wide temperature variability by returning the timing and quantity of river flow to a more natural state. This objective is pursued through the purchase, transfer, or lease of water rights; irrigation efficiency improvements and changes in flow management; and increased natural and artificial storage. (p.12)

The objectives of restoring riparian wetland habitat involves restoring ecologically functional floodplains and riparian wetlands by creating adequate hydrologic conditions to reconnect habitats in tributary and mainstem floodplain areas by 2015. In addition to implementing specific restoration projects, the plan calls for “purchasing water rights from willing sellers in unregulated tributaries and exploring opportunities for alterations in hydrologic management.” (p.14).

The BPA Division of Fish and Wildlife Project:
Yakima Basinwide Tributary Passage and Flow Plan (Project No. 2007-398-00) in 2010 includes elements that restore flow to various tributaries by constructing pipelines, setting up water transactions to improve flows, and other methods of improving flow for fish. For example, a project element coordinated by the Cowiche Creek Water Users Association (CCWUA) secures water from the South Fork of Cowiche Creek in the amount of 7.7 cfs and transfers the water delivery point to the Tieton

River. The additional flow will lengthen the season when fish will be able to access additional habitat which has been opened due to previous project activities such as barrier removal and screening.

A noted above in Section 2.0 “General Principles,” an improvement in irrigation efficiency does not necessarily lead to an increase in streamflow because the water saved by improved transport from river to irrigated fields may be used to expand the acreage irrigated. To address the basic objective of improving streamflow for anadromous fish, many of the irrigation efficiency improvements funded by BPA and other agencies have been connected to water transactions which withdraw the saved water diversions from the irrigated agriculture sector. Hence, the two elements are closely allied in the overall effort to improve water conditions for spawning and rearing of salmon in the tributaries.

Irrigation Efficiency Improvements

Irrigation efficiency is addressed in two primary ways: (a) replacement of earthen ditches with lined ditches or with pipelines, and (b) use of sprinklers or drip systems instead of flood irrigation. In the Yakima subbasin there have been 20 BPA funded projects that install pipelines, and 11 that install sprinkler systems during the period from 2004 through early 2011 (see Table 3.1 in the main text above). Recently initiated projects of these two types in the Yakima River Basin are listed in Table B.1 below.

Water Transactions

Water rights in the Yakima sub-basin have primary and secondary diversion rates, where the primary rate applies to diversion during January - June, while the secondary rate (1/2 of the primary quantity) applies to diversions after July 1 through December. For example, a 10 AF primary water right permits the owner to divert 10 AF in the spring, but only 5 AF during the summer. Hence, a water rights purchase for flow enhancement has an estimated primary and secondary quantity of water/yr. that is re-allocated to instream flow (acre-feet per year, AF/Y). In the discussions of water rights transactions below, the flow rates (AF/Y) are listed as the primary rates.

Purchase and lease of water rights have been important features of the Yakima sub-basin project since at least 2003. The water transactions are facilitated and documented by the Columbia Basin Water Transactions Board which lists 37 such transactions in the Yakima sub-basin during 2003-2010, 26 in the Teanaway tributary, 6 in Manastash Creek, 3 in the Naches tributary (which includes Cowiche Creek), 2 in Taneum Creek. Twenty-seven of these were water right leases ranging from 1 to 15 years in duration (mostly 1 to 5 years) for water used in agricultural irrigation. Details of these lease transactions are displayed in Table B1. Ten were permanent transactions, including direct purchase of water rights, and donation or purchase of agricultural land with appurtenant water rights, displayed in Table B2. And many of the water rights transactions were tied to construction of water-saving infrastructure (e.g. lining irrigation diversion canals) or other irrigation efficiency projects.

Table B1. Some Recent Irrigation Efficiency Improvement Projects

Work Element Title	Work Start	Work End	Work Progress	Effective WE Budget
Pipeline installations				
C: Cooke/Rock/ Forbes Pipeline	10/15/2007	9/30/2009	Completed	$87,434
F: Eslinger/Sorenson Parke Creek pipeline	10/2/2006	11/24/2006	Completed	$34,764
AE: Construct Toppenish Ridge West Pipeline	10/1/2005	9/30/2006	Completed	$14,000
Sorenson Piping	10/1/2004	9/19/2005	Completed	$50,000
H: MWDA pipeline - MWDA Diversion to KRD lateral 13.8	11/15/2009	11/14/2011	In Progress	$52,602
J: Cowiche Creek Water Users Association (CCWUA)	4/1/2009	3/31/2010	In Progress	$24,500
G: Fagalde/Wilson pipelin	4/2/2007	3/28/2008	In Progress	$20,260
X: Cowiche Creek Water Users	4/2/2007	3/28/2008	In Progress	$30,000
H: Cowiche Creek Water Users Association (CCWUA)	4/1/2010	3/31/2011	Other	$31,000
F: Cowiche Creek Water Users Association (CCWUA)	4/1/2011	11/28/2011	Planned	$34,500
AA: Ahtanum Ridge-- Install Stockwater Pipeline	5/30/2007	7/30/2007	Other	$0
AD: Construct Toppenish Ridge Pipeline	10/1/2005	9/30/2006	Other	$12,000
Sprinkler Projects				
N: Gregerich Sprinkler Conversion	9/15/2008	9/30/2009	Completed	$292,706
E: Anderville Sprinkler Conversion	11/15/2009	11/14/2011	In Progress	$45,000
F: Dyk Sprinkler Conversion	11/1/2010	1/14/2011	In Progress	$104,846
P: Mellergaard Sprinkler Conversion	11/1/2010	1/14/2011	In Progress	$65,000

The short-term water leases involved a total of 8,176 acre-feet (AF) of irrigation water, with a total transaction cost of $487,000. If we divide the transaction cost by the number of acre-feet per year (AF/Y) acquired (which equals the transaction's annual AF/Y times the term of the transaction in years), we get a simple average cost per AF/Y. Across transactions, this cost ranges from $0 (for donated water) to $44.45 for a 15-year lease on the Teanaway River. Summed over 27 leases, we get an average cost per AF/Y of $21.28. Since the up-front cost of each lease is expected to equal the discounted present value of the future water diversions given up by the seller, we may prefer to express the cost in terms of the un-discounted cost of a year's purchase per AF. This would give us a comparable measure of cost per AF/Y across all lease terms. This "undiscounted Cost per AF/Y" for the temporary water leases ranged from $0 to $61.17, with an average of $24.61 per AF/Y.

The ten permanent projects involve an increased streamflow of 7,437 AF and an overall cost of $2,423,914 (Table B2). The ten permanent water rights transactions involve a larger cost overall due to the number of years involved, which yields the much larger number of AF/Ys. Computing the simple average cost per AF/Y as described above (using 100 as the number of years), we get a cost per AF/Y that ranges from $1.79 to $14.29 over the 10 transactions, and averages $3.26. Again, assuming the up-front cost of purchasing a permanent water right represents the discounted present value of the water over 100 years, the "Undiscounted Cost per AF/Y" for the permanent water rights ranges from $7.24 to $69.58 per AF/Y, with an overall average of $15.64 per AF/Y.

These rough, first-cut calculations of costs for water for streamflow enhancement provide some means of comparing the cost-effectiveness of various projects that may be considered for streamflow enhancement in the Yakima basin.

Because the many sub-basins in the Yakima basin have streamflow management projects in various stages of development, this report will focus on a creek – the Manastash -- that is nearing completion of a long-term enhancement project.

Table B2. Temporary Water Leases in the Yakima River Basin during 2003-2010.

WTP Transaction Name	Term Yrs.	Acre-Feet Acquired[1]	Total Water Cost	Simple Annual Cost per AF/Y	Un-Discounted Cost/Year[2]	Un-Discounted Cost per AF/Y
WWT Teanaway River No. 2	5	426.00	$38,710	$18.17	$8,941	$20.99
WWT Teanaway River No. 1	1	172.50	$0	$0.00	$0.00	$0.00
Teanaway River No. 3	1	53.90	$1,215	$22.55	$1,215	$22.55
Teanaway River No. 5	3	149.64	$9,940	$22.14	$3,476	$23.23
Teanaway River No. 12	5	32.85	$2,269	$13.82	$499	$15.20
Chap/Bark Teanaway River No. 1	1	55.00	$1,240	$22.55	$1,240	$22.55
Teanaway River No. 9	1	99.00	$2,232	$22.55	$2,232	$22.55
Teanaway River No. 10	1	55.00	$1,240	$22.55	$1,240	$22.55
Teanaway River No. 4	3	48.90	$2,916	$19.88	$1,019	$20.85
Teanaway River No. 6	1	271.60	$5,400	$19.88	$5,400	$19.88
Teanaway River No. 7	3	61.60	$3,564	$19.29	$1,246	$20.23
Tom Conner	1	575.00	$8,000	$13.91	$8,000	$13.91
WWT Teanaway River No. 2	15	64.66	$43,110	$44.45	$3,955	$61.17
WWT Teanaway River No.3.9.10.12.13	5	363.55	$46,270	$25.45	$10,178	$28.00
WWT Teanaway River No. 14	30	394.69	$46,750	$3.95	$2,896	$7.34
Teanaway No. 15	5	76.40	$9,000	$23.56	$1,979	$25.91
WWT TeanawayNo.2 - 2006	15	147.19	$65,356	$29.60	$5,996	$40.74

Table B2. continued

WTP Transaction Name	Term Yrs.	Acre-Feet Acquired[1]	Total Water Cost	Simple Annual Cost per AF/Y	Un-Discounted Cost/Year[2]	Un-Discounted Cost per AF/Y
Teanaway River No. 5	4	149.64	$14,963	$25.00	$4,018	$26.86
WWT Teanaway No.4 - 2006	2	49.00	$1,994	$20.35	$1,021	$20.84
WWT Teanaway River No.7 & 6	7	339.47	$53,282	$22.42	$8,769	$25.83
TeanawayRvr No.1 - 2009 split	1	52.82	$1,330	$25.19	$1,330	$25.19
WWT Cowiche No.4	5	170.00	$0	$0.00	$0.00	$0.00
WWT Teanaway River No. 16 - 2009	3	13.69	$1,000	$24.34	$349	$25.54
WWT Teanaway River No. 17 - 2009	3	19.16	$1,403	$24.41	$490	$25.60
WWT-Teanaway No.18	1	1,997.00	$42,865	$21.46	$42,864	$21.46
WWT - Teanaway No. 18 - 2010	1	1,959.32	$71,205	$36.34	$71,205	$36.34
WWT Teanaway No. 21 - 2010	1	378.37	$11,670	$30.84	$11,670	$30.84
Totals		8,175.95	$486,925	$21.28	$201,236	$24.61

[1] "Acre-feet" acquired includes acre feet of water listed as "Annual Duty" and as "Secondary Duty"; 78% of the total was annual duty.

[2] We assume that the total cost is equivalent to the annual costs discounted to the present at 5% per year. The undiscounted cost per year is calculated by dividing the Total Water Cost by the discounted value of a dollar per year over the term of the lease. The equation for this is sum of $[1/(1+.05)]^y$ over n years, where y runs from 1 to n, and n is the "Term Yrs" listed in the table. Then this adjusted annual cost is divided by the acre-feet acquired.

Table B3. Permanent Water Rights Transfers in the Yakima River Basin.

WTP Transaction Name	Acre-Feet Acquired	Total Cost	Simple Annual Cost per AF	Un-Discounted Cost per Year	Un-Discounted Cost per AF/Y
WWT Naches River No. 1	167.92	$30,000	$1.79	$1,439	$8.57
WWT Taneum Creek No. 1-2005	5,427.00	$830,316	$1.53	$39,841	$7.34
WWT Cowiche Creek No.1 - 2006	225.60	$61,600	$2.73	$2,955	$13.10
Manastash Auction-English/Repsher	15.00	$20,505	$13.67	$983	$65.59
Manastash Auction-Allen	32.00	$43,744	$13.67	$2,099	$65.59
Manastash Auction-Miller	26.00	$35,542	$13.67	$1,705	$65.59
Manastash Auction-Graf	20.00	$27,340	$13.67	$1,311	$65.59
Manastash Auction-High Valley	844.23	$844,230	$10.00	$40,509	$47.98
Manastash - Gregerich	254.80	$364,192	$14.29	$17,475	$68.58
WWT Taneum Creek No. 3 - 2010	424.72	$166,445	$3.92	$7,986	$18.80
Totals	7,437.27	$2,423,914	$3.26	$116,308	$15.64

[1] Acre-feet Acquired includes acre feet of water listed as “Annual Duty” and as “Secondary Duty”; 97% of the total was annual duty.

[2] We assume that the total cost is equivalent to the annual costs discounted to the present at 5% per year. Then the undiscounted annual cost is calculated by dividing the Total Water Cost by the discounted value of a dollar per year over 100 years.. The undiscounted value of a dollar per year is the sum over 100 years of $[1/(1+.05)]^y$, where y runs from 1 to 100, which yields a value of $20.84.

The Manastash Creek watershed

The Manastash Steering Committee was formed in 2001 consisting of representatives of the Manastash Water Ditch Association (MWDA), individual irrigators from Keach Ditch, Jensen Ditch, Hatfield Ditch, Reed Ditch, Anderson Diversion, and Barnes Road Diversion, as well as Washington Department of Ecology (WDOE), Washington Department of Fish and Wildlife (WDFW), Washington Environmental Council, West Side Irrigating Company, Kittitas County Reclamation District (KCCD), US Bureau of Reclamation (BOR), and Yakama Nation.

In 2003 the Washington State Legislature appropriated $2.24 million for construction of fish screens and fish passage at Manastash Creek diversions and the Bonneville Power Administration awarded $1.4 million to the Manastash Project. These funds were provided to construct fish screen and fish passage facilities. The strategy for improving streamflow underwent a number of changes between 2003 and 2006,. Initially, the Anderson, Reed, Hatfield, and Keach-Jensen diversions were to be consolidated at the MWDA diversion site. That plan was abandoned in 2005 and the subject diversions were simply to have fish screens installed at their current locations. The consolidation plan was then modified and revived in early 2006. The current plan includes consolidating three diversions, those for the Reed Ditch, Anderson Diversion and Hatfield Ditch, to the MWDA diversion site. The Keach-Jensen and Barnes Road diversions will be screened at their present locations. KCCD is still planning to remove a concrete structure on the lower creek and to make changes to the Barnes road diversion.

The KCCD worked with the water right owners in 2006 on the Hatfield Ditch, Reed Ditch and Anderson diversions and Department of Ecology to complete applications to change their points of diversion to the MWDA diversion. Twenty eight applications were received by Ecology in August and September, 2006. Public notice of the change applications was published in the Ellensburg Daily Record on February 5, 2007 and February 12, 2007. Letters describing the proposed changes were sent by Ecology to each of the individual water right owners in early February 2006. No protests were received during the public comment period.

Also in 2006, at the direction of the Steering committee, the KCCD applied for a continuation of BPA funds ($1.5 million) to complete the fish screen and fish passage projects. KCCD also applied for additional BPA funds ($893,000) to begin addressing instream flow. BPA funded both proposals in the 2009-2011 Fish and Wildlife Program.

Currently the project has installed 18 to 20 flow monitors on the creeks and they have constructed the new diversion structure for the three ditches. The pipelines from the consolidated diversion point to the three irrigation lands have not been built since the easements across properties between the ditches and the diversion point must be completed first. There are some absentee landlords who have water rights at existing diversion points who have not yet signed the agreement to shift to the consolidated diversion point. Once the easements are fully signed, the pipelines are scheduled to be completed in the fall/winter of 2011.

