Instream Flow in the Deschutes Basin: Monitoring, Status and Restoration Needs

DWA Final Report

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Deschutes Water Alliance
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FOREWORD

BACKGROUND

The upper Deschutes Basin comprises about 4,500 square miles of watershed between the highland areas to the east, south and west, and Lake Billy Chinook to the north. The Central Oregon area, located within the upper basin, is experiencing rapid growth and changes in both lifestyle and land uses. Along with these changes, long-recognized water resources issues have become more important and a number of others have developed.

More effective use of water resources to broaden the benefits of water use in connection with irrigation, stream flow restoration, protection of scenic waterway flows and water quality improvements has long been an important resource management issue in the upper basin. Other developing issues include need for safe, reliable water supply for future basin needs, urbanization of irrigated lands and impacts on agriculture, and needs to protect flows for fishery, recreation and other instream uses.

The significance of basin water issues has increased considerably over the last few years. The rapid growth and subsequent water needs that the region is experiencing presents an opportunity to study these issues in more detail given changing values and availability of funding. Consequently, water usage and availability are now a major topic in discussions among basin water suppliers and planners. Due to increased dialogue and awareness relative to water issues, regional urban water suppliers, irrigation districts and other private, government and individual water users now recognize their interdependency in the use, management and protection of Deschutes Basin water resources. This recognition and related dialogue enjoined the major water suppliers in a common vision that commits energy and resources in a collaborative effort to respond to basin water issues.

Water supply, water quality, flow depletion and irrigation district urbanization issues in the upper Deschutes Basin establish the framework for need for the Deschutes Water Alliance. Mutually beneficial opportunities exist for municipalities and flow restoration interests to obtain needed water supply and for irrigation districts to resolve urbanization and conservation issues. Some of the key management considerations involved with these opportunities:

- Full appropriation of surface waters
- Declaration of groundwater restrictions and related mitigation requirements
- Dependency of municipal water providers on groundwater for future needs
- Diversion of substantial river flows by irrigation districts
- 303(d) listings for water quality parameters and need for TMDLs throughout the Deschutes and Crooked Subbasins.
- Protection of scenic waterway flows in the lower reaches of the Deschutes and Crooked Rivers

- Potential Endangered Species Act issues
- Re-Introduction of anadramous fish species in the Deschutes and Crooked Rivers
- Rapid growth, urbanization and land-use change in the basin

Organization

The Deschutes Water Alliance (DWA) was formed by four major basin partners to develop and implement integrated water resources management programs in the upper Deschutes Basin. The partners include**:**

- Deschutes Basin Board of Control (DBBC): represents seven irrigation districts in the basin including BOR's Deschutes Project (North Unit Irrigation District) and Ochoco Projects formed under ORS 190.125.
- Central Oregon Cities' Organization (COCO): which is comprised of cities in the basin and affiliated drinking water districts and private companies providing potable water supply.
- Deschutes River Conservancy (DRC):
- Confederated Tribes of Warm Springs (CTWS)

Goals and objectives

The DWA is investing in managing the water resources of the Deschutes Basin in a unified way to provide:

- Reliable and safe water supply for the region's future municipal and agriculture needs and sustained economic viability considering growth, urbanization and related effects on water resources;
- Financial stability for the Basin's irrigation districts and their patrons;
- Protection of the fishery, wildlife, existing water rights, recreational and aesthetic values of the Deschutes River along with stream flow and water quality improvements;
- Focus on maintaining the resource and land base in the Basin, consistent with acknowledged comprehensive land use plans; and
- An institutional framework that supports the orderly development of local water markets to protect participants and create an "even playing field" for water transactions.

These considerations are key elements to be incorporated into development of the integrated water resources management and restoration program.

Approach

Mutually beneficial opportunities exist to boost water supply for agriculture, municipal needs and stream flow for fish, wildlife and water quality improvements. Mutually beneficial opportunities also exist through integrated planning for irrigation districts to resolve urbanization issues. In order to develop a framework and program to achieve these objectives, the DWA is implementing five planning studies under a Water 2025 Program grant to generate facts and background information necessary for program formulation. The planning study results will be synthesized into a Water Supply, Demand and Water Reallocation document with project scenarios, five-year implementation bench marks and 20-year timeframe. The five planning studies are as follows:

- Irrigation District Water Conservation Cost Analysis and Prioritization-an evaluation and prioritization of opportunities to save water through piping and lining of canals, laterals and ditches, as well as through on-farm conservation technologies.
- Growth, Urbanization and Land Use Change: Impacts on Agriculture and Irrigation Districts in Central Oregon. (Title in Water 2025 Grant was *Impacts of Urbanization on Irrigable Lands*) -an inventory of amounts, patterns and rates of district water rights becoming surplus due to urbanization or other changes in land use patterns in Central Oregon and corresponding impact on district assessments.
- Reservoir Management (Title in Water 2025 Grant was *Reservoir Optimization Study and Water Quality*)- prepare rapid assessment of potential gains from optimization of existing reservoirs and their potential impact on improving flow and quality, and prepare terms of reference for more formal and rigorous assessment.
- Future Groundwater Demand in the Deschutes Basin (Title in Water 2025 Grant was *Municipal Water Demand*)-assessment of the water supply needs, quantity and timeline of the Basin's regional urban suppliers.
- Instream Flow in the Deschutes Basin: Monitoring, Status and Restoration Needs (Title in Water 2025 Grant was *Measurement, Monitoring and Evaluations* Systems)- In-stream Flow Needs for Fish, Wildlife and recreation along with Measurement, Monitoring and Evaluation Systems-assessment of the suitability and completeness of existing flow measurement sites and existing Water Quality and Monitoring Plan for the Upper Deschutes Basin and prepare funding and implementation action plan.

EXECUTIVE SUMMARY

The Deschutes Water Alliance working mission includes the objective of moving stream flow 'toward a more natural hydrograph while securing and maintaining improved instream flows and water quality to support fish and wildlife.' The purpose of this paper is to quantify instream flow needs in the upper Deschutes Basin, particularly in those reaches affected by irrigation district water storage and diversion.. The methodology employed to this end is to identify the affected reaches, gather existing data and information on instream conditions and instream flow targets, identify existing senior instream rights and then develop quantitative estimates of stream flow needed to meet flow targets. This information will be used alongside other information on the demands for and the sources of water to develop scenarios for meeting instream, agricultural and community needs over a 20-year time frame. This paper also considers the monitoring and measurement needs required to verify flow and water quality outcomes related to instream flow restoration.

Water Resources

The paper begins by using existing data to characterize the availability and use of water resources in the upper portion of the Deschutes Basin. Precipitation and lateral movement of groundwater into the basin provide the water resources input available for human and ecosystem use in the upper Deschutes Basin. This input then (a) either evaporates or transpires from the surface or soil moisture (evapotranspiration), largely due to plant growth, (b) percolates through the ground and recharges the aquifer, where it ultimately discharges to surface waters or (c) runs off to surface waters. Ecosystem uses consist of water used to support upland vegetation and ecological processes as well as instream and riparian uses where the hydrograph supports a wide range of physical, chemical, biological and ecological functions of rivers. Human uses occur either directly through capture, diversion or withdrawal of surface and ground waters or indirectly through the harvesting of plants and animals that consume water to grow and reproduce.

The assessment focuses on the Groundwater Study Area which comprises the upper Deschutes Basin except for that portion of the Crooked River system above Prineville and Ochoco Reservoirs. Extensive work by the US Geological Survey, estimates of exempt well water use from OWRD, and calculation of irrigation crop water use conducted for this paper suggest that for the Groundwater Study Area human activities over the last 150 years or so have:

- Stored and diverted a large portion of stream flow, altering stream hydrographs and decreasing summer and winter stream flows in specific places and reaches by 96% to 100%

- Rerouted surface water flows to increase groundwater recharge by approximately 12%, through transmission and on-farm losses from irrigated agriculture

- Led to increased consumption (evapotranspiration) on the order of 350,000 acre-feet of water per year (480 cfs) which is equivalent to about 10% of mean annual stream discharge

- Led to the consumption of roughly just over 1% of the annual groundwater flux via groundwater pumping.

In sum, human activities have altered the water resource regime in the upper Deschutes Basin to varying degrees. Groundwater consumption comprises a relatively small amount of the annual groundwater flux. Seepage losses from irrigation returning to the regional aquifer are 15 times as large as groundwater withdrawals. The prospect of large-scale implementation of water efficiency projects and increasing groundwater use will affect this ratio going forward and have raised concerns about future seasonal impacts on the lower Deschutes River, the reach where all the changes in storage, diversion and surface-groundwater interactions come together in one place. Overall consumption of annual stream discharge from the Groundwater Study Area is approximately 10%. However dramatic seasonal modifications to the water resources regime in the upper basin are apparent. These are demonstrated by low stream flows in reaches observed below irrigation district diversions and storage facilities.

The assessment that the portion of the upper Basin represented by the Groundwater Study Area has only tapped its water resources in a modest manner does not eliminate the need to carefully plan for and regulate the impacts of future changes in water management, particularly as the upper basin sees dramatic changes in land use and types of demand for use of water resources. With instream flow protection and restoration yielding services that are important components of not just the environment in Central Oregon, but the economy, the impacts on stream flow need to be carefully evaluated.

Reach Assessment

Instream flows are critical to the maintenance of floodplain, riparian, and aquatic ecosystems. Seven of the eight reaches included in the assessment of reach conditions and trends experience water quality or quantity impairments due to flow alteration. In these reaches, flow is highly modified by storage or diversion by irrigation districts. Six of these are in the upper Deschutes Basin, including:

- Little Deschutes River
- upper Deschutes River
- middle Deschutes River
- Tumalo Creek
- Whychus Creek
- lower Crooked River

The lower Deschutes River is also included in this assessment, as it is the reach where all water flow changes in the upper Deschutes Basin come together. The Metolius River is included as a reference river that has been largely unaltered by human use.

Monitoring, Instream Flows, and Water Quality

Water quantity and quality monitoring in each reach allows for an understanding of current status and historic trends. The Deschutes Basin has a relatively comprehensive water quantity monitoring system. Each reach discussed in this paper contains two or more gages operated by state or federal agencies. The Oregon Water Resources Department, the United States Geological Survey, and the Bureau of Reclamation publish both historical and near-real time data for these gages, allowing the analysis of both historic trends and current status.

Water quality monitoring stations exist on each of the reaches as well. First, the Oregon Department of Environmental Quality's ambient water quality monitoring network provides long term water quality monitoring in several of the reaches discussed in the study. Second, the Upper Deschutes Watershed Council's (UDWC) Water Quality Monitoring Program is a comprehensive, cross-jurisdictional, hydrologic unit based monitoring effort that encompasses six out of the eight reaches discussed here. The UDWC runs the program in coordination with local, state, and federal agencies. Water quality monitoring in the other two reaches, the lower Deschutes River reach and the lower Crooked River reach, is managed by other organizations. Flow alteration has affected instream flow patterns and water quality in seven out of the eight reaches discussed in this study. This study used Oregon's 2002 303(d) list of impaired waters to identify water quality issues in the Deschutes Basin. The state lists seven of the reaches for not meeting water quality standards for one or more parameters. Temperature, dissolved oxygen, and pH dominate the list of impairments in these reaches, and instream flow reduction contributes to or causes these impairments. The state has not monitored all reaches in the basin and has not monitored for all parameters in each reach, so actual impairments in these reaches and their tributaries may be more extensive than those listed.

Fisheries and water quality restoration drive instream flow restoration in the Basin. The reaches historically supported large salmon and trout populations, and several of them still support Endangered Species Act listed salmon and trout. Anadromous salmon re-introduction in three reaches, one reach and two tributaries to other reaches, has drawn attention to water quantity issues in the basin. 303(d) listing has drawn attention to water quality impairments.

ODFW has applied for and received instream water rights to support aquatic life in most reaches of the Deschutes Basin. This study used the instream water rights applied for by ODFW as preliminary flow targets. The targets were set as minimum flows to support salmon and trout populations. Whether they are sufficient to meet state and federal water quality standards and restore aquatic and riparian ecosystem function is not assured. Current research suggests that ecosystem processes depend on the volume and timing of stream discharges. Both high flow and low flow events are important in supporting these processes. Further scientific work to assess ecosystem needs for water may be helpful in order to better assess the likelihood of success of ongoing and future restoration efforts.