Further, BPA funds budgeted for sprinkler conversions have been used to complete conversion to water-saving sprinkler systems and the final one is under construction.

Water rights are being purchased to augment instream flow during the low flow summer period . Working with the Washington Rivers Conservancy (Trout Unlimited), KCCD performed a reverse auction to purchase 3 cfs in water rights. A reduction of 4.7 cfs from the conversion of flood irrigation to sprinklers was expected. Overall, the project has 10 cfs of water rights which will be used for enhancing streamflow with plans to expand this to about 20 cfs.

The effort to re-establish steelhead in the upper Manastash Ccreek through improved summer flows seems to be well underway. But these efforts still need to (1) obtain sufficient water rights to assure the desired summer flow, (2) obtain necessary easements and construct the pipelines from the new consolidated diversion site to the irrigated lands, and (3) monitor the numbers of fish using the improved creek.

Summary

The stream flow and habitat restoration efforts in the Yakima sub-basin are well into the execution stage. But there is little information available about the direct effects that these efforts will have on the key anadromous fish populations: steelhead, sockeye, coho and Chinook salmon. To complete a more quantitative analysis of project cost-effectiveness, reckoned as adult population size increase per unit expenditure, will require expansion of the project to involve specific research aimed at quantifying the likely impacts of the projects adopted in the Yakima sub-basin on the fish population which is migrating there.

References

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Appendix C: Salmon Creek

Background

Salmon Creek is a tributary of the Okanogan River in the Columbia Cascade Province of north central Washington. Salmon Creek has been recognized for its outstanding spawning habitat potential for steelhead trout and spring run Chinook salmon for decades. The historic runs were eliminated by irrigation development including Conconully Reservoir dam, built in 1905, and an additional dam at Salmon Lake. In most years, the entire flow of Salmon Creek was diverted for irrigation leaving no flow in the lower 4 mile reach for fish to reach 14 miles of quality spawning grounds above Salmon Lake. In dry years, a 24 cfs diversion from the Okanogan River can be used to augment irrigation supplies for Okanogan Irrigation District (OID).

A plan to restore flow and fish runs was developed in the early 2000s. The Proposed Project included (1) improved water control, (2) on-farm efficiency to reduce irrigation water use, (3) a new pump station on the Okanogan River, (4) increased storage capacity in Salmon Lake, and (5) temporary utilization of a water bank until the other project elements could be implemented. This plan would have relied primarily on an exchange of water supply from the Okanogan River to leave water in Salmon Creek. In addition, changes to the stream channel were proposed to utilize the available water for flow most effectively and to improve conditions for up-migrants.

The IEAB (2001) reported on this plan and found that

> Water acquisition might be used to reduce costs of Salmon Creek restoration by reducing water use and allowing the saved water to remain in Salmon Creek. In summary, a long run strategy of improving efficiency of water use and increasing streamflow for fish might include a significant effort to relax the current restrictions on marketing of water within watersheds like Salmon Creek.

Water Transactions and Irrigation Efficiency

Currently the plan for Salmon Creek has changed to one based on water transactions (McCloughlin, 2011). Annual transactions were completed each year for three years beginning in 2007. The Washington Water Trust is currently committed to a cost of $777,600 for 1,200 acre-feet per year (AF/Y) for the period 2010 to 2018 at a cost of $91.17 per AF. The average cost of all past and planned transactions for water received through 2011 is $78.27(Table 3.3). Funds from the 9-year transfer will be applied toward a permanent acquisition, if there is one. No price has yet been established. Essentially, decisions on how to provide the water are left to OID. Most water is being provided by conservation, re-regulation of stored water and installation of high-efficiency laterals. Work to improve the stream channel has been completed and initial indications are that steelhead trout are spawning successfully.

The costs of the original plan can be compared to the water transaction plan. The costs of the original plan from the 2001 IEAB report were updated to 2010 dollars using the GNP implicit price deflator. Table C1 shows results.

Table C1. Costs of 2001 Salmon Creek Plan Compared to Current Transaction Cost

Original Plan Component	Annual AF	$2001/AF NPV	$2010/AF NPV
District-Wide Ag. Water Conservation	593	$717	$884
Okanogan River Water Exchange	7,234	$2,018	$2,490
On-farm Water Management	1,153	$627	$774
Interim OID Water Bank [4.]	1,585	$538	$664
Raise Salmon L. Dam & Feeder Canal	236	$12,628	$15,584
TOTAL not including interim water [5.]	10,801	$2,032	$2,507
2010-2018 Transaction Cost			
WWT Salmon Cr Lease #1 2010-2018	1,200		$1,804

The average cost of water in the original plan was $2,507 per AF for 50 years, or $137 per AF ($2,507, 50 years, 5 percent), as compared to $1,804 under a 50-year water lease paying $91.17 per AF (the present value of $91.17 for 50 years, 5 percent, is $1,804). However, the original plan would have provided 10,801 AF/Y as compared to 1,200 under the water transaction. If OID were asked to provide 10,000 AF/Y the average cost required to provide the water might be more. Also, it is not clear to what extent the threat of endangered species laws enforcement may have influenced the agreement. However, it is clear that the water transaction plus the streambed improvements have combined to allow restoration of steelhead at a much lower cost than originally contemplated.

It is not clear that the existing water transaction can continue indefinitely. Lakefront property owners have complained. The transaction would allow flow to decrease if upstream storage falls below limits (5,000 AF) provided in the arrangement, but endangered species compliance might still require the flow.

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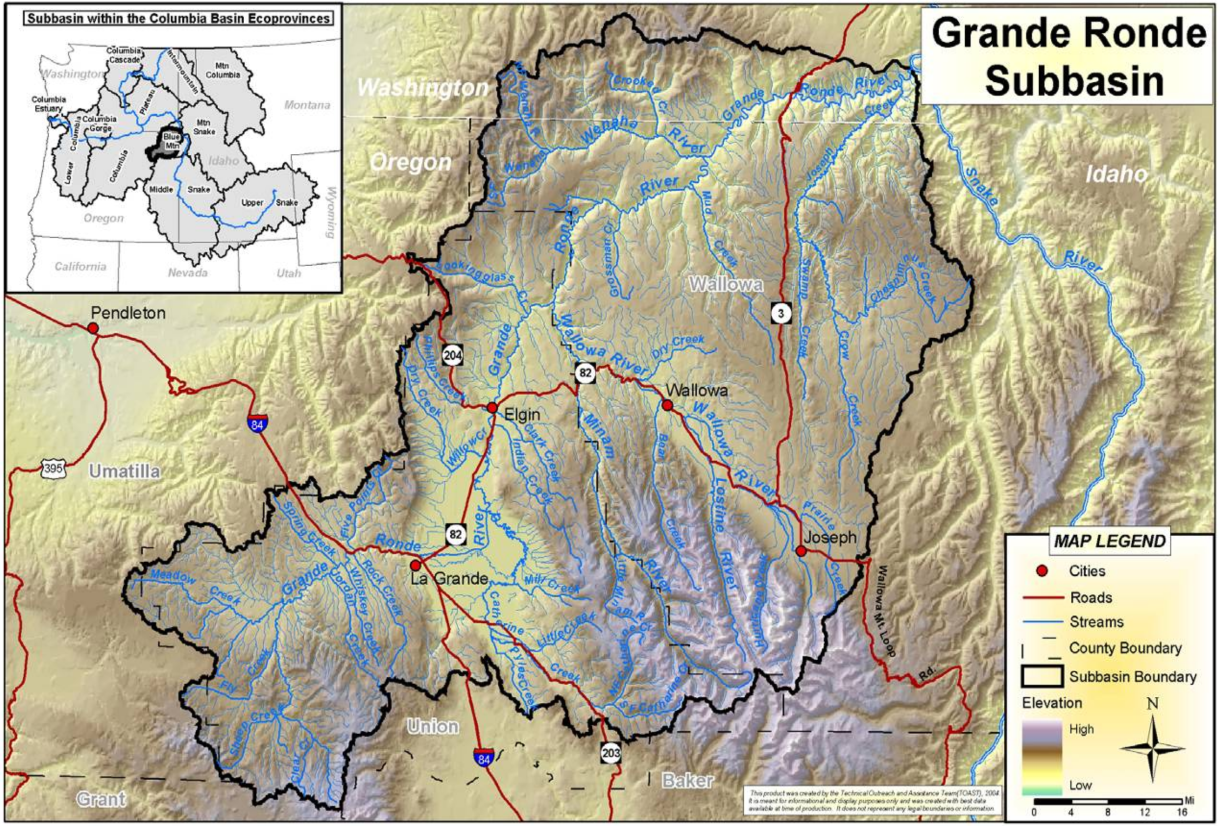
Appendix D: The Upper Grande Ronde Basin

Background

The Grande Ronde River basin is a tributary of the Snake River located in northeastern Oregon (Figure 1). The study basin is the upper portion of the Grande Ronde River basin and Drains approximately 1,650 square miles and contains 917 miles of streams (221 miles of salmon habitat) (Northwest Power and Conservation Council, 2004). Elevations in the watershed range from 2,312 ft. at the confluence of the Grande Ronde and Wallowa Rivers to over 7,000 ft. in the headwater areas. The climate is transitional, sharing characteristics of the moist Mediterranean climate to the west and the dry interior mountain climate to the east. Most precipitation falls as snow with peak stream discharge generally occurring March to May. Summer maximum air temperatures exceed 30^{o} C and winter minimum air temperatures fall below -5^{o} C. Most segments of the upper basin violate the maximum water temperature standard and are subject to Total Maximum Daily Load (TMDL) regulations (ODEQ, 2000).

Figure D1: The Grande Ronde River Basin



Source: Northwest Power and Conservation Council (2004)

The Grande Ronde River Basin is sparsely populated with a total population of 24,484, and12 persons per square mile in Union County in 2002 (Northwest Power and Conservation Council, 2004). The economy in the Basin is heavily dependent on agriculture and timber resources. Major crops in Union

County include wheat, hay and forage, grass and legume seeds, peppermint, potatoes and specialty crops such as canola. Livestock production accounts for nearly 40 percent of the gross farm income.

There were 351 irrigated farms in 2007 in Union county according to the 2007 Census of Agriculture. These farmers had a total of 242,361 acres of land of which 63,266 acres were irrigated in 2007. About 54% of the irrigated farms in the Union county had less than 70 acres of irrigated land in 2007, but there were 35 farms that irrigated 2,000 acres or more. According to the 2007 Farm and Ranch Irrigation Survey, the surveyed farmers in the Union county applied 1.41 AF/ac, with a pump cost of $35.29/AF/ac, a maintenance cost of $8.55/AF/ac, and a fixed cost of $63.15 per irrigated acre. About 61 percent of Oregon's irrigated lands used sprinkler systems to deliver water, most of the remaining irrigated land used gravity flow systems. Although there had been little change in the use of both sprinkler and gravity systems, the use of drip, trickle, or low-flow micro-sprinklers has increased by 500% since 2003, the year when the last irrigation survey was conducted. However, these more precise application systems still remain a small proportion of the irrigated land.

The Grande Ronde River basin is an important spawning and rearing habitat for spring/summer Chinook salmon (Oncorhynchus tshawytscha) and steelhead (O. mykiss), species listed as “threatened” under the ESA. Chinook salmon escapement in the Grande Ronde River basin dropped from an estimated 12,000 in 1957 to 400 in 1992 (West and Zakel, cited by Grande Ronde Model Watershed Program). Adult spring and summer Chinook salmon migrate into freshwater from late winter to early summer, usually to the streams in which they were reared, and spawn in late summer or early fall, usually in the headwaters of streams and rivers. One of the primary causes for the decline in salmon populations associated with habitat degradation is elevated water temperatures in juvenile salmonid habitat and rearing areas. Water temperatures significantly affect the distribution, health, and survival of native salmonids in the Pacific Northwest (USEPA). For this reason, water temperature is treated as a “pollutant” and regulated under EPA’s Total Maximum Daily Load (TMDL) criteria. Water temperatures in summer and early fall frequently exceed sub-lethal levels in the PNW (Oregon Department of Environmental Quality 2000).

The two primary reasons for elevated water temperatures in the PNW are a decrease in discharge resulting from water diversions for agricultural uses and the deterioration in riparian conditions. The latter decreases the shade along a stream, increasing the amount of solar radiation received by the stream surface. The reduction in discharge (flow), due primarily to irrigation diversions, results in larger water temperature increases when that water volume receives the same amount of solar radiation.

Water Transactions and Irrigation Efficiency

Table 2 provides a summary of the CBWTP water transactions in the Grande Ronde River Basin. The Columbia Basin Water Transaction Program had a total of nine water transactions in the Grande Ronde River Basin from 2004 to 2009. Except for the Carlsen Water Right Purchase in 2008, the rest of the projects are either minimum flow agreements or instream water leases. The timing of increased flow is during summer months, three from June 1 to September 30, four from August 22 to September 30, and one from May 1 to September 30. For the temporary leases or agreements, the primary annual cost of water ranged from $26.42/AF to $138.05/AF. The cost of the Carlsen water rights purchase, based on 5 percent interest per year, was $13.89 per AF. Because only about 20% of the cost for the Carlsen water right purchase was paid by CBWTP, the annual cost to the CBWTP was only $2.78/AF. From Table 3.3 the average cost in 2010 dollars per AF of water acquired and used through 2011 was $92.43, the highest of any subbasin.

Table 2. Summary of the CBWTP Water Transaction Projects in the Grande Ronde River Basin

Funded FY	2009	2008	2008	2007	2007	2006	2005	2005	2004
Transaction name	Lostine 3 Year Minimum Flow Agreement	Carlsen Water Right Purchase	Lostine Minimum Flow Agreement	Birkmaier Lease	Lostine Forebearance Agreement	Lostine Forebearance Agreement	Carlsen Lease	Upper Lostine Forebearance Agreement	Birkmaier Lease
Proposing Entity:	The Freshwater Trust	The Freshwater Trust	The Freshwater Trust	The Freshwater Trust	The Freshwater Trust	The Freshwater Trust	The Freshwater Trust	The Freshwate Trust	The Freshwater Trust
Stream Names:	Lostine River	Lostine River	Lostine River	Joseph Creek, Chesnimnus Creek, Cow Creek, Elk Creek	Lostine River	Lostine River	Lostine River	Lostine River	Joseph Creek, Chesnimus Creek, Crow Creek, Elk Creek
Term (Years in effect):	3	Permanent	1	5	1	1	3	1	2
WATER COSTS:									
Total Water Cost:	$492,000.00	$137,520.00	$164,000.00	$30,000.00	$148,010.01	$180,000.00	$27,000.00	$184,425.00	$10,271.83
Total Water Cost From CBWTP:	$492,000.00	$27,000.00	$164,000.00	$30,000.00	$148,010.01	$180,000.00	$22,950.00	$180,000.00	$10,271.83
FLOW IMPROVEMENT:									
Primary Rate (cfs):	15	2.22	15	0.81	20	15	2.15	15	0.81
Secondary Rate (cfs):	15	0	15	0	20	15	0	15	0
Primary Annual Volume (AF):	1188	495	1814.88	197.7	1814.88	1814.88	360	1814.88	194.4
Secondary Annual Volume (AF):	1188	0	1814.88	0	1814.88	1814.88	0	1814.88	0
Timing of Increased Flow:	08/22 - 09/30	05/01 - 09/30	08/22 - 09/30	06/07 - 09/30	08/22 - 09/30	08/01 - 09/30	06/01 - 10/01	08/01 - 09/30	06/01 - 09/30
Primary $/Per AF Annually:	$138.05	$2.78	$90.36	$30.35	$81.55	$99.18	$25.00	$101.62	$26.42
Secondary $/Per AF Annually:	$138.05	$0.00	$90.36	$0.00	$81.55	$99.18	$0.00	$101.62	$0.00

References:

1. Grande Ronde Model Watershed Program. Draft Operations – Action Plan. La Grande, OR: Grande Ronde Model Watershed Program. 1994.