Reservoir storage and releases for irrigation have highly altered flows in five of the seven water quality impaired reaches in the basin. The upper Deschutes River reach does not often meet target flows in the winter due to upstream reservoir storage. Irrigation diversions have reduced summer flows in six of the seven water quality impaired reaches. Most reaches experience low summer flows due to irrigation diversions, and some reaches experience low winter flows due to irrigation water storage (see Table ES-1). Prior to current restoration efforts, sections of Whychus Creek and Tumalo Creek typically dried up during the irrigation season due to extensive diversion. The daily probability of reaching flow targets during each month appears below.

Table ES-1. Probability of meeting instream flow targets under managed conditions

Month	Probability of Meeting Instream Flow Target in Selected Reaches*							
	Little Deschutes River	Upper Deschutes River	Middle Deschutes River	Tumalo Creek	Whychus Creek	Lower Crooked River	Metolius River	Lower Deschutes River
Jan	Low	Low	Very High	Very High	Very High	Very High	Very High	High
Feb	Low	Low	Very High	Very High	Very High	Very High	Very High	High
Mar	Low	Low	Very High	Low	Very High	High	Very High	Very High
Apr	Medium	High	Medium	Low	Low	High	Very High	High
May	Medium	Very High	Very Low	Low	Medium	Low	Very High	High
Jun	Medium	Very High	Very Low	High	Medium	Low	Very High	High
Jul	Very High	Very High	Very Low	Low	Very Low	Medium	Very High	High
Aug	Very High	Very High	Very Low	Very Low	Very Low	High	Very High	Very High
Sep	High	Very High	Very Low	Very Low	Very Low	Very High	Very High	Very High
Oct	Very Low	High	Medium	Medium	Very Low	Very High	Very High	Very High
Nov	Very Low	Very Low	Very High	Very High	Very High	Very High	Very High	Very High
Dec	Low	Low	Very High	Very High	Very High	Very High	Very High	Very High

*period of record varies for each reach

Key to Table ES-1

Percent of Days Meeting Target	Probability
80-100%	Very High
60-79%	High
40-59%	Medium
20-39%	Low
0-19%	Very Low

Federal and state regulatory approaches all have the potential to affect instream flow allocation in the Deschutes Basin. Federal approaches include the Wild and Scenic Rivers Act, the Clean Water Act, and the Endangered Species Act. State approaches include the State Scenic Waterways Act and instream flow rights to support aquatic life. Voluntary, market-based approaches, enabled by the state legal framework, provide the greatest opportunity for restoring instream flows in the Deschutes Basin. Tools available include instream transfers, leases, storage leases, allocation of conserved water. The Deschutes River Conservancy, local irrigation districts and state and federal partners are working together to restore water to reaches by using these tools.

The Deschutes Water Alliance (see foreword) intends to meet instream, agricultural and community needs for water resources. For the purposes of development of long-range planning scenarios for water management in the upper Deschutes Basin, the findings of this paper can be used as preliminary assessment of instream flow demands in the most altered reaches (see ES-2). Scenarios for meeting these needs and those developed in the other DWA papers may then be subjected to further analysis to assess the nature of their impact on the lower Deschutes, with the expectation that flows in this reach may also be improved under the scenarios for restoring flows in upper basin reaches.

Table ES-2. Summary of instream flow needs for DWA priority reaches

Reach	Storage Release Requirements (AF)	Conversion of Summer Irrigation Water Rights (cfs)
Upper Deschutes River	62,500	
Middle Deschutes River		218.5
Tumalo Creek		14
Wychus Creek		14
Lower Crooked River	18,000	

The total volume of water represented by these instream needs is just over 183,000 acre-feet. Over the course of a 214-day irrigation season, this volume is equivalent to a rate of 430 cfs. To put it in a larger context, it is 2% of total available water resources and 5% of unregulated blue water flow for the Groundwater Study Area portion of the upper Deschutes Basin. Despite the relatively minor portion of overall water this need represents, the technical, operational and financial challenge will be significant. At approximate current average costs for large conservation projects and instream transfers of $600/acre-foot the total price tag for projects would reach $110 million. However, it is likely this cost will rise as more costly conservation projects are brought on line. Social coordination in terms of the collaboration between a wide range of groups and individuals in the basin will also require a major effort and implies additional costs.

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1. Introduction

National and international interest in instream flow restoration has increased over the last three decades. A recent study found 207 methods to determine instream flow needs across 44 countries (Tharme 2004), demonstrating widespread interest in instream flow restoration. Motives driving river restoration efforts include ecosystem restoration, habitat restoration, flood control, recreation and aesthetics, floodplain reconnection, sediment management, bank protection, and water quality improvements (Whiting 2002; Wheaton 2005). Instream flow restoration efforts in the Deschutes Basin have followed the global trend and have increased over the last decade.

Instream flows are critical to the maintenance of floodplain, riparian, and aquatic ecosystems. A multitude of studies have suggested that instream flows drive ecological processes in these systems (e.g. Baron and Poff 2004; Thoms and others 2004; Poff and others 1997). In particular, Poff and others (1997) highlighted the rate and timing of discharge as critical factors for ecosystem health.

Water management affects the rate and timing of discharge and can reduce ecosystem health. Altering flows can reduce floodplain connectivity (Thoms and others 2004), negatively impact aquatic ecosystems (Baron and Poff 2004), and reduce biodiversity (Hauer and Lorang 2004). Periodic or prolonged droughts in a stream, including those caused by water management, can influence stream morphology and affect fish populations (Hakala and Hartman 2004). Flow alterations can also cause water quality impairments such as increased stream temperature.

Numerous studies outline the effects of stream flow alteration in the Deschutes Basin on water quality, habitat, and fish and wildlife (e.g. NPCC 2004; SWRB 1961; USDA 1997; USDA 1996a; UDWC 2003; Reclamation 1997; Aney and others 1967; Grant and others 1999). These alterations of the natural hydrograph come from withdrawals that reduce flow rates, reservoir storage that reduces flow rates, reservoir releases that artificially increase flow rates, and increases in groundwater recharge/discharge from irrigated agriculture. In 1961 the State Water Resources Board concluded that while "the total basin yield is adequate to supply all existing and contemplated future needs of water. . . simultaneous use of any major portion of existing rights results in flows at or near the zero level in many streams during the summer months" (SWRB 1961).

The state of Oregon has listed 1,219 miles of streams in the Deschutes Basin for water quality impairments under Section 303(d) of the Clean Water Act (DEQ 2002). These listings are primarily for temperature, dissolved oxygen, and pH impairments, but also included chlorophyll-a, turbidity, and sedimentation impairments. Stream dewatering from agricultural diversions has been identified as the most important factor contributing to these water quality impairments (UDWC 2003).

The Deschutes Water Alliance working mission includes the objective of moving stream flow 'toward a more natural hydrograph while securing and maintaining improved instream flows and water quality to support fish and wildlife.' The purpose of this paper is to quantify instream flow needs in the upper Deschutes Basin, particularly in those reaches affected by the storage and diversion of water by irrigation districts. The methodology employed is to identify the affected reaches, gather existing data and information on instream conditions and instream flow targets, identify existing senior instream rights and then develop quantitative estimates of stream flow restoration needed to meet flow targets. This information will then be used alongside other demands for water and the sources of supply to develop scenarios for meeting instream, agricultural and community needs over a 20-year time frame. This paper also, therefore, considers the monitoring and measurement needs required to verify flow and water quality outcomes.

The paper begins with a summary of the state and federal legal framework as it relates to instream flow protection. An introduction to water resource management at the scale of the upper Deschutes Basin is then provided based on existing data. The impacts of human settlement and a century and a half of water resources development are then briefly assessed in terms of the distribution and consumption of surface water and groundwater in the upper basin. The paper then turns to a reach-by-reach consideration of monitoring and measurement capability for flow and water quality, followed by a review of existing information and studies on the conditions and trends in each reach. The paper highlights water quality impairments, current instream flow status, instream flow targets, and critical periods for flow restoration in each reach. An effort is made at the end of each reach section to identify and quantify the instream flow required to meet stated targets.

2. Federal Legal Framework

Federal laws and related programs create a supporting framework for instream flow and water quality protection. Specifically, the Wild and Scenic Rivers Act, the Clean Water Act as amended (CWA), and the Endangered Species Act (ESA) provide regulatory mechanisms for protecting or restoring instream flows and water quality. Each of the following Acts provides a layer of regulatory protection for instream flows. Ultimately, however, instream flows can only be protected from diversion under state law.

2.1 Wild and Scenic Rivers Act

The federal Wild and Scenic Rivers Act created a program designed to protect the character of free flowing rivers. Enacted in 1968, the Wild and Scenic Rivers Act created several categories of rivers with different levels of protection for each category. The program is currently administered by the National Park Service.

Section 7 of the Wild and Scenic Rivers Act provides minimal protection for instream flows. Section 7 prohibits federal assistance to or the federal licensing of water resource development projects within listed sections of river. Additionally, Section 7 prohibits federal agencies from recommending any activities that will negatively affect the unique characteristics of a listed reach without adequately notifying Congress, the Secretary of Agriculture, and/or the Secretary of the Interior. Individual states administer management programs for each federally listed reach within their boundaries, and the federal government has authorization to acquire land along each reach to maintain the character of the river (16 U.S.C. 1271-1287). However, the Wild and Scenic Rivers Act does not authorize federal regulation of water diversions, nor does it authorize federal acquisition of instream water rights.

The Wild and Scenic Rivers System includes ten rivers in the Deschutes Basin. Six of these rivers are considered in detail in this paper (see Table 1). This paper does not considered instream flow issues on four of the Basin's Wild and Scenic Rivers: Crescent Creek, Big Marsh Creek, the White River, or the North Fork of the Crooked River. These rivers clearly provide ecological and social value, but they do not fall within the scope of the paper.

Table 1. Federal Wild and Scenic Rivers in the Deschutes Basin

Waterway	Description
Little Deschutes River	From its source to the north section line of Section 12, T26S, R7E
Middle Deschutes River	From Wikiup Dam to the Bend Urban Growth Boundary; From Odin Falls to the upper end of Lake Billy Chinook
Whychus Creek	Source to USGS Gage 14075000
Lower Crooked River	From the National Grassland boundary to Dry Creek
Lower Deschutes River	From the Pelton Reregulating Dam to the confluence with the Columbia River
Metolius River	From the Deschutes National Forest boundary to Lake Billy Chinook

Source: National Park Service (No date available)

2.2 Endangered Species Act

The Endangered Species Act (ESA) sets the preservation of biodiversity as its highest priority. Under the ESA, NOAA Fisheries or the United States Fish and Wildlife Service (FWS) list species as threatened or endangered. The ESA prohibits both federal actions that jeopardize listed species and private actions that result in the taking[2] of listed species. Court rulings have explicitly identified that habitat modification can lead to a taking even if the modification does not affect a specific individual member of the species (e.g. Babbitt v. Sweet Home 1995). The ESA authorizes for civil and criminal suits to be brought against entities that violate its substantive or procedural provisions (16 U.S.C. 1531-1544).

The ESA protects threatened or endangered populations or habitat of listed salmon and trout in the Deschutes Basin. Federal actions in the Klamath Basin have demonstrated the power of the ESA to change water allocation. In 2001, Reclamation released a proposed 2001 Operation Plan for the Klamath Project. Subsequently, NOAA Fisheries and FWS issued opinions that Reclamation's proposed 2001 Operation Plan would harm three listed species. Reclamation approved an alternative plan that protected these species but curtailed water deliveries to the Klamath Irrigation District (KID). KID sued the federal government claiming an illegal taking of their property (Klamath Basin Irrigators v. United States 2005). This case illustrates the difficulties associated with using regulatory approaches to protect instream flows.

The Deschutes River and its tributaries provide spawning habitat for several populations of ESA listed fish. Both wild summer steelhead and bull trout are currently listed as threatened under the

[2] In this context. take means to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (16 U.S.C. 1532)

ESA. Historically, these two species thrived throughout the Basin. However, flow modification and habitat degradation have reduced available spawning habitat and limited population sizes (ODFW 2003).

Historically, bull trout were found throughout the Deschutes River, the Little Deschutes River, and the lower Crooked River (NPCC 2004; ODFW 2003). Documented bull trout spawning currently occurs in the Warm Springs River, Shitike Creek, and the Metolius River and its tributaries. Bull trout have been found in lower Whychus Creek, the Crooked River, and the middle Deschutes River, but no documented spawning has occurred in those areas (ODFW 2003). According to ODFW (2003), the bull trout population has been increasing above Lake Billy Chinook since 1986. In all likelihood, this increase is due to restrictions on harvest. Spawning distribution has increased as harvest has increased (ODFW 2003).

Summer steelhead were historically found throughout the Deschutes Basin. Documented spawning occurred in the Crooked River and its tributaries and the Deschutes River its tributaries below Steelhead Falls (ODFW 2003). The elimination of fish passage at the Pelton Round Butte Project eliminated steelhead from the upper Deschutes Basin. Steelhead currently spawn throughout the lower Deschutes River and its tributaries (NPCC 2004; ODFW 2003).

The Pelton Round Butte Project may not limit steelhead populations in the future. As part of a hydropower re-licensing agreement, Portland General Electric and the Confederated Tribes of Warm Springs agreed to restore passage at the project and re-introduce anadromous fish to the upper Deschutes Basin. In particular, they plan to re-introduce steelhead to Whychus Creek and to tributaries of the lower Crooked River. The re-introduction of threatened species to the upper Deschutes Basin has the potential to affect future water allocation.

2.3 Clean Water Act

Congress originally intended the Federal Water Pollution Control Act Amendments of 1972, as amended and known as the Clean Water Act (CWA), to achieve the broad goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters. In the early implementation of the CWA, efforts focused on addressing discharges from traditional point-source facilities such as municipal sewage plants and industrial facilities. Implementation of the CWA led to water quality improvements in many of the nation’s degraded waterways.

The CWA’s emphasis over the last decade has evolved from a source-by-source, pollutant-by-pollutant approach to a holistic watershed-based approach. To make progress towards the goal, states develop water quality standards based on designated uses and water quality criteria. States monitor waterbodies to determine whether the water quality standards are met, and water bodies that do not meet water quality standards are placed on the state’s 303(d) list and reported to the EPA.

The EPA requires states to develop Total Maximum Daily Loads (TMDLs) for each pollutant entering a listed waterbody. The TMDLs describe the amount of each pollutant that the waterbody can receive without violating water quality standards. In conjunction with the TMDL’s, states develop Water Quality Management Plans that outline management activities which will be undertaken by agencies and landowners to help meet water quality standards in listed water bodies.

The CWA specifically does not affect existing water rights or the rights of states to allocate water (33 U.S.C. 1251). As the state develops TMDLs and Water Quality Management Plans, though, agencies or individuals may develop voluntary changes in water management that will help to meet the water quality standards. By highlighting factors limiting stream ecosystem health, the CWA has potential impacts water quality and quantity management in the Basin.

3. State Legal Framework

Oregon state laws and programs provide the primary basis for instream flow restoration in the Deschutes Basin. State actions range from early minimum flow regulations to instream water right legislation. The state's framework currently provides for instream water rights that are equivalent in status to consumptive use rights.

3.1 Minimum Perennial Stream Flows

The Oregon legislature recognized early on that water is a limiting resource in Oregon. In 1955, the legislature passed a comprehensive multiple purpose water bill which addressed instream flow needs (Bastasch 1998). The Act recognized the value of instream flows to support recreation, aquatic life, and pollution abatement, and it provided for the development and protection of minimum flows to support these activities (Bastasch 1998; OAR 690-076). The priority date of a minimum flow was the date on which the state requested the flow. The state set minimum flows on 547 reaches between 1958 and 1988 by administrative rule. The legislature repealed the state's authority to set additional minimum perennial flows in 1997.

The 1955 legislation contained three weaknesses. First, minimum flows were junior to senior water rights. Second, minimum flows were based on administrative rules, not on water rights. The state often suspended these rules to meet other objectives. The third weakness in the state's minimum flow standards came from its fish-centric approach to setting minimum flows. This weakness will be discussed further in other sections of this analysis.

3.2 Oregon Scenic Waterways

In 1970, Oregon voters passed the initiative that created the Scenic Waterways Act and initiated the Scenic Waterways program. The state lists waterways through this program in order to protect their unique scenic beauty, recreation, fish, wildlife, or scientific features (OAR 736-0040). The program lists waterways under six categories. Each category defines different management goals and allows different activities to occur along and adjacent to the river. The Oregon Parks and Recreation Department administers the Scenic Waterways program. Landowners wishing to pursue a new activity within a quarter mile of a Scenic Waterway may need to notify the Parks and Recreation Commission, and the Commission may deny this activity if it impairs the unique qualities of the waterway.

Many of the listed waterways' unique qualities depend on adequate instream flows (ORS 390.835). The Scenic Waterways program prohibits new activities in a Scenic Waterway area if those activities would impair flow and if that impaired flow would harm the unique qualities of the waterway. Oregon Senate Bill 1033, passed in 1995, added groundwater pumping to these regulated activities.

Table 2. State Scenic Waterways in the Deschutes Basin

Waterway	Description
Deschutes River	From Little Lava Lake to Crane Prairie Reservoir
Deschutes River	From the gaging station below Wickiup Dam to General Patch Bridge
Deschutes River	From Harper Bridge to the COID diversion structure near river mile 17
Deschutes River	From Robert Sawyer Park to Tumalo State Park
Deschutes River	From Deschutes Market Road Bridge to Lake Billy Chinook (excluding the Cline Falls hydroelectric facility near river mile 145
Deschutes River	From the Pelton Reregulating Dam to the confluence with the Columbia River (excluding the City of Maupin)
Metolius River	From Metolius Springs to Candle Creek

Source: Oregon Revised Statutes 390.826 (No date available)

3.3 Instream Water Rights

The majority of the Western states have established statutory or judicial methods to protect instream flows. Nine of the eleven states west of the Rockies use statutory methods to protect instream flows, one state relies on a court ruling, and one state has no statutory or judicial method to protect instream flows (Boyd 2003). Oregon was one of the first states to acknowledge that instream uses were beneficial and to create a framework for instream flow protection.

In 1987, the state legislature passed the Instream Water Rights Act and created the statutory framework necessary to establish instream water rights. OWRD holds these rights in trust for the public, but they can be purchased, leased, or gifted to the state by anyone (OAR 690-077). The rights are intended to provide public benefits such as fisheries enhancement, pollution abatement or recreation. OWRD regulates instream rights based on a rate, duty, and priority date in the same manner that they regulate traditional water rights. Instream flow rights may not injure other water rights holders, may not cause the enlargement of a water right, and may not exceed the flows necessary to increase public benefits (OAR 690-077).

3.3.1 Establishing New Instream Water Rights

The majority of instream water rights held by the state of Oregon are junior water rights. These junior rights are not often met during the summer irrigation season. Many of there rights were converted from minimum perennial stream flows and have the same 1955 or later priority dates as their predecessors. Additional junior instream flow rights have been created since 1987.

Three state agencies can apply for new instream water rights. When the Department of Environmental Quality (DEQ), Department of Fish and Wildlife (ODFW), or Parks and Recreation Department (OPRD) determine that instream flow rights are not adequate to provide the specified public benefits, they can apply to OWRD for additional instream flow rights (ORS 537.336). In general, instream water rights cannot exceed the estimated average natural flow of a stream. Oregon allows exceptions in streams where high-flow events, such as those that would allow for fish passage, would contribute to public benefits (OAR 690-077-0015).

ODFW has successfully applied for instream water rights to support fish populations in the Deschutes Basin. They calculated most of the instream flow requirements by using the Oregon Method. This early technique estimates the amount of water needed in a stream to support the spawning, rearing, and migration of salmon or trout based on the physical characteristics of the stream. For example, the Oregon Method assumes that salmon and trout generally require six inches of water to over a riffle and that Chinook require eight inches of water over a riffle (Marx, pers. communication 2005). While the Oregon Method does not account for as many spatial or temporal factors as more in-depth methods such as the Instream Flow Incremental Methodology (IFIM; FISRWG 2001), it does provide a preliminary estimate of ecosystem water needs.

When ODFW applies for an instream water right, they request both minimum and optimum flow rates for a given reach. The minimum flow rate would provide the minimum amount of water needed to sustain salmon and trout populations without allowing for harvest. The optimum flow rate would provide the amount of water needed to support populations that are large enough to allow for cultural, recreational, and commercial harvests (Marx, pers. communication 2005). These instream flow rates support fish populations but do not necessarily provide for ecosystem processes. The actual instream water right granted by OWRD depends on OWRD's estimate of average natural flow (EANF); in most instances, instream water rights do not exceed EANF (Marx, pers. comm. 2006).

3.3.2 Establishing Senior Instream Water Rights

The techniques described above create junior instream water rights. These rights preclude additional consumptive uses and provide water on paper, but they do not necessarily provide additional "wet" water instream. Protecting "wet" water instream requires the creation of instream water rights with senior priority dates.

Three techniques allow individuals or agencies to create senior instream water rights. First, individuals or organizations can lease an existing water right for instream use. Oregon's administrative framework allows individuals to lease all or part of their water right for instream use during all or part of the year (OAR 690-077). In the Deschutes Basin, the majority of leased water comes from irrigation districts and their customers. Water rights created through instream leases have the same priority date as the original water right.

Leasing water instream provides a flexible, low-cost technique for improving instream flows, but it does not permanently protect water instream. Oregon's legal framework allows individuals to permanently transfer existing water rights instream (OAR 690-077). Permanent water transfers allow individuals to transfer water off of their land while improving instream flows in the basin. They are often associated with a change in the character of the land from agriculture to other uses. As with temporary transfers, instream water rights created through permanent transfers have the same priority date as the originating water right that was transferred instream.

Oregon's Conserved Water program provides a third technique for creating senior instream water rights (OAR 690-018). This program is relatively unique within western water law (Boyd 2003). Oregon adopted its Conserved Water rules in 1987 to encourage water conservation and to promote local cooperation in instream flow improvement (Bastasch 1998). To be eligible for the Conserved Water program, a water rights holder needs to satisfy the use listed on their permit with less water than they have the right and ability to divert.

Water rights holders who implement water conservation projects can lease, sell, or transfer a portion of their conserved water. At least 25% of the conserved water goes to the state, which transfers the water instream if instream needs are not already met. The water rights holder receives a proportion of the remaining conserved water that depends on project funding. The proportion depends upon on what percentage of the Conserved Water project is funded through public sources and on any special agreements that financing partners have made with the water rights holder. Unless otherwise agreed upon, the water rights holder usually receives between 25% and 75% of the total conserved water. Instream water rights created through the conserved water program usually have the same priority date as the originating water right. The three techniques described above, leasing, transfers and conserved water can be used to place existing junior or senior water rights instream.

Non-profit organizations, government agencies, and individuals use the three techniques described above to place existing water rights instream. These institutions work through the state legal framework and apply economic tools to increase instream flows. In the Deschutes Basin, where the majority of the water rights are held by six irrigation districts, working with local communities is essential to restoring instream flows for recreation, abating pollution, and supporting aquatic life. For example, the DRC uses leasing, permanent transfers, and conserved water to improve instream flows while benefiting local water rights holders.

3.4 Deschutes Groundwater Mitigation Program

The use of available surface water resources for irrigated agriculture in Central Oregon began in the 1860s and accelerated at the turn of the century. Surface water rights in the Deschutes Basin have been limited since the early 1900's. In the 1990s, growth and development in Central Oregon led municipalities, developers and small irrigators to turn to groundwater to supply new water needs. Growing demand for groundwater led to concern that the groundwater permitting process ignored the potential for groundwater withdrawals to impact surface waters. A century of geologic and hydrologic investigation suggested that surface water and groundwater in the Basin were hydraulically connected.

In 1995, the concern that further groundwater development could affect Scenic Waterway flows led OWRD to condition groundwater permit approvals with the possibility that mitigation would be required. From 1998 onwards, groundwater permit applications were put on hold pending the outcome of a collaborative examination of groundwater in the upper Deschutes Basin. The study, carried out by USGS and OWRD and released in 2001, confirmed that snowmelt infiltrates into the ground and recharges the underlying aquifers and that aquifer discharge provides much of the surface water to streams in the Deschutes Basin (Gannett and others 2001).