2. Northwest Power and Conservation Council. Grande Ronde Subbasin Plan. May 28, 2004. (Lead Writer M. Cathy Nowak, Cat Tracks Wildlife Consulting).

3. Oregon Department of Environmental Quality. Upper Grande Ronde River Sub-Basin Total Maximum Daily Load (TMDL). Oregon Department of Environmental Quality. Salem, OR, 2000.

4. USEPA. EPA Region 10 Guidance For Pacific Northwest State and Tribal Temperature Water Quality Standards. Available online at http://yosemite.epa.gov/R10/water.nsf/6cb1a1df2c49e4968825688200712cb7/b3f932e58e2f3b9488256d16007d3bca/$FILE/TempGuidanceEPAFinal.pdf

Appendix E: Walla Walla Basin

Background

The Walla Walla Subbasin represents 1,758 square miles of land located primarily in Walla Walla and Columbia Counties in Washington State and parts of Umatilla, Union and Wallowa Counties in Oregon (NWPCC 2004). The main watercourses are the Walla Walla River and the Touchet River, both of which originate in the Blue Mountains. The Touchet River is a tributary to the Walla Walla which itself is a direct tributary to the Columbia River. About 73 percent of the drainage area lies in Washington. Melting snow from the Blue Mountains provides much of the annual runoff to the streams and rivers in the subbasin; the water level in many streams diminishes greatly during the summer months. (See Figure E1.)

Elevations in the subbasin range from 1,800 meters in the southeast to 80 meters at the Columbia River on the western edge of the basin. Temperatures exhibit large seasonal variation with maximum temperatures above 100° (F) in summer to -18° (F) in winter. Precipitation falls mainly in winter from October to March.

Vegetation in the subbasin is characterized by grassland, shrub-steppe, and agricultural lands at lower elevations and evergreen forests at higher elevations (NWPCC 2004). The Walla Walla Subbasin is a highly productive agricultural region with dryland agriculture throughout the subbasin and intensive irrigated cropland in the Walla Walla River valley. Timber harvest and urban land use are also significant. Approximately 90 percent of the subbasin is privately owned with 9 percent managed by federal/state agencies. The Confederated Tribes of the Umatilla Indian Reservation also owns approximately 8,700 acres within the subbasin (NWPCC 2004).

The economy of the Walla Walla Basin includes the city of Walla Walla (population 31,000) and Milton-Freewater (population 6,685). The economy of the area has grown moderately in the past decade. The work force of Walla Walla County has grown at a 1.5% rate and real income per capita has grown at about a 1% annual rate. Agriculture is an important sector in the basin, although its direct contribution to employment and earnings is less than 10% in both Walla Walla and Umatilla Counties. The largest employers and sources of income are manufacturing and government employment.

The agricultural economy is dominated by wheat and grapes, with the wine industry growing significantly in the past 20 years. Fruits, onions and other vegetables are also important. Land in farms has declined slightly in recent years. The gross value of farm production has averaged $340 million in recent years for Walla Walla County; $320 million in Umatilla County.

There are two primary drainage areas within the Walla Walla Subbasin, the Walla Walla River and the Touchet River. The Touchet River drains into the lower Walla Walla River which subsequently drains into the Columbia River. Tributaries to the Touchet River include the North Fork Touchet, South Fork Touchet, Robinson Creek, Wolf Fork, and Coppei Creek. Primary tributaries to the Walla Walla River include the South Fork Walla Walla, North Fork Walla Walla, Couse Creek, Dry Creek, Pine Creek and the Mill Creek system (NWPCC 2004). The Mill Creek system originates in Washington, dips into Oregon, and then returns to Washington where it passes through the City of Walla Walla and joins the Walla Walla River.

Because of the irrigation diversions serving irrigation districts in the area, especially in and around Milton-Freewater and west and north of Milton-Freewater (see Figure 2), segments of the Walla Walla and its tributaries have become essentially “de-watered” for significant periods during summer months. For example, Table 1 indicates that the North Fork of the Walla Walla River is reduced to 4 cfs in August and Dry Creek is reduced to 1 cfs. These summer flows represent significant barriers to fish passage and survival.

These and other pressures have resulted in two primary aquatic species being listed as threatened under the ESA: steelhead and bull trout. Although listed at the larger ESU scale, spring Chinook are no longer present in the Walla Walla Subbasin.

Limited instream flow is a recurring seasonal issue in several reaches of the Walla Walla basin. BPA funded projects and projects undertaken by the Walla Walla Basin Watershed Council (WWBWC) have addressed these issues with either water transaction projects or irrigation efficiency projects. The WWBWC has undertaken 21 irrigation efficiency projects over the past decade. These include piping and lining projects as well as on-farm irrigation efficiency projects. Many of the WWBWC projects have been funded via BPA and the CBWTP, but also from Oregon Watershed Enhancement Board and the Washington Salmon Recovery Funding Board. Summary information on these 21 projects are provided in Table 2. The location of many of these projects in and around Milton-Freewater are shown in Figure E3.

One of the complicating factors for these kinds of projects in this area is that piping and canal lining projects have led to a significant drop in groundwater levels which have harmed groundwater users and spring fed flow. As a result, WWBWC has been implementing groundwater recharge projects. This has been accomplished in several ways including passive recharge (filling canals with water in winter months) as well as with infiltration basins (shallow ponds that are filled in winter to cause seepage into the shallow aquifer). These activities have been successful in offsetting the effects of irrigation efficiency improvements.

The 21 projects identified have so far been estimated to have increased instream flows by 34.6 cfs, or 8,200 acre-feet when assuming a 120 day period of increased flows. Based on available information, the cost per acre-foot for the completed projects ranges from \$5 to \$37, with a median of \$23. These figures are computed by assuming a permanent increase in instream flows and converting the upfront costs to an annual payment, or perpetuity, using a 5% discount rate. For comparison, four transactions projects in the same basin for which permanent water rights were transferred to instream flow had a median annualized cost of \$26 per acre-foot.

Additional details on other WWBWC projects can be found online with other funding agencies such as the Oregon Watershed Enhancement Board or the Salmon Recovery Funding Board (Washington State). The WWBWC has some projects which predate the Pisces database (2002). The Pisces database lists 7 projects of this kind that were started and/or completed since 2004 for piping and 4 additional projects involving on-farm sprinkler installation (a separate accounting of these lists 9 for each of these two types of projects).

Although there appears to be considerable success with these irrigation efficiency projects in this basin, it is unclear whether large numbers of additional projects would have similar success in the future. The most obvious opportunities for potential benefits from piping and other irrigation efficiency improvements may have been identified and implemented (Wolcott, 2011).

The results of these efforts, nevertheless, appear to have benefited fish significantly. The previously dewatered section of the mainstem Walla Walla is no longer dry during summer months.

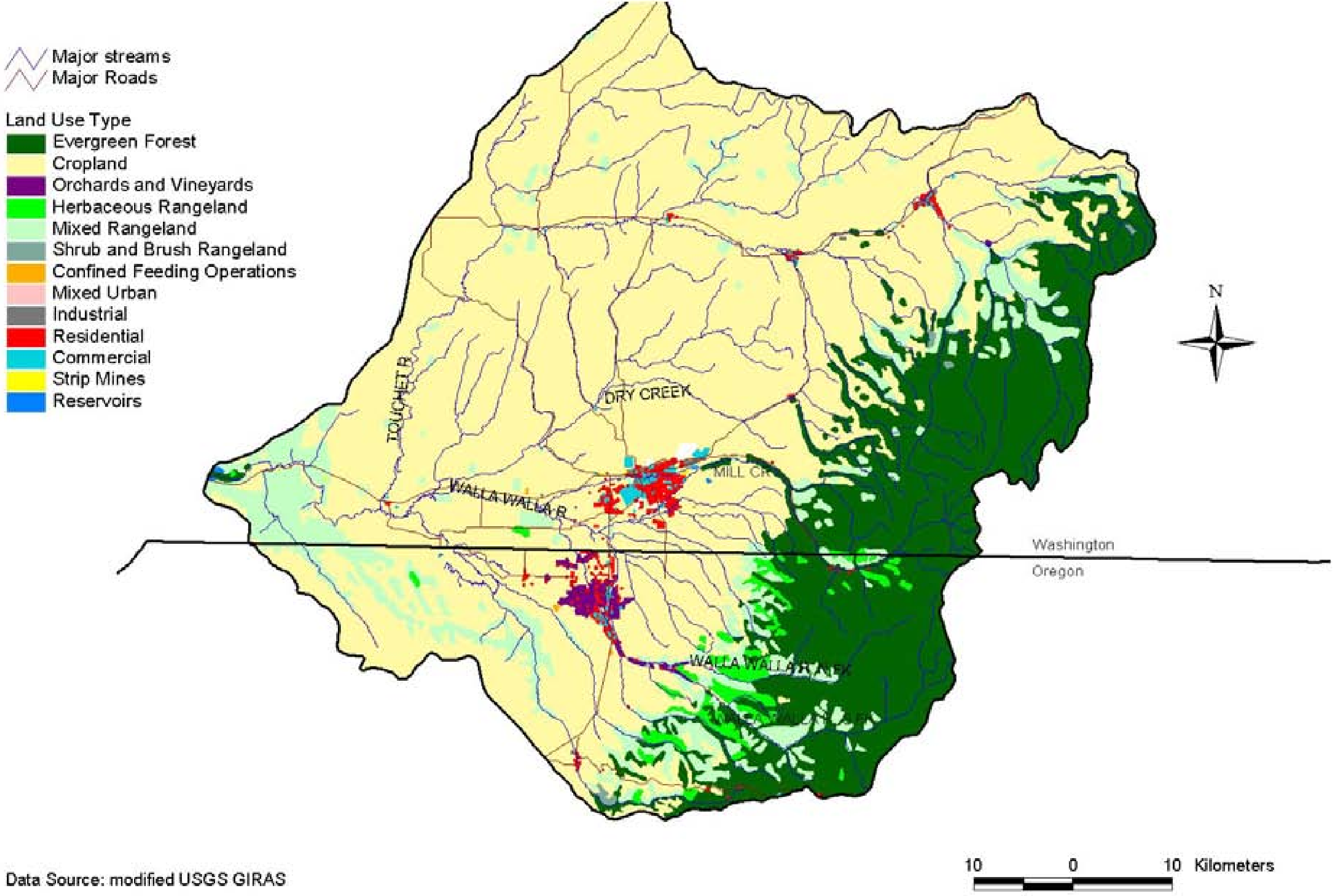
References:

1. Walla Walla Basin Watershed Council website.http://www.wwbwc.org/

2. Wolcott, Brian, Executive Director, Walla Walla Basin Watershed Council, personal communication, March 15, 2011.

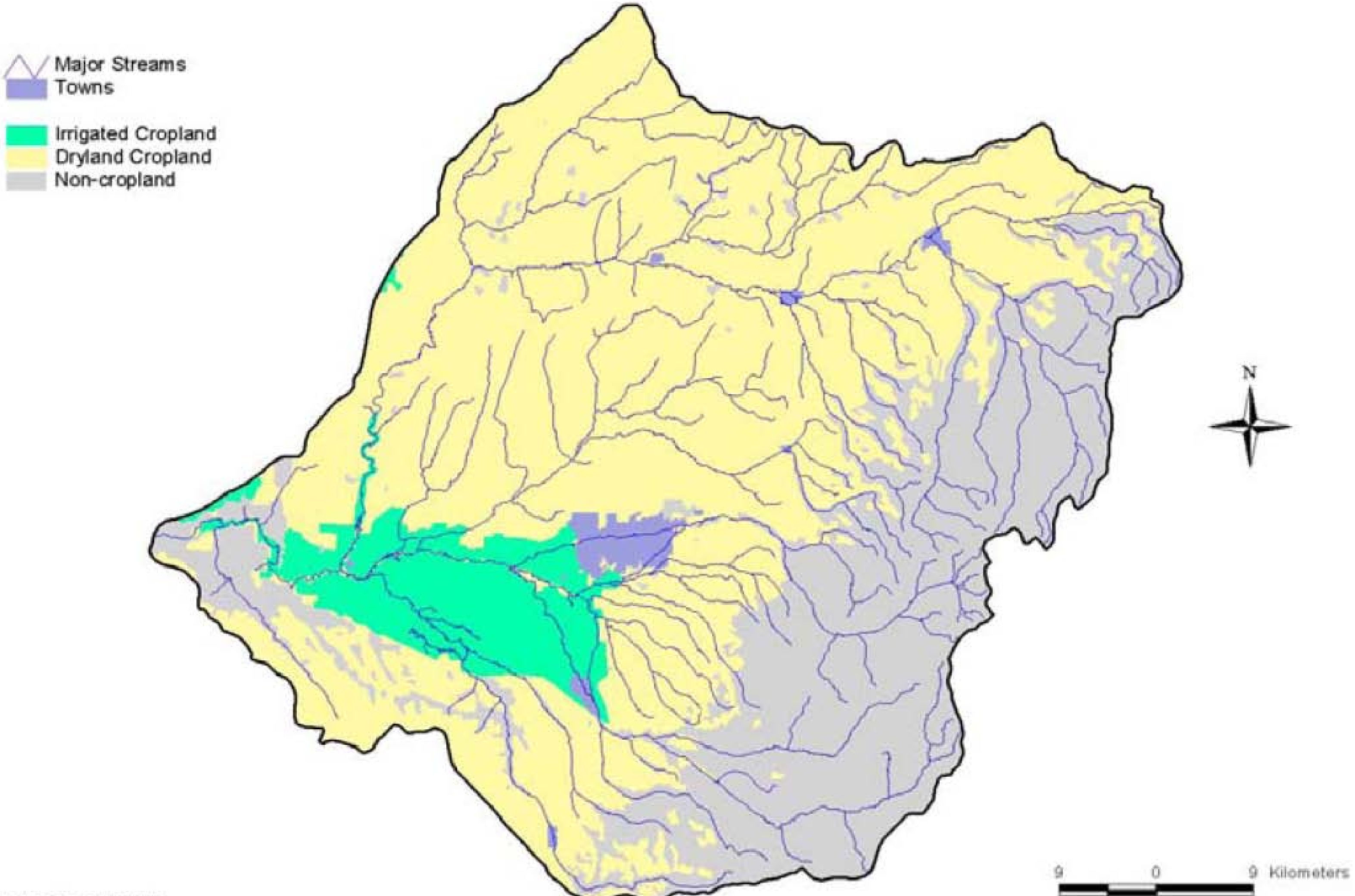
3. Walla Walla County and the Walla Walla Basin Watershed Council, “Walla Walla Subbasin Plan: May 2004 version.”

Figure E1. Walla Walla Basin Vegetation and Land Use



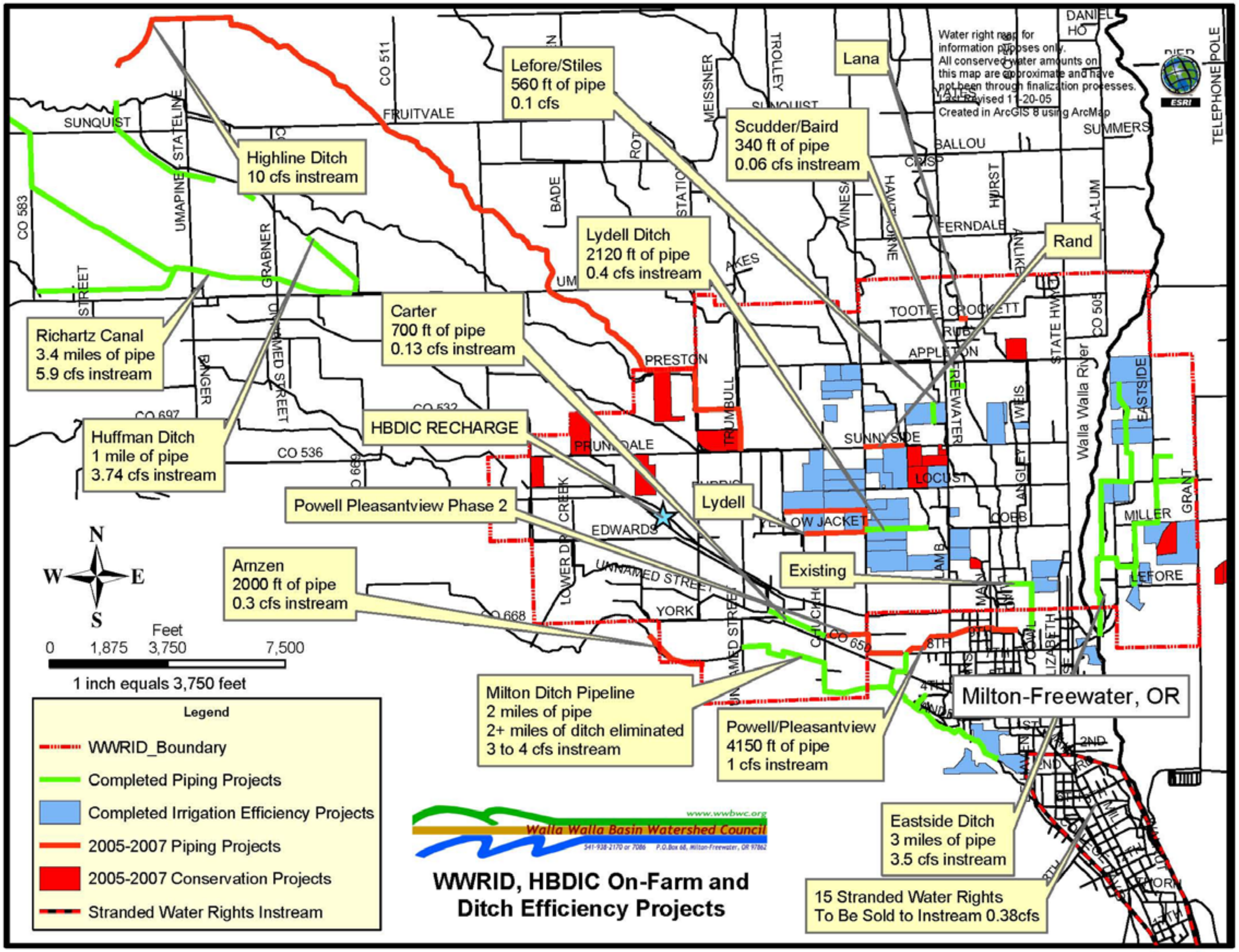
Data Source: modified USGS GIRAS

Figure E2. Walla Walla Basin Hydrology



Data Soure: ICBEMP

Figure E3. Location of Selected Irrigation Efficiency Projects in the Walla Walla Basin



Highline Ditch
10 cfs instream

Lefore/Stiles
560 ft of pipe
0.1 cfs

Lana

Scudder/Baird
340 ft of pipe
0.06 cfs instream

Lydell Ditch
2120 ft of pipe
0.4 cfs instream

Rand

Richartz Canal
3.4 miles of pipe
5.9 cfs instream

Carter
700 ft of pipe
0.13 cfs instream

HBDIC RECHARGE

Huffman Ditch
1 mile of pipe
3.74 cfs instream

Powell Pleasantview Phase 2

Lydell

Existing

Arnzen
2000 ft of pipe
0.3 cfs instream

Milton Ditch Pipeline
2 miles of pipe
2+ miles of ditch eliminated
3 to 4 cfs instream

Powell/Pleasantview
4150 ft of pipe
1 cfs instream

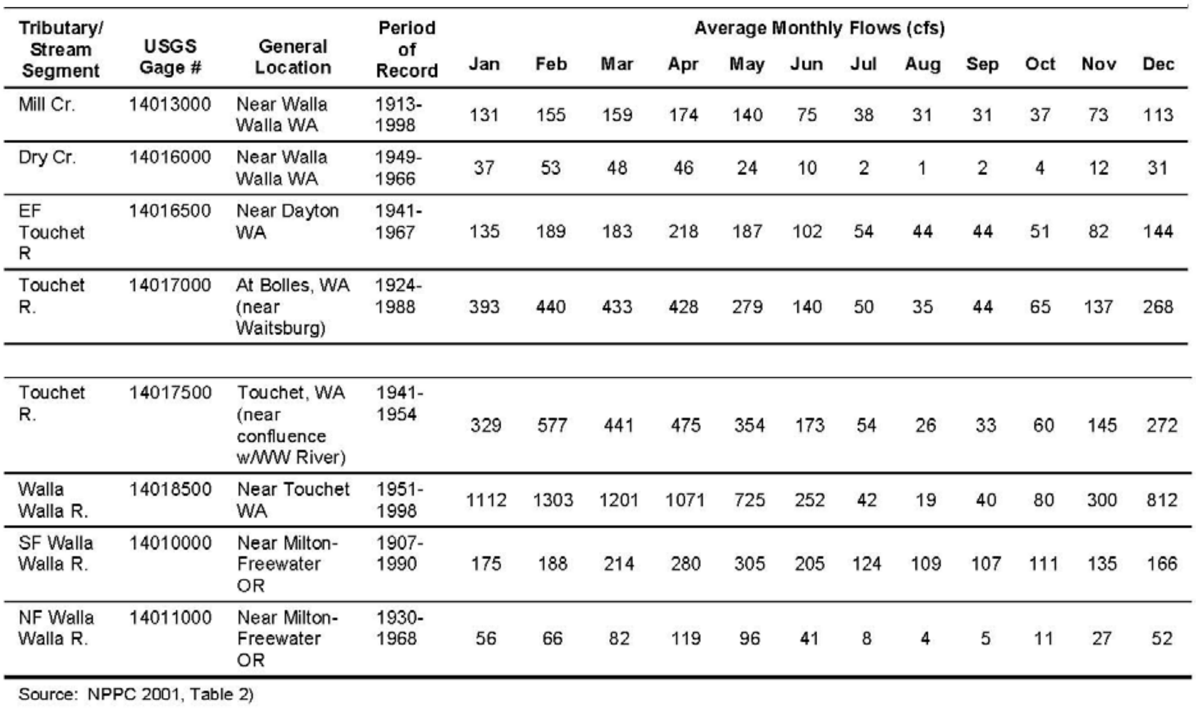
Eastside Ditch
3 miles of pipe
3.5 cfs instream

15 Stranded Water Rights
To Be Sold to Instream 0.38cfs

Water right map for information purposes only. All conserved water amounts on this map are approximate and have not been through finalization processes. Revised 11-20-05 Created in ArcGIS 8 using ArcMap

WWRID, HBDIC On-Farm and Ditch Efficiency Projects

Table E1. Average monthly flows for principle tributaries in Walla Wall river basin



Tributary/ Stream Segment	USGS Gage #	General Location	Period of Record	Average Monthly Flows (cfs)											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mill Cr.	14013000	Near Walla Walla WA	1913-1998	131	155	159	174	140	75	38	31	31	37	73	113
Dry Cr.	14016000	Near Walla Walla WA	1949-1966	37	53	48	46	24	10	2	1	2	4	12	31
EF Touchet R	14016500	Near Dayton WA	1941-1967	135	189	183	218	187	102	54	44	44	51	82	144
Touchet R.	14017000	At Bolles, WA (near Waitsburg)	1924-1988	393	440	433	428	279	140	50	35	44	65	137	268
Touchet R.	14017500	Touchet, WA (near confluence w/WW River)	1941-1954	329	577	441	475	354	173	54	26	33	60	145	272
Walla Walla R.	14018500	Near Touchet WA	1951-1998	1112	1303	1201	1071	725	252	42	19	40	80	300	812
SF Walla Walla R.	14010000	Near Milton-Freewater OR	1907-1990	175	188	214	280	305	205	124	109	107	111	135	166
NF Walla Walla R.	14011000	Near Milton-Freewater OR	1930-1968	56	66	82	119	96	41	8	4	5	11	27	52

Source: NPPC 2001, Table 2)

Table E2. Walla Walla Basin Watershed Council Conserved Water Projects

Landowner/Irrigation District/Project	Sponsor / Implementer	Project Location	Project Status	Estimated Quantity	Water savings (cfs)	Water savings (a-f)	Project cost	Annualized cost per a-f per year*
Lampson	Individual landowner	Walla Walla River - OR	Complete	0.7 (0.1 downstream)	0.1	24		
Jackson	Individual landowner	Walla Walla River - OR	Complete	0.027	0.027	6	2,698	21
Liebrand	Individual landowner	Walla Walla River - OR	Complete	0.335	0.335	80		
MF City Golf Course	MF City Golf Course	Walla Walla River - OR	Ongoing	0.4				
WWRID - Milton Ditch	WWRID/CTUIR	Walla Walla River - OR	Complete	2	2	475	220,000	23
WWRID - Misc. lower ditches	WWRID/WWBWC	Walla Walla River - OR	Complete	4	4	950	701,494	37
Eastside Ditch	WWBWC	Walla Walla River - OR	Complete	4	4.74	1,126	811,000	36
HBID - Huffman / Richardz Ditch piping	HBID/WWBWC	Walla Walla River - OR	Ongoing	9.61	9.61	2,283	242,664	5
Garden City	WWCCD/CTUIR	Walla Walla River - WA	Ongoing	1				
Lowden 2	WWCCD/CTUIR	Walla Walla River - WA	Designed	2.5				
Old Lowden	WWCCD/CTUIR	Walla Walla River - WA	Ongoing	2.5				
Bergevin-Williams	WWCCD/CTUIR	Walla Walla River - WA	Ongoing	1.75				
Probert – on farm	WWCCD	Walla Walla River - WA	Complete	0-7.04 Mar-Oct	7.04	1,673		
Borgens - on farm	WWCCD	WW R-Mud Cr – WA	Complete	0-2.31 year round	2.31	549		
Mud Creek 7	WWCCD	WW R-Mud Cr – WA	Ongoing	1		-		
Stiller-Schwenke – on farm	WWCCD	Mill Cr - WA	Complete	0-1.95 March-Oct	1.95	463		
Hofer (Eastside/Westside)	WWCCD/CTUIR	Lower Touchet	Complete	5 in spring; 7 to 23	5	1,188		
		River - WA		mid-Sept to mid-Nov		-		
GFID - Riggs Road & Huesby-Bennington	WWCCD	Walla Walla River - WA	Complete	1.4	1.4	333		
GFID – S.Lateral Ph I & II	GFID	Walla Walla River - WA	Complete	1.8	1.8	428		
GFID – S.Lateral Phase III	GFID	Walla Walla River - WA	Ongoing	2.2		-		
GFID - North Lateral	GFID	Walla Walla River - WA	Beginning	3.6		-		

* Annualized costs are computed by converting upfront costs into a perpetuity using a 5% discount rate.

Source: Walla Walla Basin Watershed Council.

Figure E4. Comparison of "before" and "after" summer flows in the Tumalum (mainstem) branch of the Walla Walla River.

August 1999

August 2002

Appendix F: Deschutes River Basin

Background

The Deschutes River Basin includes 6.8 million acres of land of which about 200,000 acres are irrigated. These irrigated lands lie in the middle portion of the Deschutes River and divert up to 90% of the streamflows from that portion of the river through irrigation canals during summer months. These seasonal flow disruptions degrade fish habitat and contribute to low water quality.

In its natural state the Deschutes River displayed a unique flow regime that sets it apart from other eastern Oregon rivers. The U.S. Reclamation Service recognized the river's unique character in 1914 and reported *"The flow of the river is one of the most uniform of all streams in the United States, not only from month to month, but also from year to year."*

The NWPCC (2004) vision statement for the Deschutes River is "to promote a healthy, productive watershed that sustains fish, wildlife and plant communities as well as provides economic stability for future generations of people. An inclusive consensus-based process will be used to create a plan for the achievement of sustainable management of water quality standards, instream flows, private water rights, fish and wildlife consistent with the customs and quality of life in this basin."

The report continues: "The steady flows through the length of the Deschutes River were primarily due to the volcanic geology of the upper subbasin and substantial groundwater storage. Porous volcanic soils and lava formations absorb much of the snow and rain that falls on the Cascade Basin, creating a large underground aquifer. Much of this groundwater surfaces as springs in the upper and middle watershed."

"Compared to historical records, the current situation in the Deschutes basin has seen a number of changes affecting fish populations:

- Reduced fish distribution and connectivity from artificial obstructions has resulted in fish population fragmentation, isolation or extirpation.
- Conversion of native upland vegetation led to the introduction of exotic plant species and invasion of western juniper, and reduced the watershed's ability to collect, store, and slowly release runoff and maintain soil stability.
- Stream flow extremes, especially seasonally low or intermittent flows, are probably the most significant factors limiting fish production in much of the Deschutes River subbasin today.
- Reduced water quality, including high summer water temperatures, limited focal fish species distribution and productivity. It also reduced connectivity between populations and, in some cases, fragmented populations.
- Loss of riparian and floodplain function reduced habitat complexity, contributed to water quality deficiencies, accelerated erosion, reduced water quantity, lowered water tables, and reduced beaver numbers and distribution.

- Loss of instream habitat diversity and complexity reduced focal fish species carrying capacity. Instream habitat, including large wood, boulders or emergent or aquatic vegetation is important for formation and maintenance of pools, braided channels and backwaters.

- Interactions with hatchery fish from the Upper Columbia River Basin pose potential serious genetic risk to wild summer steelhead in the Deschutes subbasin. These interactions could have a long-term effect on the subbasin steelhead production through reduced resilience to environmental extremes and diverse survival strategies.

- Indigenous focal fish species have been negatively impacted by the introductions of exotic fish species. Brook trout are of special concern where they have displaced indigenous focal fish species, including redband and bull trout."

Fish species of concern in tributary streams include Chinook salmon, Bull trout, Redband trout, Steelhead and Pacific lamprey. Priority streams for flow restoration include the Mainstem, Middle Deschutes River, Lower Crooked River and Whychus Creek.

Diversions of water for irrigation cause significant seepage losses due to the porous, volcanic soil characteristic of the region. Losses are estimated at 50% of the diverted water according to the Deschutes River Conservancy.

The Deschutes basin includes the city of Bend with over 80,000 people. When the surrounding "greater Bend metropolitan area" is included, the regional economy has seen a population increase of 31% from 2001 to 2009, rising from 120,000 to 159,000. Per capital income in Bend grew as well at a 2.3% rate until 2007, after which per capita income declined 15% in the three years ending in 2009 due to the economic recession.