The results suggested the potential for groundwater withdrawals to impact surface water flows and cause injury to surface water rights holders, including junior instream rights.

A multi-year process led to a series of innovative ideas for a groundwater mitigation program but consensus on the program was never reached. In 2002, the Water Resources Department put forward a program intended to offset withdrawals on a long-term volumetric basis. The Water Resources Commission approved rules for the implementation of the Deschutes Groundwater Mitigation Program in September 2002 (OAR 690-505). The program allows for water development while mitigating for the effects of groundwater withdrawals on surface water flows in the Basin.

Groundwater permit applicants need to acquire groundwater mitigation credits in order to receive a groundwater permit. These credits mitigate for the applicants' annualized consumptive water use, which varies with the type of use. The program suggests that credits may be established through instream transfers, aquifer recharge, storage release and conserved water projects. State-chartered groundwater mitigation banks may use temporary transfers to establish credits subject to holding an equal amount of credits in reserve (OAR 690-521). Applicants may acquire permanent credits from individuals or they may purchase temporary credits through a mitigation bank. The only mitigation bank currently operating in the Deschutes Basin is the Deschutes River Conservancy's Groundwater Mitigation Bank (GMB). Three years into the program only leases and transfers have been used to create mitigation credits.

The Groundwater Mitigation Rules established for the Deschutes Basin do not require drop-for-drop mitigation of groundwater withdrawals on a specific temporal and spatial schedule. Instead, they allow groundwater applicants to mitigate for the effects of their groundwater withdrawals under an annual, zone-based framework. OWRD has delineated zones of impact (ZOI) where groundwater withdrawals will theoretically affect specific reaches in the basin. For example, a groundwater applicant in Whychus Creek ZOI may obtain credits established through an instream lease in Whychus Creek. The applicant may withdraw water year-round, but the instream lease is only effective during the irrigation season.

Concerns regarding timing (and other issues) led to a prima facie lawsuit by a number of protestants, including WaterWatch of Oregon against the program rules. The suit was decided in favor of the protestants in early 2005. Subsequently HB 3494 was passed by the legislature. The law confirmed the legislature's intent that the program rules govern the program and the allocation of new groundwater permits in the Deschutes.

The Mitigation Rules set a 200 cfs cap on final orders for new groundwater permits in the Deschutes Basin. Once 150 cfs of final orders are in place OWRD must initiate a review of the program. In March 2006, permit applications in the Deschutes Basin surpassed 200 cfs. New groundwater applications can be filed after March 2006, but OWRD is currently not processing those applications until after it processes the pre-March 2006 applications.

4. Water Resources Assessment: upper Deschutes River Basin

Precipitation inputs and net inter-basin transfers of groundwater determine the water resources available in a river basin for ecosystem and human uses. In terms of long-term basin water balance this water is either consumed through evaporation or transpiration or runs off to surface waters. Evaporation occurs from water on ground, vegetative or other surfaces, and from soil moisture. Evaporation is also associated with human domestic, industrial and commercial uses. Transpiration occurs from plant and animal respiration as part of organism growth and maintenance. Water discharge from a basin may come from surface water runoff or from the percolation of water through to the water table as aquifer groundwater recharge, which in turn ultimately discharges to surface waters. Water resources in a basin are available for human and ecosystem use, either directly through capture, diversion, withdrawal, or instream use or indirectly through the harvesting of plants and animals that use this water for growth.

Previous studies of groundwater resources, combined with available information about surface and groundwater use, allows for an estimate of basin water balance for a significant portion of the upper Deschutes Basin known as the Groundwater Study Area (GSA). Estimates for these flows can be derived under current and pre-settlement conditions. As employed below the term ‘regulated’ refers to current situation in which river flows are regulated for human uses and the term ‘unregulated’ refers to estimates of flows under ‘natural’ conditions, i.e. pre-settlement. Understanding basin water balance under regulated and unregulated conditions provides information about the impact of human use on ecosystems, as well as indicators of the sustainability of this resources use.

This assessment begins with an overview of the Deschutes Basin and its hydrology. The post-settlement regulation of water resources through their development for human uses is then described. The methods, data and results for the assessment of water resources under regulated and unregulated conditions is then provided. Comparison of regulated and unregulated flows provides a useful characterization of the availability of water resources, their uses and information on the degree to which the different components of the hydrologic system have been affected by settlement.

4.1 Overview of Basin Hydrology

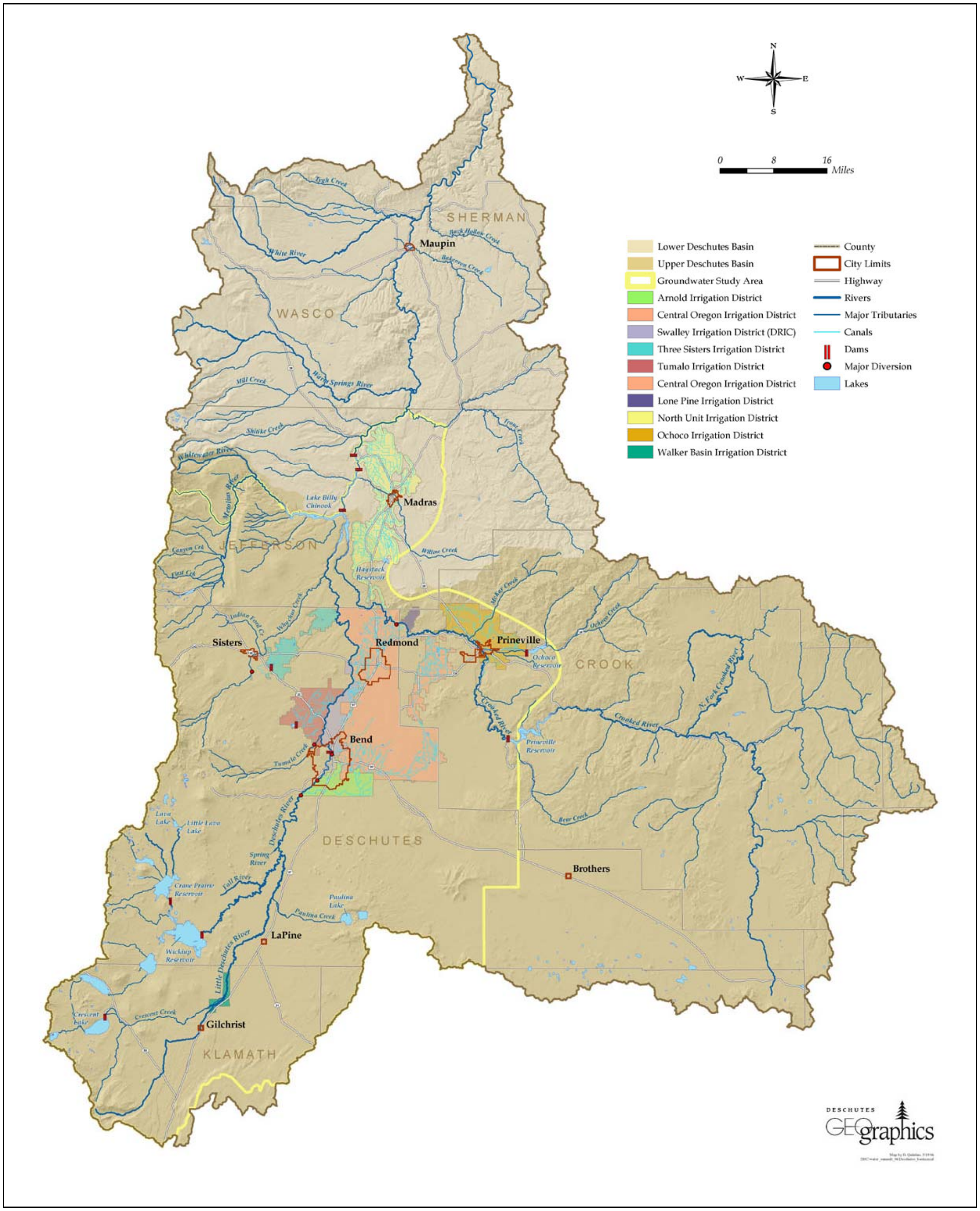
The Deschutes Basin is the second largest river basin in Oregon covering 10,700 square miles. The counties of Crook, Deschutes, Jefferson, Sherman and Wasco make up a majority of the basin. Central Oregon, defined in this paper as Crook, Deschutes and Jefferson counties, constitute 73% of the basin (see Table 1). Central Oregon is roughly congruent with the upper Deschutes Basin, defined as the area above the confluence of the Metolius, Deschutes and Crooked Rivers and above the bulk of the groundwater discharge that happens above, in and just below the Pelton-Round Butte complex (see Figure 1). Total area for the upper basin is just over 5,000 square miles. Another important hydrologic unit is the regional aquifer through which a large amount of the precipitation input passes on its way to discharge in the confluence area.

Table 3. Land area and precipitation

	Land Area		Rainfall	
	acres	square miles	total ac-ft / yr	inches / yr
1. Administrative Areas				
Crook	1,914,231	2,991	1,674,952	10.5
Deschutes	1,955,191	3,055	1,955,191	12.0
Jefferson	1,146,235	1,791	974,299	10.2
Subtotal - Central Oregon (3 counties)	5,015,656	7,837	4,604,442	
Wasco	1,533,433	2,396	1,904,012	14.9
Sherman	531,838	831	660,365	14.9
Subtotal - Five counties	7,080,927	11,064	7,168,820	
2. Hydrologic Areas				
Drainage Basins				
A. Deschutes Basin	6,847,968	10,700		
B. Upper Deschutes Basin	5,004,800	7,820		
Groundwater Unit – Aquifer				
C. Groundwater Study Area	2,879,987	4,500	7,890,340	32.88

Sources: County websites, Gannett and others 2001, NWPCC 2004

Figure 1. Deschutes Basin



Despite being largely a high elevation, semi-arid plateau Central Oregon has relatively abundant surface and groundwater resources. Drainage and aquifer recharge from precipitation in the eastern Cascade Mountains provides the majority of the water resources in the Deschutes Basin above Lake Billy Chinook. Annual precipitation, mostly due to orographic effects, exceeds 200 inches per year in the mountains. Precipitation at lower elevations, in the rain shadow of the mountains, is ten inches per year or less (Gannett and Lite 2004). Variability in precipitation occurs on a year-to-year and on a decadal time scale.

In Central Oregon, water that moves through the aquifer discharges into streams throughout the upper Deschutes Basin (Gannett and others 2001). These discharges occur most noticeably at the headwater of the Metolius River and near the confluence area of the Deschutes, Crooked and Metolius Rivers at Lake Billy Chinook. This upwelling of groundwater is largely due to the intersection between the younger Deschutes Formation and the older John Day Formation. The groundwater flows through the permeable Deschutes Formation until it runs into the impermeable John Day Formation. Groundwater flows upwards and emerges as springs at the surface. In hydrologic units that drain to the Crooked River, soils and geology are largely of the impermeable John Day Formation. Little groundwater recharge occurs in these hydrologic units, and runoff patterns vary rapidly with precipitation.