The high growth rate in the upper portion of the Deschutes Basin has caused an increased demand for water. Surface water sources have been closed to new water rights for many years and are therefore not available to be tapped to support new development. As a result, groundwater has been relied upon to satisfy the growth in water demand. This has raised concerns about the capacity of the resource to accommodate increased use and the potential for added groundwater pumping to result in diminished streamflows. An additional concern relevant to irrigation efficiency improvements is the possibility that lining irrigation canals to reduce their substantial leakage could result in the lowering of the water table in certain areas (USGS 2005).

Irrigation district lands amount to about 160,000 acres. In recent years competition between irrigated agriculture and urban expansion for land and water have led to a range of activities and efforts to reconcile and mitigate these conflicts. These activities have included water transactions, water banking, and conserved water projects.

Water Transactions and Irrigation Efficiency

Instream flow restoration activities in Deschutes basin have focused on the middle Deschutes because of the extremely low flows in this middle section of the river in summer months. The upper reaches of the Deschutes produce summer flows as high as 2,000 cfs and in the lower portion summer flows are above

4,000 cfs. The middle reach of the Deschutes, however, has summer flows below 30 to 75 cfs. (See Figure 1) The decline in flows begins at Bend where five irrigation canals and the City of Bend draw most of the streamflow away from the Deschutes main stem. The irrigation diversions are estimated to divert 700 cfs. The main stem flows increase to high levels about 30 river miles downstream where the Metolius River and Crooked River join the Deschutes adding more than 2,500 cfs.

Beginning in 2007, five BPA-funded projects were undertaken involving piping and irrigation improvements for a total cost of $61,000. The vast majority of projects aimed at irrigation efficiency improvements, however, have been undertaken by the Deschutes River Conservancy (DRC) ($30,600,000 as of 2011). The detailed data on irrigation efficiency projects described below are from the DRC.

The middle section of the Deschutes River is in many ways ideal for successful implementation of irrigation efficiency improvement. A number of factors contribute to this situation. First, the porous volcanic soils create significant seepage losses in conveyance canals to and within irrigation districts. Second, the major irrigated lands served by the canal in the middle Deschutes are at some distance from the main stem. As a result there is little in the way of return flows to the river from irrigation applications or canal leakage. This implies that improvements in irrigation efficiency on-farm, or during water conveyance to the farm, could reduce the amount of water diverted from the Deschutes without having those reductions simply offset by nearly simultaneous and equal reductions in return flows to the river.

Third, because there are a very small number of points of diversion (10 or 12) for the main irrigation districts along the middle Deschutes River, and because there are no significant diversions downstream of these centralized diversions, the threat of “saved water” being subsequently diverted by other downstream water rights holders is not serious. Fourth, because the middle Deschutes is characterized by extremely low summer flows compared to the upper and lower portions of the river, the potential benefits to fish from relatively small increases in stream flows over this portion of the river are significant.

The combined effects of these four factors create a situation with high potential for benefits because: a) irrigation efficiency projects such as canal piping can reduce seepage significantly, b) the canal piping produced documented increases in instream flows, c) the increased instream flows are protected over a significant number of river reaches, and d) the increased stream flows alleviate a significant constraint on the fish habitat in the Deschutes.

The Deschutes subbasin has seen the largest number of “conserved water” projects aimed at restoring instream flows among the subbasins of the Columbia system. The Deschutes River Conservancy has completed about 30 projects of this kind since 2004, mainly piping and canal lining projects, but also including on-farm efficiency projects. The estimated conserved water for the projects completed between fiscal years 2004 and 2011 is 85 cfs, or more than 33,000 acre-feet. Three-quarters of this conserved water has occurred on the Middle Deschutes with smaller amounts on Whychus Creek and Tumalo Creek. According to Aylward (2008), a majority of the irrigation efficiency projects of this kind in Oregon are on the Deschutes River.

Projects undertaken by the Deschutes River Conservancy have included monitoring and detailed study to confirm instream water rights as a result of their projects. The Oregon Water Resources Department has detailed models of the groundwater-surface water connectivity that allows them to evaluate the amount of “saved water” resulting from irrigation efficiency improvement. Cost data from the DRC projects provide a basis for examining the cost-effectiveness of these projects. The amount of conserved water in all of the DRC projects has been evaluated and certified by the Oregon Water Resources Department. Payments to landowners were made in exchange for agreeing to reduce water diversions following the contracted improvements in lining canals or piping. The costs represented in the DRC data are the costs to the DRC, that is, the payments made in exchange for the agreed reduction in irrigation diversions. However, the actual net costs associated with achieving the added instream flow may have been lower or higher than this amount. In some cases the costs may be lower if improved irrigation efficiency allows the irrigation districts to save energy when pumping less water. In other cases the irrigation districts may receive funding from other sources which subsidize a particular project making it possible for the DRC to buy the saved water at a price lower than the full cost of the project (McCaulou 2011).

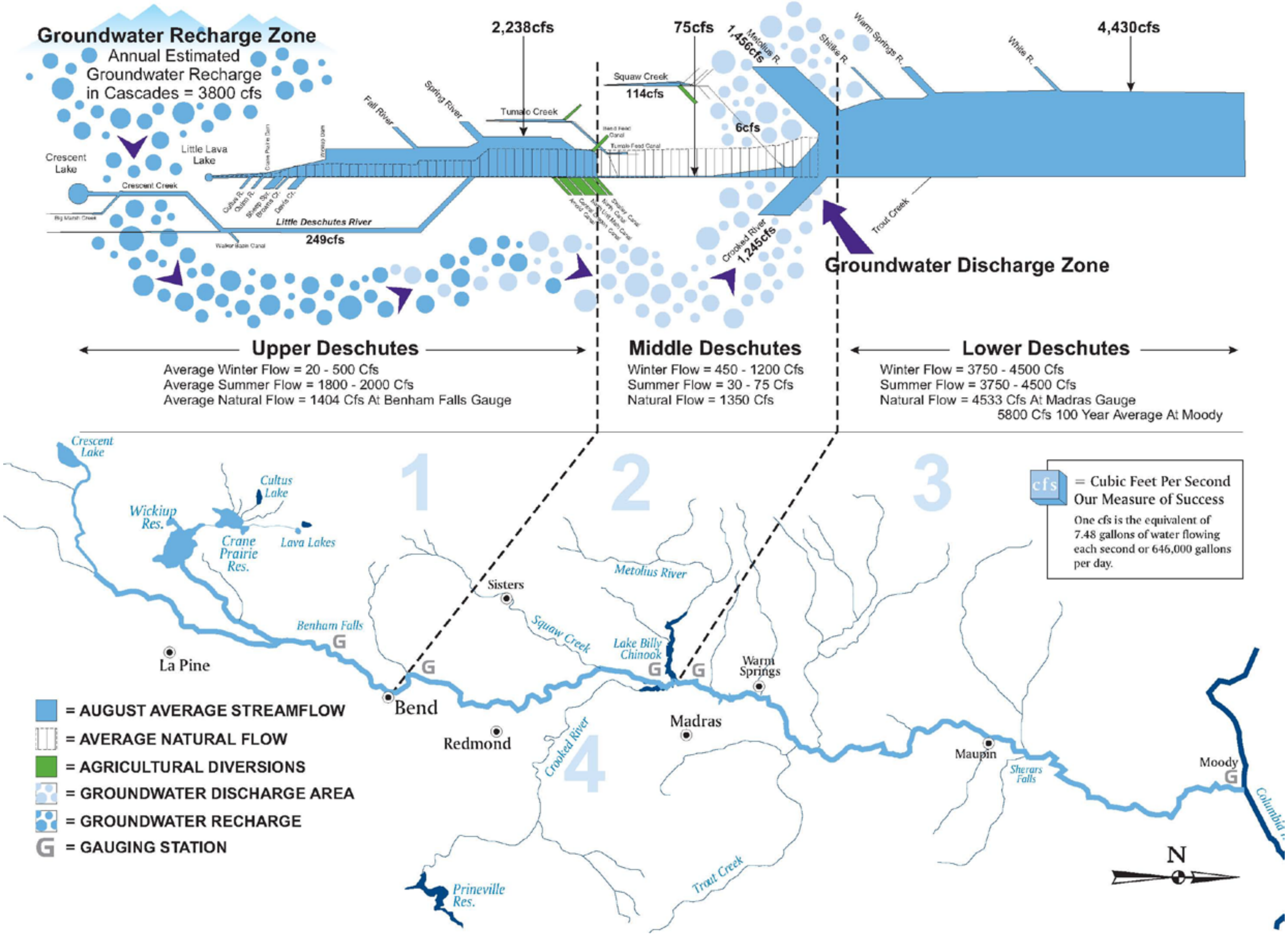
The data presented in Figure F2 below indicate an average cost of $58 per AF in 2010 dollars (a simple average across all projects), ranging from $6/AF to $159/AF. The total amount of saved water from the DRC projects since 2003 is 43,400 AF annually. As a percentage of the summer flow at the mouth of the Deschutes, this is about 2%. However, in the middle Deschutes where summer flows had previously been at 75 AF, these saved waters represent 85 cfs, or more than a doubling of summer flows.

The cost of water reflected in these conserved water projects is significantly higher than the cost of water from water transactions. Evidence from transactions in the Deschutes and other basins suggest that purchases of irrigation water rights to augment instream flows can cost less than $15 per AF in 2010 dollars (see, for example, Jaeger and Mikesell 2002; Turner and Perry 1997). Based on data coming from BPA (rather than from DRC, the organization implementing nearly all of the BPA-funded projects), results for water transactions projects involving permanent purchases of water rights to augment instream flows range from $7 to $52 per AF, with a median cost of $25 per AF.

According to DRC, one reason they have pursued conserved water projects to increase streamflow is because it represents a mechanism that can increase streamflow without reducing the level of farm production. In many cases, farm communities are concerned about the adverse impacts that transfers of water rights to instream flows will have on farm production and hence indirect effects on the scale of local economic activity (including input suppliers, processors, and related sectors). Conserved water projects appear to be more expensive than water transactions based on the data assembled here. But the DRC sees them as having an advantage in terms of the way they are viewed by the local community.

Overall, it is unclear how much additional benefit may be had from future projects of this kind. The most cost-effective projects for purposes of reduced seepage and improved irrigation methods are likely to have been already completed. And there is no doubt a limit to the number of canals that can be piped. Indeed, the 31 DRC projects with an average cost of $58 per acre-foot have exhibited rising costs over the eight years of their implementation. Figure 2 presents these projects in terms of their estimated annualized cost per acre-foot. The data indicate a significant increase in inflation-adjusted cost between 2004 and 2011. This may be an indication of the limited scope, and corresponding rising cost, for these actions in this basin. As a result, the potential for continued or expanded irrigation efficiency projects may not be large.

Figure F1. Hydrology of Deschutes River



Source: Deschutes River Conservancy.

Figure F2. Cost of Conserved Water Projects of the Deschutes River Conservancy (2010 dollars per acre-foot per year)

Source: Data provided by Deschutes River Conservancy.

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Appendix G: Hood River Basin

Background

The Hood River is located in Hood River County in north central Oregon and joins the Columbia River 22 miles upstream of the Bonneville Dam. The Hood River subbasin is 339 square miles and is bounded on the west by the Cascade Mountain Range crest, on the east by surveyors Ridge and the Wasco County line, and on the south by the White River drainage. The subbasin includes the towns of Parkdale and Odell and part of the City of Hood River (see Figures 1 and 2). [1]

The Subbasin geology is dominated by the 11,245 foot high strato-volcanic cone of Mt. Hood. Boulder-rubble substrates dominate most streambeds. The Hood River's major tributaries originate on Mt. Hood and 5 uppermost tributaries are fed by glacial sources. These glacial streams transport large amounts of sediment into the Middle Fork, East Fork, and mainstem Hood River, and to a lesser extent into the West Fork Hood River. Mt. Hood continues to experience extensive glacial erosion. Natural landslides, debris flows, and dam-break floods originating on the moraines and slopes of Mt. Hood frequently impact downstream channels.

The Hood River is located in the transition zone between the west side marine climate and the drier continental climate to the east. Maritime weather systems sometimes enter via the Columbia River Gorge and moderate its otherwise continental climate (Pater et al. 1998). Annual precipitation has a pronounced geographic distribution with an average of 130 inches per year along the Cascade crest to less than 30 inches along the northeast subbasin boundary. Snowfall is heavy at high elevations and can reach 30 feet deep at timberline on Mt. Hood (SWRB 1965). Most precipitation falls from November through January. Rainfall amounts from June through September average less than one inch per month (Sceva 1966). The mean annual temperature near the City of Hood River at 510 feet elevation is 52 °F.

The greatest proportion of land cover in the subbasin is conifer forest. Vegetation cover types are variable depending on elevation, longitude and aspect. Douglas fir dominates the western subbasin. Ponderosa pine and Douglas fir stands dominate the eastern subbasin area. At lower elevations, Oregon white oak and pine-oak stands are common, especially to the east and on south-facing slopes. Deciduous stands, including large leaf maple in some areas, and grasslands are found on the eastern foothills of the Cascades.

Approximately half the subbasin is within the Mt. Hood National Forest or designated wilderness areas. Major land uses on non-Federal lands are agriculture and timber production. Approximately 25 percent of the subbasin or 50,000 acres are managed as industrial forest and 21 percent is otherwise owned privately. The majority of private land is zoned either as Forest or as Exclusive Farm Use (EFU). Of the 27,201 acres zoned as EFU land, 15,000 acres are planted in orchard crops.

Small urban centers exist in Odell, Parkdale and the City of Hood River. The population is dispersed with 67% of residents living outside of urban growth boundaries. An estimated 16,245 people were living inside the subbasin boundary in 2003. This estimate was obtained by subtracting half the current population of the City of Hood River and all of the City of Cascade Locks population from the current population of Hood River County. Hood River County experienced an annual growth rate of approximately 2% from 1990 to 2000.

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[1] This section draws heavily from the Hood River Subbasin Plan (NWPCPC 2004).

Agriculture is the leading industry followed by tourism and forestry. The Hood River Valley contributes about a third of the total U.S. winter pear crop. Apples, cherries, blueberries, peaches, and wine grapes are also grown in smaller amounts. Agriculture contributes about 10 percent of total income in the County, down from 20 percent in 1974. The wood products industry has declined in recent years, including the closure of two large sawmills. Tourism has expanded into the second biggest economic activity in the area. A strong link between tourism and land development in the Hood River Valley is noted by historians and continues today.

The principal human disturbances to aquatic habitats in the Hood River subbasin are: 1) loss of the extensive delta area at the Hood River mouth by inundation from Bonneville reservoir; 2) depletion of stream flows at irrigation, hydropower and municipal water diversions; 3) fish migration barriers at dams, diversions, and road crossings; 4) loss of large woody debris recruitment and reduced riparian-floodplain interactions caused by historic timber practices; 5) channel confinement and interference with stream and riparian processes by roads and other land use; 6) water quality alteration by sediment inputs from roads and irrigation networks, pesticide and nutrient contamination from agricultural and other non-point sources (NWPCPC 2004).

These chronic human-caused habitat disturbances are believed to exacerbate the effects of frequent large scale natural disturbances leading to population declines in the focal species bull trout, spring Chinook, fall Chinook, and summer and winter steelhead. Key limiting factors for Chinook and steelhead included flow, channel stability, habitat diversity, key habitat quantity, and sediment load. The removal of the Powerdale Hydroelectric Project and dam in 2010, as well as other actions, is expected to substantially increase the survival of focal species in the Hood River. Based on one study, the largest predicted increase in spawner and juvenile outmigrant production for all species from a single restoration action was the Large Woody Debris restoration scenario. However, other assessment information indicates that flow restoration and fish passage will have significant positive effects on populations (NWPCPC 2004).

Streams have been diverted into canals and ditches to irrigate orchards and other crops since the 1880s,. Dams were built for mills, irrigation, or power generation. The largest and most significant dams remaining in the subbasin are Clear Branch Dam in Clear Branch of the Middle Fork Hood River. The ditching and draining of wetlands and springs has been common in agriculture and other land uses. Historic timber practices including splash damming and stream clearing continue to effect fish habitat. Symptoms of disturbance are channel incision, fewer pools and pieces of instream wood, and less variation in water velocity and substrate size. Channel confinement by roads, revetments, and bridge fills affects at least 24 miles of stream in the subbasin. Streamflow is interrupted or diminished by irrigation, domestic, municipal, and hydroelectric diversions. The total volume of legally appropriated water rights for out-of-stream uses is approximately 678,094 acre feet, or 94 percent of the estimated median natural stream flow at the Hood River mouth (NWPCPC 2004).

Five irrigation districts account for the majority (~95%) of the consumptive water use in the subbasin. Major diversions are located on the East Fork Hood River, mainstem Hood River, Coe Branch, Eliott Branch, Clear Branch at the Dam and West Fork Hood River. The upper Dog River is legally depleted each summer at the City of The Dalles municipal diversion. Prior to efficiency measures in the mid-1990s, the East Fork Hood River became fully depleted below the East Fork Irrigation District diversion during severe droughts.

The majority of water supply in the subbasin is obtained by the direct diversion of surface water or springs. The estimated actual consumptive diversion for the peak summer irrigation period is 296 cfs. or 40 percent of the average natural flow of the Hood River from July to September. Only a small amount of groundwater is withdrawn for human use. Construction of Green Point Reservoirs in Ditch Creek and Laurance Lake Reservoir on Clear Branch inundated a total of 1.7 miles of stream habitat. Laurance Lake impounds 5,500 acre-feet behind Clear Branch Dam. The Farmers Irrigation District operates the Green Point reservoir system. The storage volume is approximately 1,000 acre-feet.

The use of drain tiles and ditches to reduce soil saturation has been associated with agriculture and other land uses in the subbasin. A network of open irrigation ditches and road ditches intercept surface flows and shallow groundwater at numerous locations. Loss of wetland recharge and storage functions has probably had a greater effect on base flows in small streams than on subbasin peak flow characteristics. Historically, irrigation overflows and canal leakage may increase summer stream flows in Baldwin, Odell and Tieman creeks. The West Fork Neal Creek flows during the irrigation season are increased 5 to 10-fold over the natural baseflow by the creek's use as an inter-basin irrigation transfer system.

Water Transactions and Irrigation Efficiency

A list of irrigation efficiency and other projects funded by BPA, OWEB, and the Columbia River Inter Tribal Fish Commission are summarized below in Table 1. The combined funding for these projects is nearly $6 million, the majority of which involve irrigation system improvements, piping, habitat restoration and fencing.

This is a partial list of actions that have contributed to improvements in fish habitat in the basin over the past 30 years. In addition to these projects, the three main irrigation districts have undertaken projects to pipe water conveyance and centralize pumping (pressurization) of water systems. Individual irrigators have also shifted from spray to micro-sprinklers. Currently the large majority of the conveyance systems are in pressurized pipes. These actions have been undertaken to provide water pressure, to conserve water for irrigation use and for instream flow, and in the case of the Farmers Irrigation district (FIE), to operate their small scale hydropower facility which generates revenue (around $1million/year). Although some sections of the main conveyance canals in the FID have not been piped, there is very little seepage in these areas so that they estimate irrigation efficiency is now 95% and therefore it is not currently cost-effective to pipe these remaining segments of the canal.

Given the topography and types of irrigation (mainly fruit trees), piping and centralized pressurization has become the dominant system in this basin in recent years. One irrigation district (East Fork) still has some significant opportunities for piping ditches and centralized pressurization. Centralized pressurization represents some economies of scale and lower energy costs. A range of other actions have been taken by these irrigation districts to protect fish habitat by, for example, restoration of streams to a natural state that had been used as part of their conveyance system.

Many projects in the Hood River basin have been undertaken over the past 25 years involving irrigation efficiency improvements and actions beneficial to fish habitat. The kinds of projects undertaken recently can be illustrated by the two following examples:

A. East Fork Irrigation District (EFID): The EFID has used Neal Creek to convey irrigation water from the East Fork Hood River to the Central Lateral Canal for many decades to serve orchards and farms in the valley. Use of the creek for these purposes degraded the creek and failed to provide fish protection. In 2008, the Central Canal Pipeline Project installed 4.5 miles of large diameter pipe and returned Neal Creek to compliance with state water quality standards. The project also opened up 4.8 miles of habitat to two ESA-listed fish species and permanently conserved 3.44 cfs of East Form Hood River water for instream flow. The piping also protected Neal Creek from potential orchard chemical contamination (Hood River SWCD). This project's $10 million cost involved funds from many sources including PBA, Oregon Water and Electric Board, Pacific Coastal Salmon Recovery Fund, USFS Title II Funds, a DEQ loan and the EFID patrons.

B. Farmers' Irrigation District (FID): The FID (65 members involving 352 water rights) undertook a project on Indian Creek, a project similar to several previous projects completed in the past 10 years. This Indian Creek project involved replacement of canals with pressurized pipe in several locations, changes in pumping stations, and elimination of end-spills and canal leakage and evaporation. Flow controls would also regulate overuse on the part of district members. Total project costs were estimated in 2009 to be $3.92 million. A central feature of the project involving Energy Trust's Production Efficiency Program is focused on project pumping energy savings. The other major benefit of the project involved "saved water" from reduced leakage and end-spills, which contribute to increased instream flows, reduced water diversions, and increased power generation and sale from the FID's own small scale hydropower facilities. This has enabled the FID to earn revenue from the sale of power to Pacific Power. This project generated an estimated 4.37 cfs in saved water including an estimated 4.42 cfs for additional power generation.

The projects undertaken in the Hood River basin appear to differ in several ways from some of the irrigation efficiency projects in other basins. In particular, many of these projects have benefited the irrigation districts financially and in many cases have been self-financed. Benefits include pressurized water supply, reduced pumping costs due to reduced leakage, lower-cost centralized pumping, and the generation of additional hydroelectric power from the "saved water." Although some of the projects examined involved partial funding from sources including Energy Trust of Oregon, EPA Department of Environmental Quality, BPA and the Columbia Basin Inter-Tribal Fish Commission., it would be difficult to compute a measure of the cost-effectiveness of these projects based strictly on the increased instream flow, mainly because there were significant direct and indirect net financial benefits to the irrigation districts implementing the major piping projects in the basin over the past 25 years.

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Figure G1.Location of Hood River Subbasin in Oregon.

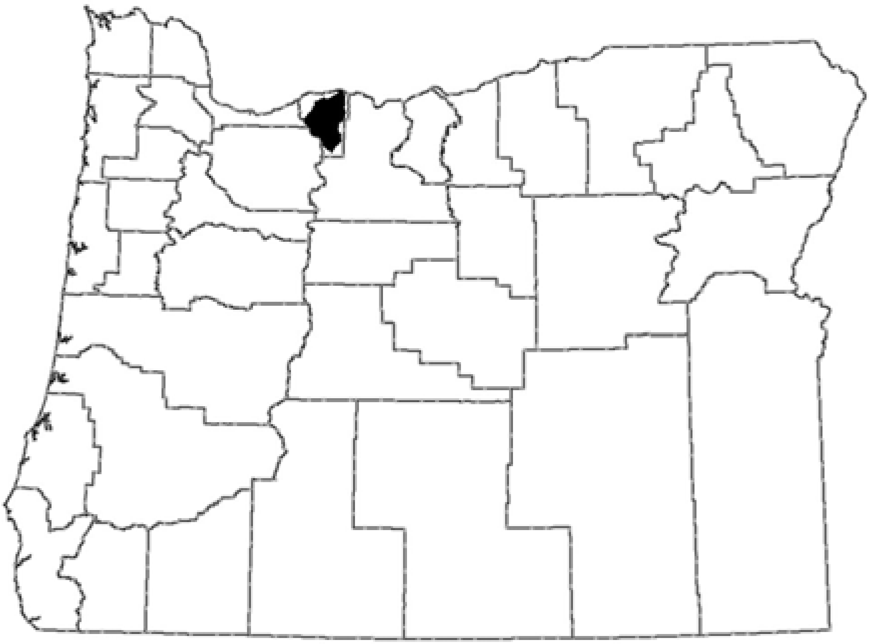

Figure G2. Stream segments in the Hood River basin where 1998 Oregon temperature standards are exceeded.

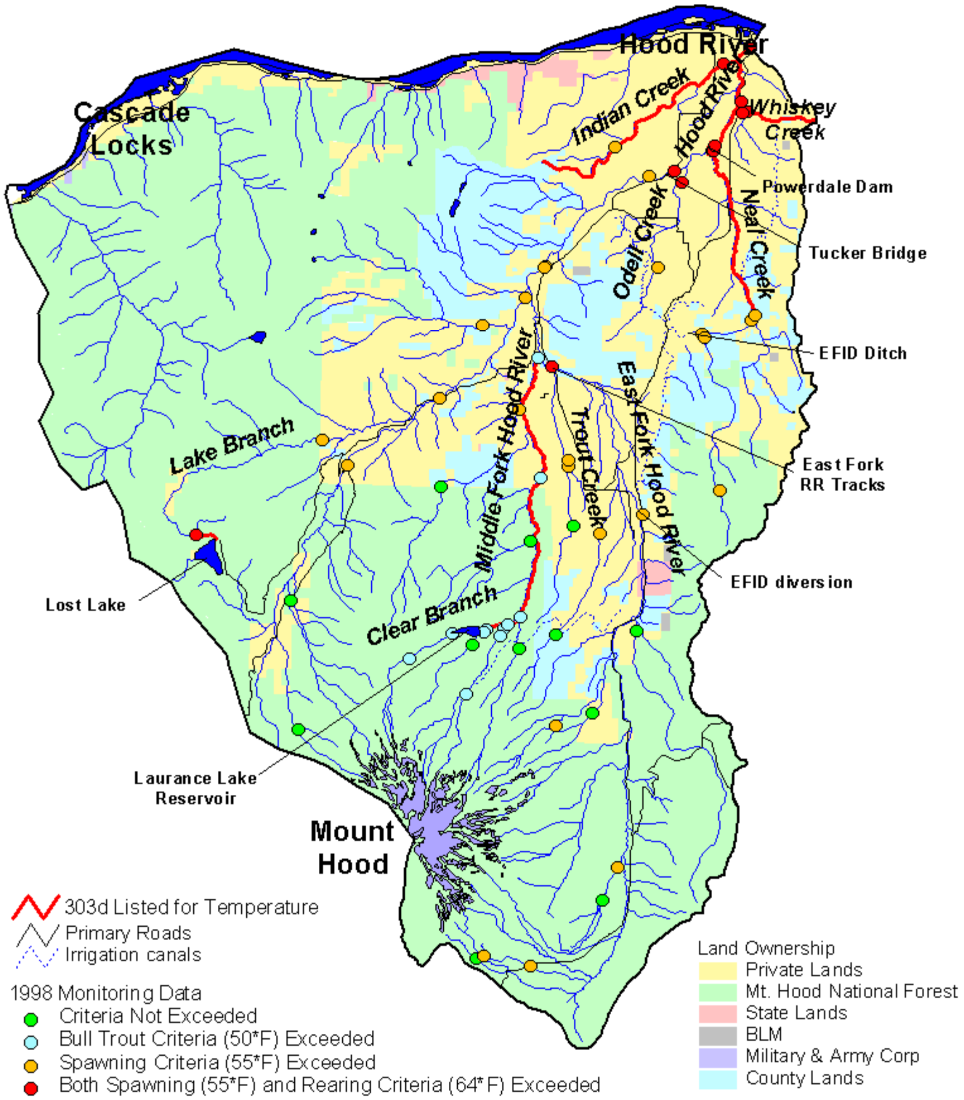

Table G1. Hood River Projects sponsored by BPA, OWEB, others

Project ID	Description	Sponsor	Date	Budget ($)	Status
1998-021-00	Pipeline construction	BPA	2007	487,000	Completed
1998-021-00	Pipeline construction	BPA	2006	495,000	Completed
1998-021-00	Pipeline construction	BPA	2005	500,000	Other
1998-021-00	Pipeline construction	BPA	2008	546,336	Completed
1998-021-00	Pipe DID irrigation ditch.	BPA	2013	2,728,691	Planned
735424	Baskins Farm Irrigation Improvement	OWEB	2003	5,538	Completed
735414	Cascade Orchards Irrigation	OWEB	2001	9,580	Completed
735007	Central Canal Pipeline Middle Phase	OWEB	2005	100,000	Completed
735408	Dee Mill Levee Removal	OWEB	2001	10,000	Completed
730345	East Fork Irrigation District Central Lateral Canal I	CRITFC*	2001	31,171	Completed
200052	East Fork Irrigation District Central Lateral Canal Project II	CRITFC	2002	83,827	Completed
735420	Emil Creek Cattle Exclusion	OWEB	2001	4,360	Completed
789	Evans Creek Fish Passage	OWEB	2000	76,000	Completed
1139	Farmers Canal Fish Screen/Bypass	OWEB	2001	130,000	Completed
200027	Farmers Irrigation District Screen	CRITFC	2001	40,000	Completed
1954	Green Point Creek Watershed Restoration - Project 2000	OWEB	2000	36,212	Completed
735419	Griswell Creek Enhancement Project	OWEB	2001	8,311	Completed
735407	Halo Stables Roof Runoff Management	OWEB	2001	10,000	Completed
10126	Hood-Deschutes Basin Direct Seed /	OWEB	2004	84,949	Completed
1316	Lower Evans Creek Bridge & Culvert	OWEB	2001	15,750	Completed
735413	Luhr Jensen Debris, Weed Removal	OWEB	2001	3,740	Completed
735410	Martens Riparian Fencing	OWEB	2001	1,412	Completed
735423	McNerney Farms Irrigation	OWEB	2003	10,000	Completed
735422	Neal Creek Manure Management	OWEB	2003	10,000	Completed
735415	Nickerson Orchards Irrigation	OWEB	2001	7,913	Completed
735417	Odell Creek Cattle Exclusion	OWEB	2001	10,000	Completed
1083	Odell Creek Horsekeeping	OWEB	2000	44,788	Completed
10125	Phase 2 Central Canal Upgrade	OWEB	2004	300,000	Completed
735425	Scribner Surface Water Piping	OWEB	2003	4,400	Completed
735427	Smith Farm Irrigation Improvement	OWEB	2003	10,000	Completed
735411	Swyers Riparian Fencing	OWEB	2001	2,579	Completed
1406	Tieman Cr Fish Passage & Sediment	OWEB	2002	30,965	Completed
735421	Tieman Creek Fish Weirs	OWEB	2001	1,320	Completed
730152	West Fork Hood River Wood	CRITFC	2004	70,000	Completed
735409	Wy-east Vineyard Irrigation	OWEB	2001	2,933	Completed
	Total			5,912,775	

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* CRITFC is the Columbia River Inter Tribal Fish Commission

Appendix H: Blackfoot Subbasin – Rock Creek & Murphy Spring Creek

This case study is focused on the Blackfoot Subbasin and several specific water transactions/irrigation efficiency projects within that subbasin, Rock Creek and Murphy Spring Creek, which are tributaries to the N. Fork Blackfoot. In this first section, the subbasin context and the main Blackfoot River are briefly described. The following sections focus on the specific projects.