4.2 Water Resources Development

Prior to the arrival of white settlers to Central Oregon in the late 1800's there was little modification of the water cycle by local tribes. Records suggest that the first whites to over-winter in the Basin were cowboys on a cattle drive through to Idaho in 1862. In the next century the hydrologic regime was modified in five principle ways by the settlers:

- Ecosystem simplification through eradication of beavers and their dams, channelization and dredging of streams and the removal of riparian vegetation – changes that reduced water storage, evapotranspiration and increased the 'flashiness' of the hydrograph

- Damming and diversion of waters from creeks, streams and rivers; first as individual uses at prime locations and, subsequently, as large irrigation schemes at the few places where gravity could feed large tracts of land (principally, at Bend, above Sisters and above Prineville) – changes that reduced or dried up stream flow at specific points (and downstream) in mid-basin during summer irrigation periods, increased groundwater recharge rates from canal and ditch transmission loss and on-farm inefficiencies, and raised evapotranspiration rates (from natural vegetation to crops and pasture)

- Damming and impoundment of waters in large reservoirs (in cases augmenting natural storage) for irrigation and flood control – changes that reduced stream flow during winter months in the headwaters and increased evaporation and groundwater recharge rates

- Damming and impoundment of waters in large run-of river reservoirs for hydropower (the Pelton-Round Butte complex) – changes that alter the daily and weekly hydrologic regime in the Lower Deschutes, effectively blocked downstream migration of anadromous fish, and increased evaporation and groundwater recharge rates

- Drilling wells and pumping groundwater for domestic use, municipal and industrial use and for irrigation – changes that reduced groundwater storage and affected groundwater discharge to streams, and that increased evapotranspiration rates

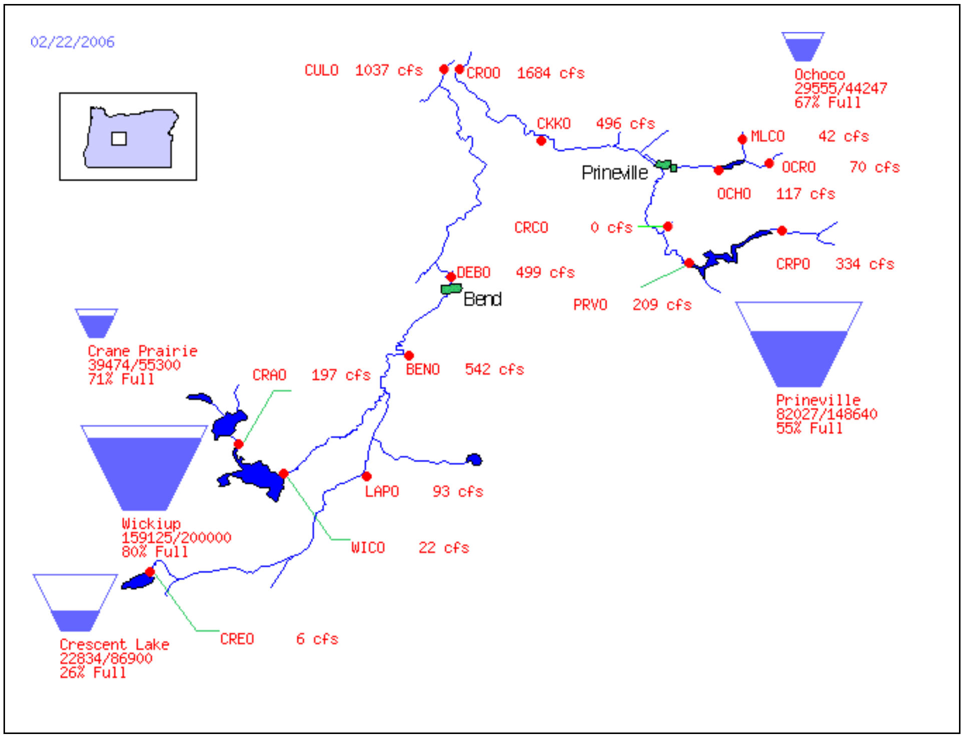
Table 4. Major diversions and storage reservoirs in Central Oregon

Storage / Diversion (from upstream to downstream)	Year Constructed or Rehabilitated	Owner	Entity Responsible for O&M	Notes
Upper Deschutes River				
Crane Prairie Dam and Reservoir	1940	United States	COID[1]	55,300 AF of active storage
Wickiup Dam and Reservoir	1942	United States	North Unit ID[1]	200,000 AF of active storage
Crescent Creek				
Crescent Lake		Tumalo ID	Tumalo ID	
Little Deschutes				
Walker Basin Headworks and Main Canal		Walker Basin ID	Walker Basin ID	Max diversion of 38 cfs
Middle Deschutes River				
Arnold Diversion Dam	1951	Arnold	Arnold	Max diversion of 150 cfs
Central Oregon Diversion Dam and Canal (CO Canal)	1900	COID	COID	Max diversion of 1382 jointly with Pilot Butte Canal
Siphon Power Plant		COID	COID	* MW off-stream hydropower with max diversion of * cfs
Mirror Pond Dam and Power Plant	1912-1914	*	*	1 MW instream hydropower
Tumalo Headworks and Bend Feed Canal	*	Tumalo	Tumalo	Piping of Canal finished 2005; Max pipe capacity of *
North Canal Diversion Dam and Pilot Butte Canal	1900	COID	COID	Max diversion of 1382 cfs jointly with CO Canal
North Unit Headworks and Main Canal	1949	United States	North Unit[1]	Max Diversion of 1101 cfs
Swalley Headworks and Main Canal	1899	Swalley ID	Swalley	Max Diversion of 125 cfs
Haystack Dam and Equalizing Reservoir	1957	United States	North Unit[1]	5,600 AF of active storage
Tumalo Creek				
Tumalo Headworks and Tumalo Feed Canal		Tumalo ID	Tumalo	Max Diversion of 214 cfs
Wychus Creek				
Three Sisters Headworks and Main Canal		Three Sisters ID	Three Sisters	Max Diversion of 153 cfs
Crooked River				
Arthur R. Bowman Dam and Prineville Reservoir	1961	United States	Ochoco ID[2]	148,640 AF of active storage
Crooked River Diversion Dam and Feed Canal	1961; 2000	United States	Ochoco[1]	
Central Ditch, People's Ditch, Rice Baldwin ditch, Lowline Ditch		Private	Private	Divert Crooked River and Prineville water
Crooked River Pumping Plant	1968	North Unit	North Unit	Max pumping capacity of *
Ochoco Creek				
Ochoco Dam and Reservoir	1918-1920;	OID	OID	39,000 AF of active storage; 5,266

	1950; 1995			AF of dead storage via pump
Ochoco Main Canal	1917	OID	OID	Max diversion of 211
Rye Grass Canal	1897	OID	OID	

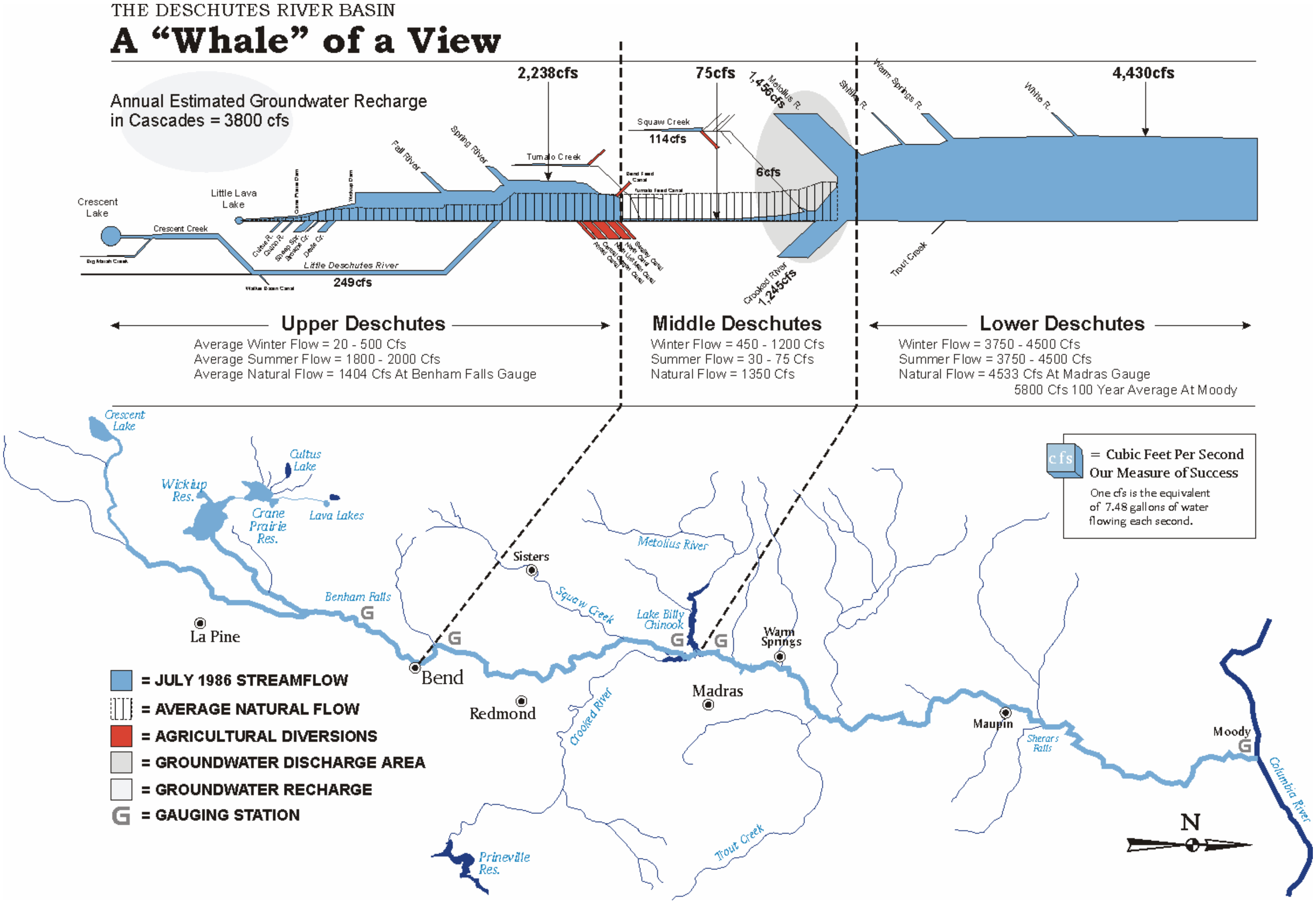
Source: Bureau of Reclamation (2005), district water right certificates
Notes: *Figures not yet obtained. Max diversions will be actual diversion during the period 1980 to 2005. [1]These are "Transferred Works"; facilities in which daily responsibility for O&M activities are transferred to and financed by the irrigation district. [2]These are "Reserved Works"; facilities in which the O&M is the responsibility of the United States. Daily O&M responsibility may be contracted to another entity, but the United States maintains the financial responsibility.

Figure 2. Reservoir levels and stream/canal gaging: The 'Teacup' Diagram showing gage readings for February 22, 2006



Major diversions and storage projects are summarized in Table 4 and their approximate spatial location provide in Figure 1 and Figure 2. The latter figure is called a 'teacup' diagram as it portrays the reservoirs status as teacups. The figure is used by water managers as it quickly conveys information on reservoir levels, stream flow and canals. The teacup diagram demonstrates that the Upper Deschutes Basin is a highly managed system. This is further revealed in Figure 3 which charts flow rates from headwaters through the mouth of the Deschutes River under unregulated and under regulated conditions. As shown in the figure (and discussed in further detail later in this paper), summer diversions virtually dewater the Deschutes River below Bend in the summer (to 2% of unregulated flow) and winter storage does the same to the Deschutes River below Wickiup and Crane Prairie Reservoirs (to 4% of unregulated flow).

Figure 3. The 'Blue Whale:' Flow Regulation in the Deschutes



4.3 Methods and Data

In 2001, the USGS completed a comprehensive study of groundwater in the upper Deschutes Basin. Available information on water resource use and availability largely pertains to the Deschutes Groundwater Study Area (GSA). The GSA effectively includes the available water resources in Central Oregon; it encompasses the permeable aquifer underlying much of Central Oregon. It excludes a large portions of eastern Crook County, particularly the North and South Forks of the Crooked River above Prineville Reservoir and Ochoco Creek above Ochoco Reservoir. The GSA covers 4,500 $miles^2$ whereas the three counties cover 7,837 $miles^2$. Precipitation and groundwater information comes from the GSA. Groundwater resources in Central Oregon are extremely limited outside of the GSA and groundwater flux is comparatively minor (Gannett and others 2001). The figures presented below reflect water resource fluxes as calculated for the Study Area by the USGS study (Gannett and others 2001; Gannett and Lite 2004). Where updated data is available on water resource use this is incorporated into the analysis as described below.

Total GSA water balance under regulated and unregulated conditions is calculated using the following step-wise approach:

1. Total inflow of water resources under regulated and unregulated conditions are derived from precipitation input and net inter-basin transfer of groundwater.