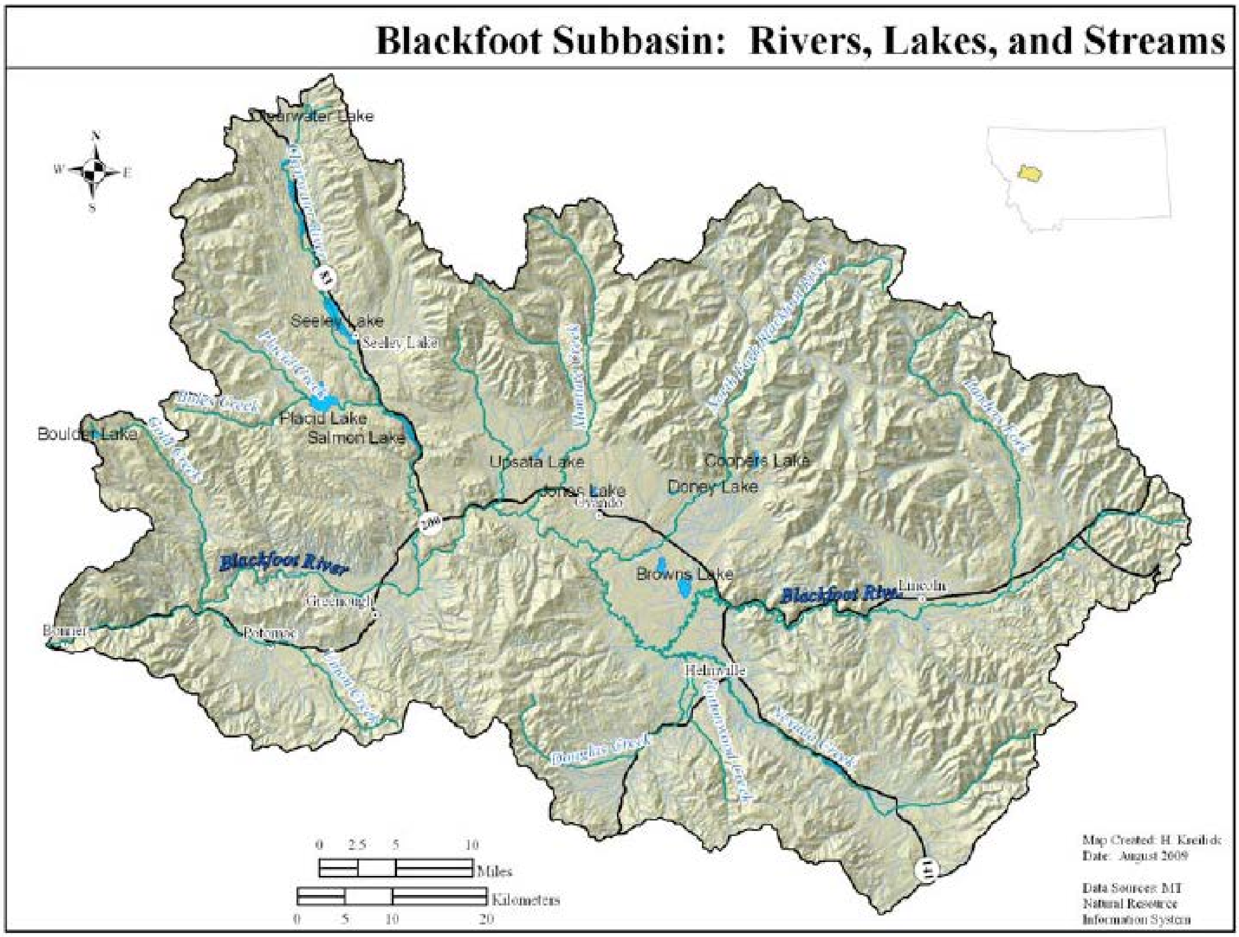
Background

The Blackfoot Subbasin is part of the Clark Fork-Pend Oreille River Basin. The subbasin encompasses 1.5 million acres (2,345 square miles) of biologically rich and diverse lands in portions of four northwest Montana counties (Lewis and Clark, Powell, Missoula and Granite). The Blackfoot Subbasin is bordered to the east by the Continental Divide, to the south by the Garnet Mountains, to the north by the Bob Marshall and Lincoln-Scapegoat Wilderness areas and to the west by the Rattlesnake Wilderness area. Elevations in the subbasin range from 9,202 feet on Scapegoat Peak to 3,280 feet near Bonner, Montana.

A tributary of the Columbia River, the free-flowing Blackfoot River runs 132 miles from its headwaters near Rogers Pass on the Continental Divide to the Clark Fork River. The subbasin is characterized by narrow headwater canyons opening to generally rolling terrain at the heart of the subbasin and ending in a narrow, incised, stream-cut canyon. The Blackfoot River is ranked as a Tier I Aquatic Conservation Focus Area in Montana’s comprehensive Fish and Wildlife Conservation Strategy. Tier I species, communities, and focus areas are considered by Montana Department of Fish, Wildlife and Parks (MDFWP) to have the greatest conservation need in Montana (MDFWP 2005).The Blackfoot River is an important fishery and recreational resource and is regarded as one of the premier fly-fishing rivers in the country (and is the river of “A River Runs Through It” book/movie fame). The mean daily discharge near the mouth is 1,968 cfs, with a mean peak of 6,070 cfs and a mean low flow of 642 cfs. Accordingly, even in the low flow summer months it is a sizeable river capable of supporting boating through the entire season.

Montana Trout Unlimited’s (TU) Western Water Project encompasses five leases in the Blackfoot including several on the North Fork, and on Poorman, Wasson and Rock Creek. The set of leases in the Blackfoot Subbasin are summarized in a following table and discussion.

The Blackfoot is one of the easternmost subbasins within the Columbia River Basin (Figure 3.1). The Columbia River Basin Fish and Wildlife Program organizes the subbasins of the Columbia River Basin into 11 ecological provinces, or groups of adjoining subbasins, with similar hydrology, climate, and geology. The Blackfoot Subbasin is part of the Mountain Columbia Ecological Province along with the Bitterroot, Clark Fork, Flathead, and Kootenai Subbasins (NPPC 2000). Although anadromous fisheries do not extend into the Blackfoot, the subbasin is significant as a headwater drainage of the Columbia River system.

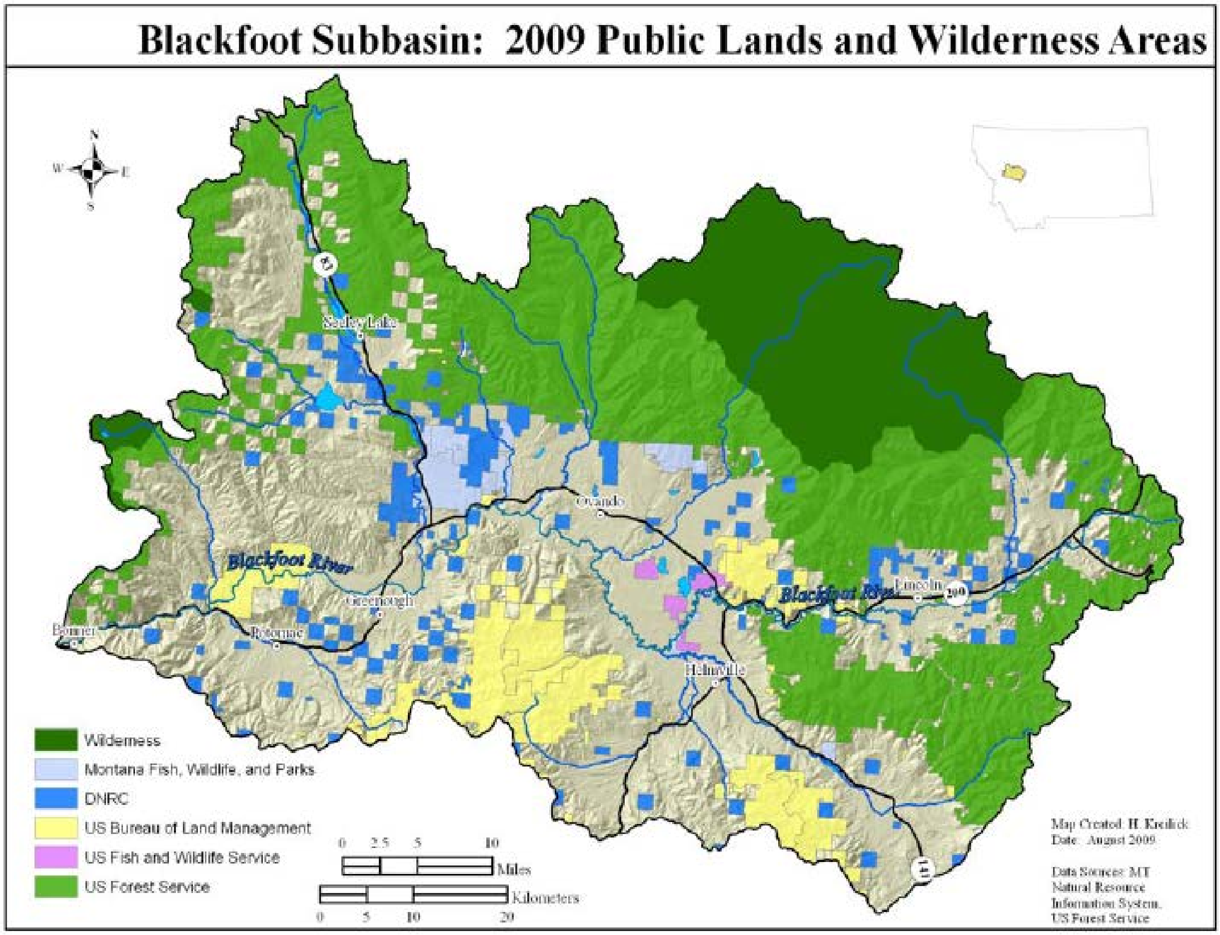


The Blackfoot Subbasin is located at the southern edge of the Crown of the Continent ecosystem (COCE), a ten million-acre area of the Northern Rocky Mountains that extends north into Canada. The COCE is one of the most intact ecosystems in North America. The Blackfoot Subbasin provides critical connections between the COCE and the Selway/Bitterroot Ecosystem to the south.

Land Use and Economy

Land use and land use change within the Blackfoot Subbasin is the result of complex interactions between geographic, socioeconomic and legal (ownership) characteristics of the subbasin. Consistent with its largely rural nature, dominant land uses in the subbasin include agriculture, timber harvest and recreation. A finer scale assessment, however, particularly within subbasin communities, reveals a range of land uses including residential and commercial development, transportation, communication and utilities, institutional and government facilities and public and private outdoor recreation (e.g., golf courses, resorts, and parks).

The majority of private land in the subbasin is located on the valley floor where ranching remains the principle land use. Approximately 14.5% of the total acreage in the subbasin is used for agriculture. The subbasin supports 44,280 irrigated acres and 180,283 grazing acres (BC 2005b). Public lands in the subbasin are mixed-use areas for recreation, wildlife habitat, grazing, timber management and research.



The presence of expansive open space in the subbasin provides an abundance of outdoor recreational opportunities, from hunting and fishing to hiking and snowmobiling. Public access to streams, lakes and public lands is highly valued.

The river itself, a world-renowned native trout fishery, is used for angling, summer camping, and floating. MDFWP is in the process of drafting a recreation management plan for the Blackfoot River and the North Fork of the Blackfoot River that will guide recreation management now and into the future (MDFWP 2009). The proposed plan is based on the recommendations of the River Recreation Advisory for Tomorrow (RRAFT) Citizen Advisory Committee.

Timber harvest on public lands has declined substantially in the past three decades. Although production from private timberlands has remained relatively constant over that same period of time (BC 2005b), recent market-driven fluctuations continue to reduce the amount of timber harvest in the subbasin.

Mining has historically been a major land use in the Blackfoot Subbasin. Today, there are several abandoned mining sites where reclamation is vital to the long-term health of the watershed. Like many rural communities, the traditional resource extraction economy in the Blackfoot Subbasin is being augmented, and in some places replaced, by a “new economy” based on services, particularly recreation, tourism, and new businesses made possible due to advances in telecommunications. The Blackfoot continues to attract retired professionals, providing transfer and investment income components to the subbasin.

Water Transactions and Irrigation Efficiency

There are 16 CBWTP Leases in the Blackfoot Subbasin. Seven of these are multi-year leases, from 5 to 30 years in length, on seven specific stream segments: Keep Cool, Weaver, Poorman, Rock Creek, Stonewall, and Wasson Creeks. The other leases are all one year leases, most of which are on the same streams and for years prior to the multi-year lease agreement being reached. The one year leases provide an opportunity for water right holders and the lessor to demonstrate the feasibility and impacts of a lease prior to agreeing to a longer term commitment. This also is an opportunity to evaluate restoration needs and whether the stream bed (which may typically be totally dewatered some of the year) is sufficiently ecologically sound to even convey any leased flows. These are all relatively small leases intended to provide flows in critical reaches. Based on the experience with one year leases on Murphy Spring Creek, this stream also is anticipated to have a multi-year lease in the near future (currently in the approval stage). The total cost for the long term leases (nominal dollars) is $346,673. Notably only one-third of this cost was supported by CBWTP, with the rest coming from the sponsoring entity and other sources varying across lease and including Trout Unlimited’s Big Blackfoot Chapter, Montana Department of Fish, Wildlife and Parks (often the Future Fisheries fund), NRCS, U.S. Fish and Wildlife Service, Northwestern Energy, and the Chutney Foundation. Accordingly, the funds provided by the CBWTP are highly leveraged, reflecting significant participation by NGOs and state and federal agencies and the benefits to fisheries (from a demand side perspective) anticipated from these projects.

The cost per acre-foot for these leases ranges from $1.60 to $32.64. Several of the leases (before correcting for inflation) value the lease at $25.00. This is a typical value for cases where the water transaction is made possible by foregone forage production. For example, on the pending Murphy Spring Creek lease, the total cost over 10 years is $81,200 for an average of 245 AF/year and an average cost of $33.14 (nominal dollars). Other leases, which can include irrigation efficiency improvements in this small sample of leases, depend on the costs of the improvement which in some cases is relatively low on an acre-foot basis.

Several leases are discussed in greater detail in the following sections,, including the Rock Creek lease, which is an irrigation efficiency improvement case, and Murphy Spring Creek, which is a transaction made feasible by reduced agricultural production of forage. The sources for this discussion are the Transaction Proposal Forms submitted to CBWTP for the respective leases, as well as discussions with Stan Bradshaw of Trout Unlimited.

Rock Creek Project

This is a 25 year lease that protects up to 1.5 cfs of base flow to Rock Creek which is tributary to the North Fork of the Blackfoot River. The lease is for water conserved by the conversion of a flood irrigation system to a center-pivot sprinkler system and the replacement of a ditch with a pipeline. This water lease is part of a large-scale restoration effort underway on Rock Creek that includes restoring the channel morphology, floodplain, and riparian habitat throughout the stream in order to restore migration corridors of fish seeking spawning habitat.