2. Total outflows under regulated conditions are obtained from gage data.

3. Total evapotranspiration under regulated conditions is calculated from total inflow less total outflow.

4. Total evapotranspiration under unregulated conditions is calculated from total evapotranspiration under regulated conditions less the increment in evapotranspiration due to human uses under regulated conditions

5. Total outflow under unregulated conditions is calculated based on total inflow less total evapotranspiration.

Data used for this assessment comes from sources delineated by county boundaries and by hydrologic units (including aquifers). This study attempts to reconcile the different data boundaries and adjust values to fit the GSA. While inconsistencies may be present, the study attempts to provide only an estimate of water use and availability. While the GSA represents only 57% of the land area of upper Deschutes Basin it accounts for the vast majority of precipitation and stream discharge, as described further below. Further, for the purposes of the Deschutes Water Alliance, all the major irrigation districts in Central Oregon are within the boundaries of the GSA. For this reason, the assessment of the GSA provides a useful characterization of water resources in Central Oregon.

4.4 Results

Step 1. Total Inflow of Water Resources

Gannet and others (2001) suggest average precipitation across the GSA of 30 in/yr, for a total of 7.2 million ac-ft. or an annualized rate of approximately 10,000 cfs. Water balance analysis and application of Darcy flow calculations by Gannett and others produces an estimate that a further 850 cfs of subsurface inflow enters the groundwater system from adjoining areas, primarily along the Cascade crest (Gannett and Lite 2004). Total inflow of water resources to the Study Area are thus approximately 10,850 cfs or 7.8 million ac-ft/yr. This inflow applies under both regulated and unregulated conditions.

Total average groundwater recharge in the Study Area from precipitation is estimated at 3,800 cfs (11.4 in/yr) or 2.7 million ac-ft/yr[3] (Gannet and others 2001). This varies from 1 in/yr, or 5% of precipitation, at lower elevations to more than 130 in/yr, or 70% of precipitation, in the high Cascades. Intra-annual variability of recharge is considerable, ranging from 3 in/yr during drought to 23 in/yr during wet periods. Seasonal variation also occurs, as the 84% of recharge occurs between November and April. Between April and May, evapotranspiration depletes soil moisture and recharge rates approach zero. Adding in inter-basin transfer of groundwater produces an estimate of total groundwater recharge under unregulated conditions for the Study area of 4,650 cfs.

Gannett and others (2001) further report that almost 500 cfs is artificial recharge due to the onset of irrigated agriculture and subsequent water loss and seepage in the GSA. This is equivalent to 11% of unregulated recharge. Total recharge under regulated conditions thus exceeds 5,000 cfs on an annual basis.

Step 2. Outflows under Regulated Conditions

The Madras gage on the Deschutes River provides information on the outflow of water from the upper Deschutes Basin. This gage is located below the Pelton-Round Butte hydropower complex. As part of the Pelton Project relicensing, Portland General Electric calculated the average discharge for each major tributary entering Lake Billy Chinook (Table 5). PGE also estimated ungaged inputs. These were largely due to upwelling of groundwater within the Lake itself. Based on data collected since the gage began operations in 1932, average discharge from the basin is approximately 4,550 cfs.

Table 5. Inflows to and Outflows from Lake Billy Chinook

River	Average Flow (cfs)	Percent of Total Flow
Deschutes	915	20%
Crooked	1,568	34%
Metolius	1,491	33%
Ungaged Inputs	579	13%
Lower Deschutes	4,553	100%

Source: PGE 1999. Application for 401 Certification, Table 3.2-1

[3] Note that in calculating recharge figures Boyd (1996) assumes that irrigated land is equivalent to sage and thus works with a pre-settlement land use mosaic.

The USGS Deschutes Groundwater Study used data from a 1962 through 1997 period of record for its assessment of precipitation inputs. Data from the Madras gage for this period of record produces an average discharge of approximately 4,650 cfs. In order to account for the portion of flow derived from the area outside the Study Area (i.e. above Prineville and Ochoco Reservoirs) flow from these dams for the period must be deducted to arrive at blue water figures for the GSA (and not the entire upper Deschutes Basin). As suggested by Boyd (1996) and verified by subsequent analysis of gage data from 1962 through 1997 the mean annual release from these reservoirs totals just 390 cfs. A preliminary total for outflow is then 4,275 cfs (4,665 cfs less 390 cfs). However, Gannett and others (2001) report that an additional 81 cfs of groundwater discharge enters the Deschutes below the Madras gage. Adding this discharge to the preliminary total, suggests GSA outflows under regulated conditions of approximately 4,350 cfs (4,275 cfs plus 81 cfs) or 3.1 million ac-ft/yr.[4] This is roughly 40% of total inflow to the GSA.

Step 3. Evapotranspiration under Regulated Conditions

In order to obtain total water consumption (evapotranspiration) under current regulated conditions, basin outflows under regulated conditions can be subtracted from total inflows. The resulting figure suggests that evapotranspiration under regulated conditions in on the order of 6,550 cfs or 4.75 million ac-ft/yr. This represents 60% of the total inflow of water resources.

Step 4. Evapotranspiration under Unregulated Conditions

If the change in the consumptive use of water in the GSA from natural to current conditions is known then unregulated evapotranspiration can be derived from the figure above for regulated evapotranspiration. Changes in evapotranspiration from direct human uses of surface water and groundwater use can be roughly estimated and are included here. Estimation of broader changes in evapotranspiration due to broader changes in land use and vegetation, as well as changes in surface water storage, are beyond the scope of this study and are not explored here.

The principal human consumptive uses of water are for irrigated agriculture, and municipal and industrial supply. The increase in evapotranspiration from irrigated agriculture is the difference between current crop water use and water use under the preexisting ecosystem type, assumed here to be sage and juniper. Irrigation use is based on 160,000 acres of irrigated land in the GSA (Gannett and others 2001). Irrigated land is allocated to irrigated pasture and crop production based on the respective shares in irrigated agriculture in Central Oregon (as reported in the companion DWA Issues Paper on *Growth, Urbanization and Land Use Change* based on 2002 census data from the USDA National Agricultural Statistical Services). Expected crop water requirement for pasture and crops are derived from Cuenca (1992). Sage and juniper use calculated as available rainfall during the irrigation season (from Cuenca 1992) which is assumed to be completely consumed under sage and juniper cover as per Gannett and others

[4] The gage below Prineville Reservoir is available for the 1962 to 1997 period, however time series data for the gage below Ochoco Reservoir only begins in 1966. As the annual average outflow from Ochoco Reservoir is only 35 cfs this is unlikely to greatly affect the assessment.

(2001). Results suggest a total crop water use of 360,000 and almost 310,000 acre-feet of net consumption or about 430 cfs of water consumed on an annual basis.

Additional surface water use comes from the last remaining significant use of surface water for municipal water supply: the City of Bends diversion of water from Bridge Creek (a tributary of Tumalo Creek). The City of Bend pumps 4 billion gallons a year of which roughly half comes from Bridge Creek (Griffiths, pers. com 2006). With a 40% consumptive use rate for municipal use this is equivalent to a consumptive use of approximately 2,500 acre-feet or just over 3 cfs on an annual basis.

Estimates of groundwater use are found in Gannett and others (2001). A rough estimate of figures for consumptive use from groundwater appropriation total 27 cfs on an annual basis. However, the figures from Gannett and others (2001) are ten years old and require updating, particularly those for private domestic use and for municipal water supply.

Gannett and others (2001) estimated private domestic use of 2 cfs. This figure is low. Under Oregon law and rule, wells for domestic purpose and up to one-half acre of irrigation are exempt from permitting requirements. Construction of new wells is reported by drilling companies to OWRD, but there are no requirements for monitoring of use. The actual pumping from these wells in Central Oregon is therefore unknown. The OWRD regional office reports that there are 20,000 exempt wells in the upper basin (Gorman, pers. comm 2006). With a current population in Central Oregon unincorporated areas of 78,000 this yields a reasonable number of residents per household (3.8) considering that some rural homeowners associations and resorts will have quasi-municipal rights rather than exempt wells. Based on the number of wells OWRD calculates a total use of 22,400 acre-feet of which just under 9,000 acre-feet is the consumed portion at a 40% consumptive use rate (Gorman, pers. comm. 2006). Approaching this calculation by dividing exempt use into likely domestic needs and lawn/irrigation needs suggests that this figure is roughly accurate if exempt wells on average irrigate a quarter of an acre. Such a calculation suggests that due to the seasonality of demand for lawn irrigation, the rate pumped will vary from 9 cfs during the winter to over 50 cfs during the summer, with an annualized average of 12 cfs.

Gannett and others (2001) provide a figure for consumptive use from public water supply pumping of 10 cfs. This number can be updated by using numbers provided by Central Oregon municipal water suppliers. In the companion DWA Issues Paper on *Groundwater Demand* a figure of 39,800 acre-feet is provided as current municipal annual groundwater demand. Adjusting for consumptive use yields a figure of almost 16,000 acre-feet or 22 cfs on an annual basis.

Total consumptive use of groundwater is therefore roughly 50 cfs or 1.1% of estimated total annual flux of 4,600 cfs (from precipitation and inter-basin transfer).

In conclusion, the bulk of the change in consumptive use comes from additional evapotranspiration caused by the conversion of a portion of the basin to irrigated agriculture from natural vegetation. Of the change in consumptive use under regulated conditions, 89% is from irrigated agriculture and the remaining 11% is from residential, commercial and industrial uses. Evapotranspiration in the high desert with an annual precipitation input on the order of 10 to 12 inches – much of which falls during the winter and early spring – is greatly affected by the change to cropping or pasture and the application of from 24 to 66 inches of irrigation water.

The total net increase in consumptive use since settlement occurred is estimated to be just under 350,000 ac-ft/yr or approximately 480 cfs on an annualized basis (Table 6).   Evapotranspiration under unregulated conditions is thus estimated to be approximately 6,000 cfs or 4.4 million ac-ft/yr.

Table 6. Consumptive Uses in the Groundwater Study Area

Consumptive Use	Calculated Annual Volume (ac-ft)	Approximate Rate (cfs)	Source
1. Surface Water Uses			
Conversion of sage and juniper and grassland ecosystems to irrigated farmland	309,580	428	Own Calculations (see text); Boyd (1996) cites Glover (1994) as stating the figure is 320,000 ac-ft
Surface water diversion for municipal use	2,451	3	City of Bend usage of Tumalo Creek water rights (see text)
Surface water evaporation (net increase)			Unknown – increase from reservoirs assumed to balance with loss of standing water from beaver dams and wetlands
Subtotal Surface Water	312,031	~430	
2. Groundwater Uses			
Groundwater pumped for irrigation	11,057	15	Gannett and others (2001)
Groundwater pumped for public supply	15,892	22	updated based DWA Paper on Groundwater Demand; Gannett and others (2001) estimated 10 cfs
Groundwater pumped for private domestic	8,946	12	updated based on OWRD estimates (see text); Gannett and others (2001) estimated 2 cfs
Subtotal Groundwater	35,895	~50	
3. Total Consumptive Use	347,926	~480	

Notes: As analysis is of annual consumptive use, the rate is the annualized value for the calculated acre-feet of consumption. Actually maximum instantaneous rates will be higher based on actual season of use.).

Step 5. Outflows under Unregulated Conditions

With figures for total available water resources and water consumed under unregulated conditions in hand, basin discharge is merely the remainder. Basin outflows under natural, unregulated conditions are therefore roughly 4,800 cfs or 3.5 million ac-ft/yr. As a result, consumptive uses under current conditions are estimated to consume approximately 10% of water resources previously available under unregulated conditions.

4.5 Findings and Conclusions

In sum, human settlement and economic development have had the following impact on water resources in the GSA:

- Stored and diverted a large portion of stream flow, altering stream hydrographs and decreasing summer and winter stream flows in specific places and reaches by 96% to 100%

- Rerouted surface water flows to increase groundwater recharge by approximately 11%, through transmission and on-farm losses from irrigated agriculture

- Led to increased consumption (evapotranspiration) on the order of 350,000 acre-feet of water per year (480 cfs) which is equivalent to about 10% of mean annual stream discharge

- Led to the consumption of just over 1% of the annual groundwater flux via groundwater pumping.

Human activities have impacted water resources in Central Oregon in a number of ways. First, the re-regulation of surface water for irrigation purposes has had major changes on summer and winter hydrographs of the Deschutes River and its tributaries. Second, basin outflow from Central Oregon has been altered in two ways: a reduction in surface water through its diversion and consumption by irrigated agriculture, and a rerouting of surface water from the Deschutes River above Bend to the lower Crooked River above Lake Billy Chinook via the groundwater system. While this rerouted surface water is available below Lake Billy Chinook, it is not available as stream flow in the Deschutes River and its tributaries.