Rock Creek is an important tributary to the North Fork of the Blackfoot River because it is the largest tributary to the North Fork and provides critical habitat for bull trout. Historically, dewatering and degradation of the stream channel below its headwaters from livestock grazing have limited fish habitat on Rock Creek. A rancher, Duane Hoxworth, has a water right for 2.5 cfs from Rock Creek to flood irrigate approximately 85 acres of hay land south of Rock Creek. This diversion is of interest in that it transfers water out of the Rock Creek and North Fork Basin and into the Blackfoot Subbasin.

TU, in concert with the USFWS, MDFWP, NRCS, and Hoxworth, developed a long-term lease arrangement in which Hoxworth replaced his flood irrigation system with a center-pivot irrigation system. Because Rock Creek has proven to be especially susceptible to dewatering in drought years, the prior single season agreements were crucial to maintaining connectivity of Rock Creek in its lower reaches. The agreements have kept as much as 4.00 cfs in the stream, where in other years it has been diverted. In addition, it allowed TU to test the efficacy of single season agreements as a drought response tool.

This particular lease has shown the importance of assuring restoration of downstream reaches in which water is to be protected. In 2003, TU measured flows downstream of Hoxworth's diversion while monitoring a single season agreement. Flows held up well through very recent restoration, and tailed off rapidly beyond the restored area and within the degraded reach. Habitat surveys completed in the lower 8.2 miles indicate the condition of the stream and riparian areas as severally degraded, being extremely wide and shallow. Livestock have sheared wet banks, logging has impacted the stream channel, irrigation has dewatered the stream, culverts have blocked fish passage, and tillage of the riparian areas has contributed to the poor condition of the stream.

Because of the degraded stream conditions, restoration was necessary for the stream to benefit from increased flows. Work has been conducted and is ongoing to restore riparian damage from historic grazing and to restore streambed degradation caused by historic grazing. Over the past several years, TU and its partners have been involved in a long-term project to restore the riparian and instream habitat. Restoration completed in 2003 excluded grazing in most of the riparian zone on Rock Creek. The set-back distances for grazing are a minimum of 100 feet, and as much as 300 feet. Grazing is to be excluded for a minimum of five years to allow riparian vegetation to reestablish and after that the riparian area will be part of a comprehensive grazing program designed to maintain and protect the productivity of the riparian zone. Over three miles of instream habitat was restored to its historic channel type. Adding woody debris to the stream, planting riparian shrubs and conifers, and grazing management have now been implemented on over 5 miles of Rock Creek.

The cost of replacing the historic flood irrigation system was used to determining the value of the water rights. The incentive to the landowner was the opportunity to install a labor-saving system to replace the historic flood irrigation system

The Rock Creek lease is one example of a broader restoration effort in the Blackfoot Subbasin. The MDFWP, working in collaboration with the Big Blackfoot Chapter of Trout Unlimited and the USFWS, has developed a basin-wide stream restoration plan for the Blackfoot watershed which includes a prioritized list of 83 tributary streams in the Blackfoot watershed that are in need of restoration efforts to restore fisheries habitat. The predominant focus of this effort is the restoration of native fisheries--bull trout and westslope cutthroat trout. The cooperators have identified restoration objectives for each stream and DFWP produces annual progress reports of its efforts on the streams listed on the priorities list.

In addition to the efforts of MDFWP, a unique cooperative landowner and agency group, the Blackfoot Challenge, has embarked on a watershed-wide planning effort that focuses on preserving the watershed. Its efforts have included a basin-wide TMDL effort that will include long-term restoration efforts intended to address the TMDLs and long-term monitoring to assess the effects of the restoration efforts.

Source: Derived in large part from CBWTP Transaction Proposal Form. Name of Transaction: Hoxworth long term Lease CBWTP Transaction Number: 08b-05 Local Entity Proposing Transaction: Trout Unlimited-MT Water Project Entity Contact Person on Transaction: Stan Bradshaw Date Transaction Proposal Submitted to the CBWTP: 04/25/2005

Murphy Spring Creek Project.

Spring Creek is a small tributary of the North Fork Blackfoot River in Western Montana, in the Blackfoot Subbasin. Montana Trout Unlimited has proposed a water transaction for funding by the CBWTP on this creek. This project was specifically mentioned to the IEAB in a recent conference call with Andrew Purkey as being of potential interest in that the water was currently being transferred to another basin (Warren Creek, which eventually discharges into the mainstem Blackfoot River) from the Murphy Spring Creek/North Fork Blackfoot basin. (A map showing the Murphy Spring Creek Project, the proposed protected reach, the historic place of use, and the irrigation conveyance is provided in a separate attachment.)

The following briefly describes the Murphy Spring Creek project and the next section provides some context for the larger Blackfoot Subbasin. The material concerning the project is adapted from the CBWTP transaction proposal form for this project and discussions with Stan Bradshaw of Montana TU.

Montana TU is proposing a ten-year lease. Total cost of the water to be acquired is $81,000 and $41,200 is requested from CBWTP. The other $40,000 will come from the Montana Department of Fish, Wildlife and Park’s Future Fisheries Fund. The proposed project is part of a long-term comprehensive restoration effort involving several water right holders (sharing two water rights that have a total flow rate of 17.5 cfs) that use the diversion on Murphy Spring Creek to deliver water to a reservoir (Doney Lake) which in turn is tapped to complete a transbasin diversion to lands on Warren Creek which adjoins the Spring Creek drainage. CBWTP has helped fund a previous series of single season agreements in the run-up to a longer-term agreement. The proposal is for a ten-year split season lease. A lease has been signed and TU has filed two change applications on behalf of the irrigators.

Spring Creek (known locally as Murphy Spring Creek) is a basin fed creek that supports populations of westslope cutthroat trout and endangered (ESA status) bull trout. It falls significantly short of its potential, however, because of a diversion approximately 1.8 miles above the mouth and a culvert at mile 0.5. Both the culvert and diversion have historically been barriers to upstream migration of juvenile bull trout. This transaction is part of a comprehensive long-term effort to improve the rearing habitat in Murphy Spring Creek for both westslope cutthroat and bull trout. Other parts of this project include the replacement of the perched culvert downstream of the diversion (completed), installation of a Coanda Fish screen, and enhancement of a storage reservoir into which water is diverted in the adjoining basin to increase the storage of early season flows and reduce reliance on late season flows. Currently 634 acres are irrigated by the diversion; the water right is 1,827.0 AF and 17.5 cfs. The right is senior on the creek (05/29/1884; 05/29/1894). Authorized period of use is 5/01 to 10/01; the split season protected period would be the first of July to the 15th of September. This period of use is most ecologically significant because it is key to providing rearing habitat for young of the year cutthroat trout and it also assures minimum flows to allow for migration of both cutthroat and bull trout to the North Fork of the Blackfoot River. The maximum flow in the protected reach will be 2.20 cfs (total volume 245.0 AF). The flow target was established by Montana FWP using the Tennant method. A limiting factor is degraded riparian habitat in the lower 0.5 miles of the creek. However, there is now an agreement with an adjoining landowner to keep cows out of the pasture adjacent to the creek. The ten-year split season is the culmination of a multiple year effort to address limiting factors and test the viability of a flow-triggered agreement on this remote creek.

The value of the water right was based on the replacement of forage for the two ranches and pro rata shares of the cost of modifying the dam on Doney Lake, the repair of which is part of a 30-year agreement between the cooperators. These water right holders are attracted to this agreement because in return for providing flows, they are not only getting needed repair but also storage enhancement in Doney Lake. The Blackfoot Subbasin Plan identifies Murphy Spring Creek as a high priority restoration target based largely on its native fish values.

Both the Murphy Spring Creek and Rock Creek projects also improve flows on a critical reach of the North Fork Blackfoot in a section of that river which is sometimes dewatered. Just below the dewatered section flows are naturally enhanced by significant ground water recharge.

Table XX. Summary of the CBWTP Water Transaction Projects in the Blackfoot River Basin

Funded FY	**FY '09**	**FY '06**	**FY '07**	**FY '09**	**FY '04**	**FY '10**	**FY '03**	**FY '03**	**FY '05**	**FY '03**	**FY '05**	**FY '09**	**FY '04**	**FY '05**	**FY '06**	**FY '07**
Transaction Name	Sawbuck Ranch: Keep Cool Creek	Murphy Spring Creek diversion reduction	Murphy Spring Creek diversion reduction	Murphy Spring Creek Diversion Reduction	Weaver Instream Lease, N F Blackfoot River	Placid Creek Forbearance and Lease	Poorman Creek Water Salvage Project	Hoxworth Agreement to not irrigate from Rock Creek	Hoxworth Lease	No Irrigation from Rock Ck. and the N. F. of the Blackfoot	Murphy Spring Creek diversion reduction	Sawbuck Ranch: Stonewall Creek	Wasson Creek Flow Maintenance	Mannix/Wasson Creek agreement	Mannix/Wasson Creek agreement	Mannix lease
Term Years in effect)	10	1	1	1	30	5	15	1	25	1	1	10	1	1	1	10
AF	100	557	557	557	2,468	143	4,578	974	365	1,430	547	152	374	198	198	296
Total Max AF	1,000	557	557	557	74,049	715	68,664	974	9,125	1,430	547	1,520	374	198	198	2,955
Total Water Cost	$ 25,000	$ 11,420	$ 8,120	$ 8,120	$ 55,813	$ 10,000	$ 107,000	$ 2,900	$ 65,860	$ 3,427	$ 11,420	$ 38,000	$ 7,500	$ 5,000	$ 5,000	$ 75,000
CBWTP Water Cost	$ 25,000	$ 8,120	$ 4,000	$ 4,120	$ 17,356	$ 10,000	$ 10,000	$ 2,900	$ 10,000	$ 3,427	$ 8,120	$ 38,000	$ 3,000	$ 5,000	$ 5,000	$ 45,000
Other Cost Share	$ -	$ 3,300	$ 4,120	$ 4,000	$ 38,457	$ -	$ 97,000	$ -	$ 55,860	$ -	$ 3,300	$ -	$ -	$ -	$ -	$ 30,000
Cost Share Source		Big Blackfoot Chapter of TU	Big Blackfoot Chapter TU	Big Blackfoot Chapter TU	TU, USFWS, Land-owner		NRCS, BBCTU, USFWS, MDFWP		NRCS and BBCTU		Big Blackfoot Chapter TU					Northwestern Eneergy ($20,000) and Chutney Foundat
Tools	Long Term Lease	Forbearance Agreement	Forbearance Agreement	Forbearance Agreement	Long Term Lease	Short Term Lease, Forbearance Agreement	Long Term Lease	Short Term Lease	Long Term Lease	Short Term Lease	Forbearance Agreement	Long Term Lease	Short Term Lease	Annual Lease	Forbearance Agreement	Long Term Lease
Timing	Split Season	Full Season	Full Season	Full Season	Conserved Water	Split Season	Conserved Water	Full Season	Conserved Water, Full Season	Split Season	Stored Water, Split Season	Full Season		Split Season, Full Season	Split Season, Full Season	Full Season
protectable cfs	1.98	2.2	2.2	2.2	18.45	0.95	15.1	4	1.5	6.85	2.2	4.28	0.5	0.5	0.5	0.75
primary af	100	556.5	556.5	556.8	2468.3	142.9	4577.6	974	365	1430	1093	152	374.22	198	198	295.5
Primary $/AF Annually (2010 $)	**$31.17**	**$21.96**	**$15.18**	**$14.75**	**$1.60**	**$15.25**	**$2.52**	**$3.51**	**$13.49**	**$2.82**	**$23.10**	**$31.17**	**$22.91**	**$27.91**	**$27.02**	**$32.64**

Appendix I: BPA's 2001 Voluntary Energy Load Reduction Program

The California energy crisis of 2000 and 2001 resulted from a number of causes: unwisely structured energy deregulation, inadequate market oversight, market manipulation, and underinvestment in energy infrastructure. One result was wildly gyrating electricity spot prices, rising to ten, twenty, and more times their usual levels (Hamilton and Taylor, 2002). Since California and the PNW electricity grids are linked by interties, the results of this price instability quickly reached the Pacific Northwest. In 2000 BPA was able to ship excess power south to the limits of intertie capacity and requirements for fish spill at the dams. In the early months of the year it became obvious that 2001 would be very dry. The Northwest Power Planning Council projected that runoff would be either the worst or the second worst year of record (Council, 2001). Not only would the PNW have little power to ship to California, there was worry that little power would be available for purchase at a reasonable price to cover PNW shortfalls.

On April 5, 2001, the Council recommended full barge transportation of juvenile salmonids from Lower Granite, Little Goose, Lower Monumental and John Day dams (Council, 2001). This allowed reductions in spill and increased power generation at John Day, The Dalles and Bonneville dams.

In this context BPA approached the managers of the Columbia Basin Project about the possibility of reducing irrigation diversions at Grand Coulee Dam. The Columbia Basin Project normally provides water to 640,000 irrigated acres. The water is diverted from Lake Roosevelt to Banks Lake by pumps at the south end of Grand Coulee Dam. The lift, which would have been 280 feet in normal years, would have increased to 370 feet in 2001 because of the extreme drawdown of Lake Roosevelt. Reductions in diversions to the Columbia Basin Project would reduce the electricity needed to pump the water to Banks Lake, reduce the electricity needed for pumping and pressurizing irrigation application systems, and leave more water in the stream that could be used for hydropower generation at Grand Coulee and the series of downstream dams.

The project to reduce irrigation diversions was known as Voluntary Energy Load Reduction (VELR). A total of 670 farmers contracted with BPA to not irrigate 91,196 acres for one year. This was about 15% of the total acreage in the Columbia Basin Project. Farmers received $330 per acre enrolled (Committee on Resources, 2001), which was a very attractive payment given that crop prices were very low in 2001. Many participating farmers were even able to get a fair dryland crop off this land without irrigating (Washington Hay Organization, 2001).

Each irrigated acre requires between 3 and 4 acre-feet of water per year. The $330 per acre payment implies a cost of about $90 per acre-foot not diverted at Grand Coulee. Each acre-foot not pumped from Lake Roosevelt, but instead sluiced through the turbines at Grand Coulee and Chief Joseph dams is equivalent to about one megawatt hour. In ordinary markets this would have a wholesale value of about $20 or less. Given the price gyrations of 2000-01 this megawatt hour sometimes had wholesale value ranging between $200 and $700 (Committee on Resources, 2001). If this acre-foot were able to sluice through the turbines at the nine downstream dams all the way to the Pacific, and not be diverted by irrigators along the way, it could generate as much as 0.57 megawatt hours additional power (Hamilton Table). BPA explained in a comment to the Council's 2001 Annual Report that after this water passes through the Grand Coulee turbines it becomes unappropriated water available for diversion by other users, and cannot be protected for hydropower or fish use. (Council. 2001).

Idaho Power Company (IPC), which serves much of southern Idaho, had similar drought and market concerns in the spring of 2001. IPC initiated an irrigation pumping power buy-back program involving 400 farmers and 150,000 participating acres, yielding 500 million kwh. Payments averaged $485 per acre or about $150 per acre-foot (Hamilton and Taylor, 2002).

The Washington VELR program successfully added some 300,000 acre feet to hydropower flows at Grand Coulee and Chief Joseph dams in 2001. It certainly added some to hydropower and fish flows at the nine downstream dams, although this was not protected from diversion and the results were not documented. The cost of the water was high by ordinary year standards, but given the drought year scarcity of water, and the potential hydropower value of this water in the overheated power market, the deal seems reasonable.

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