Even given these impacts, the overall change in water consumption remains minor. Still it is worth emphasizing that there has been a net decrease in basin discharge due to the consumption of 10% of upper basin outflow. A further question that is not answered by the annualized water balance approach employed above is how have flows been altered in the lower Deschutes River as a result of all of the changes in water management in the upper basin. As discussed later in this paper there are seasonal differences observed with the bulk of the shortfalls evidenced during the February through June period (see Figure 10)

Still the net consumption of groundwater remains relatively small. The consumption of groundwater increased by roughly 50 cfs, largely over the last half century, but artificial recharge of the groundwater system increased by roughly 500 cfs over the last century. In other words, the increase in recharge was approximately 10 times the withdrawal. For the foreseeable future a growth in groundwater pumping appears likely, just as efforts to pipe and line canals are also likely. Thus, these percentages and ratios will change over time.

Further effort to assess how these figures may change in the future is taken up in the companion DWA Scenarios Paper – where long run changes in water management are projected and evaluated in order to guide current and future decisions.

Human activities in the upper Deschutes Basin have altered the water resource regime in the basin, but on balance the impacts have been modest compared to other basins around the world.

This assessment confirms that the most dramatic modifications to the water resources regime are the extreme low flows found below irrigation district diversions in the upper Deschutes Basin. The remainder of the paper drills down into these reaches in order to assess the quantity of water these reaches require to meet current state targets for fish and wildlife.

5. Reach Assessment

5.1 Study Area

The reaches included in this study span a large part of the Deschutes Basin. The assessment area can be divided into four subbasins based on 4^{th} field hydrologic unit boundaries: the Upper Deschutes Subbasin, the Little Deschutes Subbasin, the Lower Crooked Subbasin, and the Lower Deschutes Subbasin. Descriptions of reaches in the Upper Deschutes Subbasin and the Little Deschutes Subbasin have been adapted with permission from the Upper Deschutes Watershed Council's Water Quality Monitoring Program Quality Assurance Project Plan (UDWC 2006). This assessment focuses on the following eight reaches (organized by subbasin and watershed):

- Little Deschutes Subbasin; Little Deschutes River
- Upper Deschutes Subbasin:
    - Upper Deschutes Watershed; upper Deschutes River
    - Upper Deschutes Watershed; middle Deschutes River
    - Metolius River Watershed; Metolius River
    - Tumalo Creek watershed; Tumalo Creek
    - Whychus Creek watershed; Whychus Creek
- Lower Crooked Subbasin; lower Crooked River
- Lower Deschutes Subbasin; lower Deschutes River

5.1.1 Little Deschutes Subbasin

The Little Deschutes Subbasin contains seven watersheds based on 5^{th} field hydrologic unit boundaries. These watersheds include: Newberry, Little Deschutes, Long Prairie, Sellers, Walker Mountain, Upper Little Deschutes, and Crescent. Headwater tributaries to the Little Deschutes River include Clover Creek and Hemlock Creek (UDWC 2006).

Little Deschutes watershed:

Little Deschutes River: The river flows north from its headwaters approximately 97 miles to the Deschutes River. **This reach is included in this study**. Major tributaries include Crescent Creek and Paulina Creek. The headwater of Crescent Creek is Crescent Lake, a natural lake that has been turned into a reservoir. The headwater of Paulina Creek is Paulina Lake, another natural lake that has been converted into a reservoir. Paulina Creek, although considered a tributary of the Little Deschutes River, does not have enough flow in most years to reach the river and dissipates into Paulina Prairie. (UDWC 2006)

5.1.2 Upper Deschutes Subbasin

The Upper Deschutes Subbasin includes four watersheds based on 5th field hydrologic unit boundaries: the Upper Deschutes watershed, the Metolius River watershed, Whychus Creek watershed, and Tumalo Creek watershed (UDWC 2006).

Upper Deschutes watershed:

The source of the Deschutes River is both run-off and groundwater. While run-off provides for peak flows, groundwater provides for summer baseflows (Gannett and others 2001). The Deschutes River flows south from Little Lava Lake to Crane Prairie Reservoir, travels east through Wickiup Reservoir, north through Bend, and finally north to Lake Billy Chinook. The upper Deschutes River is approximately 132 miles long, and contains sub-watersheds based on 6th field hydrologic unit boundaries (UDWC 2006).

Above Wickiup Reservoir: The Deschutes River begins at Lava and Little Lava lakes at river mile (RM) 253 then flows into Crane Prairie Reservoir, which is the first of two impoundments. The Deschutes River continues for two miles and flows into a second, larger impoundment Wickiup Reservoir. While restoration of the Deschutes River above Wickiup is important, this study does not focus on this reach of the Deschutes River (UDWC 2006).

Upper Deschutes River: From Wickiup Reservoir outlet at RM 222, the Deschutes River flows north to the end of this reach at RM 164 located at the North Canal Dam in the City of Bend. **This reach is included in this study**. Main tributaries within the upper Deschutes reach include the Fall River, Spring River and the Little Deschutes River (UDWC 2006).

Middle Deschutes River: The middle Deschutes River source is primarily discharge from Wickiup Reservoir, but springs do contribute to stream flow. From the North Canal Dam at RM 164, the Deschutes River flows in a northerly direction for approximately 44 miles to the inflow of Lake Billy Chinook at RM 120. **This reach is included in this assessment**. There are two major tributaries along this reach: Tumalo Creek and Whychus Creek. Tumalo Creek is located at RM 160 and Whychus Creek is located at RM 123 (UDWC 2006).

Tumalo Creek Watershed

Tumalo Creek: From the source to the confluence with the Deschutes River. Tumalo Creek's source is primarily springs and snowmelt originating in the snowpack of the western part of the watershed. Tumalo Creek is approximately 18 miles long. **This reach is included in this assessment.** Headwater tributaries include South, Middle, and North Forks of Tumalo Creek. Major tributaries include Bridge Creek and Tumalo Lake Creek (UDWC 2006).

Whychus Creek Watershed

Whychus Creek: Whychus Creek's source is springs and snow/glacial melt with a small amount of direct precipitation runoff. The reach assessed here extends from RM 26.5, at the stream gage upstream of Sisters, to the confluence with the Deschutes River. The reach begins upstream of all irrigation diversions on the mainstream of Whychus Creek. There are a series of springs along Whychus Creek downstream of Sisters that contribute a significant amount of flows to the mainstem. **This reach is included in this assessment**. Major tributaries include Snow Creek, Pole Creek, and Indian Ford Creek. Pole Creek is usually completely diverted for irrigation purposes and so does not flow into Whychus Creek during the summer. In addition and during most years, Indian Ford Creek does not contribute surface flows into Whychus Creek in the summer months. Whychus Creek is approximately 39 miles long (UDWC 2006).

Metolius River Watershed

Metolius River: The Metolius River source is the Head of the Metolius springs. The river flows north through Camp Sherman, around Green Ridge, and heads southeast at approximately RM 20 until it flows into Lake Billy Chinook. **This reach is included in this assessment**. The Metolius River is a major tributary of the Deschutes River, but the Metolius River now flows into Lake Billy Chinook due to the establishment of the Pelton Round Butte Dam Complex. The Metolius River is approximately 41 miles long (UDWC 2006). Lake Creek, Jack Creek, First Creek, Canyon Creek, and Jefferson Creek are important tributaries to this reach.

5.1.3 Lower Crooked Subbasin

The Lower Crooked Subbasin contains 11 watersheds based on 5th field HUCs. These watersheds include Badlands, Upper Dry River, Lower Crooked River/Dry Creek, Lower Dry River, North Unit Main/Central Oregon Irrigation Canals, Lower Ochoco Creek, Upper Ochoco Creek, Mill Creek, McKay Creek, and Lower Crooked River Grasslands. The subbasin encompasses the Crooked River and its tributaries downstream of Bowman Dam.

Lower Crooked River: This reach stretches 109 miles from the Prineville Reservoir outlet to Lake Billy Chinook. The reach begins downstream of Bowman Dam. The river flows north to Prineville, where it turns west towards Terrebonne. The river turns north again before reaching Terrebonne and flows into Lake Billy Chinook. **This reach is a reach included in this study.** Major tributaries include Ochoco Creek and McKay Creek.

5.1.4 Lower Deschutes Subbasin

The Lower Deschutes Subbasin contains 12 watersheds based on 5th field HUCs. These watersheds include Headwaters Deschutes River, Upper Deschutes River, Middle Deschutes

River, Lower Deschutes River, Willow Creek, Mill Creek, Warm Springs River, Beaver Creek, Bakeoven Creek, Buck Hollow Creek, Tygh Creek, and White River. The subbasin encompasses the Deschutes River and its tributaries downstream of Lake Billy Chinook.

> **Lower Deschutes River:** The lower Deschutes River begins below Lake Billy Chinook. Its source is primarily surface water and groundwater discharge from the upper Deschutes Basin. The river flows north through Maupin, where it turns northeast before turning north again and flowing into the Columbia River. The entire reach is approximately 100 miles. **This reach is included in this study**. Important tributaries include Shitike Creek, the Warm Springs River, Buck Hollow Creek, Bakeoven Creek, and Trout Creek (NPCC 2004).

5.2 Monitoring and Measurement

The goals of instream flow restoration in the Basin are to meet instream flow targets and to meet water quality standards. Flow and water quality monitoring help to identify baseline conditions, acknowledge the current status of reaches, and reveal any trends towards or away from goals. In the Deschutes Basin, diversions, tributary inputs, and irrigation return flows all influence water quantity and quality. The following sections focus only on monitoring in the eight reaches. Monitoring in other waterways will lead to a greater understanding of the causes of water quality and quantity impairments in the reaches, but it is not a focus of this assessment.

5.2.1 Flow Monitoring

Flow monitoring occurs across the Deschutes Basin. The Bureau of Reclamation, USGS, OWRD and the DRC all operate gages in the Basin. Priority watersheds, such as Whychus Creek watershed, have several gages to measure natural patterns and anthropogenic impacts on stream discharge. Other watersheds, such as the Metolius River watershed, are not as intensively monitored.

OWRD maintains a database of current and historic discharge monitoring sites across the state, and this database includes sites in the Deschutes Basin. The following sections outline current discharge monitoring activities in the reaches discussed in this paper. The time periods selected for further analysis of flow limitations and restoration needs is also presented. Wherever possible the selection was guided by an effort to avoid employing data that would incorporate recent stream flow restoration activities by the DRC, the Oregon Water Trust and other entities. In some cases, such as the Deschutes River reaches, the period of record was truncated to avoid including years where restoration activities had occurred. In other cases, such as Tumalo Creek and Whychus Creek, a limited period of record meant that all available data was used (Table 7). Where available, a thirty year period of record is used in order to be consistent with the length of time used by OWRD and USGS to calculate stream flow statistics.

Table 7. Time periods used for discharge analysis

Reach	Gage	Period of Record Published*	Period of Record Used*	Justification
Little Deschutes River	LAPO	1924-2006	1973-2002; 1987 not available	30 year period; stream flow restoration began in 2003
upper Deschutes River	WICO	1939-2006	1968-1997	30 year period; stream flow restoration began in middle Deschutes River in 1998
middle Deschutes River	DEBO	1916-2004	1968-1997	30 year period; stream flow restoration began in 1998
Tumalo Creek	TUMO	1997-2003	1998-2003	used all years with full year data available
Whychus Creek	SWSO	2001-2005	2001-2005	all data available
lower Crooked River	CKKO	1968-1973;1993-2004	1968-1973;1993-2004	all data available
lower Deschutes River	14092500	1924-2004	1968-1997	30 year period; stream flow restoration began in middle Deschutes River in 1998
Metolius River	14091500	1912-2003	1974-2003	most recent 30 year period available

*water years

Little Deschutes subbasin, Little Deschutes River

There is one active gage station on the Little Deschutes River (LAPO). It monitors discharge in the Little Deschutes River near La Pine, Oregon and has been in operation since 1924. Additional stations monitor levels in Crescent Lake (CRE) and discharge in Crescent Creek (CREO). No active gage stations exist on Paulina Creek.

This study used historic data from the LAPO gage to characterize instream flow conditions in the Little Deschutes River. Reclamation has published gage data from the 1924 through 2006 water years. This study used the period of record from the 1973 through 2002 water years[5] to determine historic instream flows and summary statistics for the Little Deschutes River. The DRC began leasing water in this reach in 2003, thus the 1973 through 2002 period selected for analysis of stream flow. Natural flow estimates come from OWRD. They were calculated using the 1961 through 1990 period of record.

Upper Deschutes watershed; upper Deschutes River

Two active gages monitor discharge in the upper Deschutes River. One gage monitors discharge in the Deschutes River below Wickiup Reservoir (WICO) and one gage monitors discharge in the Deschutes River at Benham Falls (BENO). An additional station monitors discharge in the Deschutes River below Crane Prairie Reservoir (CRAO). Near-realtime data is available for these three gages. One station monitors discharge in the Deschutes River upstream of Crane Prairie reservoir and downstream of Snow Creek, but no real-time data is available for this gage (14050000). An active gage station also monitors discharge on the Fall River (14057500), but no active gages exist on the Spring River.

This study used historic data from the WICO gage. Reclamation has published data for this gage for the 1939 through 2006 water years. Leasing from irrigation districts diverting water at Bend began in the late 1990s and the DRC began its work in 1998. As leasing may have altered demand and water use at Bend, with feedback effects on storage releases, the period of record from 1968 through 1997 is used to determine instream flow status and summary discharge

[5] Data was not available for the 1987 water year.

statistics for the middle Deschutes River. Daily natural discharge estimates come from Reclamation and are available for 1983 through 2006. Data from this entire period of record was used to estimate monthly median flows.

Upper Deschutes watershed; middle Deschutes River

Two active gages measure discharge in the middle Deschutes River. One gage monitors discharge in the Deschutes River below the irrigation district diversions in Bend (DEBO) and one gage monitors discharge in the Deschutes River near Culver (14076500). Near-realtime data is available for both of these gages. OWRD has suggested that an additional gage on this reach near Lower Bridge would allow for a more comprehensive analysis of water resources in this watershed.

This study used historic discharge data from DEBO gage. Discharge measured at this gage does not include the discharge from Tumalo Creek or from Whychus Creek, which enter the middle Deschutes River downstream of the gage.

OWRD has published discharge data for the DEBO gage for the 1916 through the 2004 water years. With the onset of leasing and DRC's restoration activities in the late 1990s, this study used the period of record from 1968 through 1997 to determine historic instream flow status and summary discharge statistics for the middle Deschutes River. Natural flow estimates come from OWRD. They were calculated for the 1961 through 1990 period of record.

Tumalo Creek watershed; Tumalo Creek

There is one active gage station on Tumalo Creek (TUMO). It monitors discharge in Tumalo Creek below the Tumalo Irrigation District diversion in Bend. The TUMO gage has been in operation since 1997 and OWRD publishes near-realtime data for the gage.

This study used the 1998 through 2003 period of record to determine instream flow status and summary discharge statistics in Tumalo Creek. This period of record includes increases in stream flow caused by the Deschutes River Conservancy's stream flow restoration activities with the Tumalo Irrigation District. Historic flows were likely lower than those included in this study. Natural flow estimates come from OWRD. They were calculated from the 1961 through 1990 period of record.

Whychus Creek watershed; Whychus Creek

Five active gage stations monitor discharge in Whychus Creek. One gage monitors discharge in Whychus Creek upstream of Sisters, OR (14075000). A second gage monitors discharge in the creek approximately one mile below the Three Sisters Irrigation District (TSID) diversion (SQSO). OWRD publishes near-realtime data for the SQSO gage.

The Deschutes River Conservancy operates two additional gages on this reach and one on Indian Ford Creek. One gage monitors discharge in Whychus Creek at Camp Polk and one gage monitors discharge in Whychus Creek at Rim Rock Ranch. The third gage monitors discharge in Indian Ford Creek and is operated in partnership with the Oregon Water Trust. The operation and maintenance of these gages does not currently follow OWRD monitoring protocols, but the operation of one or more of them may be improved to meet OWRD standards in the near-future.

This study used discharge data from the SQSO gage. The gage has a short period of record, from the 2001 through the 2005 water years, but it characterizes conditions below the TSID diversion at the head of the most degraded reach of Whychus Creek. The upstream gage has a longer period of record, but several ungaged diversions exist between this gage and the gaged TSID diversion. Estimating discharge below downstream of Sisters using upstream gage and the TSID diversion gage to estimate flows downstream of Sisters may lead to higher estimates of discharge than are actually present during the irrigation season. The gage below the TSID Diversion has a short period of record but provides an accurate accounting of flows in the most heavily impacted section of Whychus Creek.

This study uses the entire five year period of record to determine instream flow status and summary discharge statistics in Whychus Creek. This period of record includes increases in stream flow caused by the Deschutes River Conservancy's stream flow restoration activities with TSID and local landowners. Historic flows were likely lower than those included in this study. Natural flow estimates come from OWRD. They were calculated from the 1961 through 1990 period of record.

Lower Crooked subbasin; lower Crooked River

Four active gage stations measure discharge in the lower Crooked River. These gages monitor discharge in the Crooked River below Prineville Reservoir (PRVO), near Terrebonne (CKKO), below Osborne Canyon (14087380), and below Opal Springs (14087400). The PRVO gage monitors flows upstream of the most highly impacted reach of the Crooked River, while the Terrebonne gage monitors flows at the downstream end of the most highly impacted reach. Near-realtime data is available for these gages.

Additional gages monitor discharge in in Ochoco Creek above (OCRO) and below Ochoco Reservoir (OCHO). OWRD publishes near-realtime data for these gages as well. No active gage stations exist on McKay Creek. The de-activation of the CKKO gage and the activation of a gage on the Crooked River at Smith Rock is expected during 2006. Discussions are also underway regarding gaging needs on McKay Creek and at the mouth of Ochoco Creek

Reclamation has published discharge data for the Terrebonne gage for the 1968 through the 2004 water years. Several years have missing or incomplete data; discharge data is available for 16 years from this period. This study used available data from the full period of record to determine instream flow status and summary discharge statistics for the lower Crooked River. This period of record is longer than the length of time used by OWRD and USGS but includes data from fewer years than those agencies use. The DRC has engaged in a leasing program in this reach with Ochoco Irrigation District, however, the full series is used due to the paucity of the record and the limited nature of the leasing program to date. Estimated natural flows were not available for the lower Crooked River.

Lower Deschutes subbasin; lower Deschutes River

Two active gage stations measure discharge in the lower Deschutes River. One gage monitors discharge below the Pelton Round Butte Project near Madras (14092500), and the other gage monitors discharge near the mouth of the river at Moody (14103000). Three additional stations monitor discharge in Shitike Creek (14092750), the Warm Springs River (14097100), and Trout Creek (TRGO). OWRD publishes near-realtime data for all of these gages. No active gage stations exist on Bakeoven Creek or Buck Hollow Creek.

OWRD has published discharge data for the Madras gage for the 1924 through the 2004 water years. This study used the period of record from 1968 through 1997 to determine historic instream flow status and summary discharge statistics for the lower Deschutes River. While the DRC's stream flow restoration activities typically are not protected in this reach, this period is chosen for consistency with the upper and middle Deschutes time periods and to eliminate any possible downstream impacts from upstream leases and transfers.

The study used this period to obtain the most recent, thirty-year record that did not include changes in stream flow caused by the Deschutes River Conservancy's activities. The DRC was first active in 1998, thus the 1968 through 1997 period. Natural flow estimates come from OWRD. They were calculated for the 1961 through 1990 period of record.

Metolius River watershed; Metolius River

One active gage station measures discharge in the Metolius River. It monitors discharge in Metolius River near Grandview (14091500). Near-realtime data is available for this gage. No gage stations exist on Lake Creek. Several parties have suggested that an additional gage on the Metolius River, above the Lake Creek confluence, may allow for a more comprehensive analysis of long-term water resources trends in this basin.

OWRD has published data for this gage for the 1912 through 2003 water years. This study used gage data from the 1974 through 2003 water years to determine historic instream flow status and summary discharge statistics for the Metolius River. No stream flow restoration activities have been implemented in this reach. No natural flow estimates were available for this paper.

5.2.2 Water Quality Monitoring

Several organizations conduct water quality monitoring in the Deschutes Basin. Water quality monitoring efforts range from sustained, long-term, hydrologic unit scale efforts to project specific, short-term, site based monitoring. First, the DEQ's ambient water quality monitoring network provides long term water quality monitoring in several of the reaches discussed in the study. This program provides a long-term data set that can be used to monitor water quality trends and conditions in the Deschutes Basin. Second, the Upper Deschutes Watershed Council's (UDWC) Water Quality Monitoring Program is a comprehensive, cross-jurisdictional, hydrologic unit based monitoring effort that encompasses six out of the eight reaches discussed in the study. The UDWC runs the program in coordination with local, state, and federal agencies. Other entities perform water quality monitoring in the other two reaches, the lower Crooked River and the lower Deschutes River and the lower Crooked River.

The Water Quality Monitoring Program coordinates three categories of monitoring in its study area (see Table 8), and this paper uses these three categories when delineating monitoring sites. The City of Bend and DEQ monitor additional parameters as well, but these parameters are not discussed here (UDWC 2006). The purpose of this monitoring is to determine both baseline water quality status and trends towards or away from water quality goals (i.e. meeting water quality standards and removing waters from the state impaired list). As discussed later, most of the impairments on the seven listed reaches are related to water temperature. Correspondingly, monitoring focuses on temperature at most stations. Temperature is an inexpensive parameter to measure continuously, and it can sometimes serve as a proxy for other parameters.

Table 8. Monitoring activities and parameters

Monitoring Activities	Parameters
Continuous Temperature Monitoring (T)	Continuous temperature
Grab sampling (G)	pH Dissolved oxygen and percent saturation Specific conductance and calculated TDS Turbidity
Continuous Multiparameter Monitoring (CM)	Continuous dissolved oxygen and percent saturation Continuous pH Continuous specific conductance and calculated TDS

Source: UDWC 2006a

The following sections outline water quality monitoring activities in the Deschutes Basin. This study lists monitoring stations as active if they have contributed or will contribute data in 2004, 2005, or 2006. Monitoring information came from a variety of sources, including the UDWC, CRWC, DEQ, and BLM.

Little Deschutes subbasin; Little Deschutes River

The Little Deschutes River contains 12 active water quality monitoring stations (see Table 9). UDWC, USDA, and DEQ collect data at these stations. The reach contains an additional eight historic stations. The majority of active stations monitor temperature only. Recent concerns over seepage from septic tanks into the regional aquifer suggest that future monitoring efforts may need to focus on monitoring nutrients in both groundwater and surface water.

Table 9. Water quality stations on the Little Deschutes River

Station	River	Location	CM	G	T	Active
LDR 000.25	Little Deschutes River	Mouth			X	Active
LDR 005.50	Little Deschutes River	Hwy 42, South Century Dr., Rd 2114		X		Active
LDR 026.75	Little Deschutes River	OWRD gauge La Pine			X	Active
LDR 057.75	Little Deschutes River	Rd 62 crossing			X	Active
LDR 063.75	Little Deschutes River	d/s Gilchrist Mill Pond			X	Active
LDR 064.75	Little Deschutes River	u/s of Gilchrist Mill Pond			X	Active
LDR 066.00	Little Deschutes River	~1.25 miles u/s Crescent, d/s end USFS sec. 35			X	Active
LDR 067.00	Little Deschutes River	Off Rd 100 near Crescent			X	Active
LDR 078.50	Little Deschutes River	Rd 5825 at USFS boundary d/s of hwy 58			X	Active
LDR 080.00	Little Deschutes River	Spur Rd off 90 above hwy 58			X	Active
LDR 082.50	Little Deschutes River	Rd 5835 u/s Hemlock Creek			X	Active
LDR 089.00	Little Deschutes River	Cow Camp			X	Active
LDR 093.00	Little Deschutes River	near wilderness boundary			X	Active

Source: UDWC 2006

Upper Deschutes watershed; upper Deschutes River

The upper Deschutes River contains 16 active water quality monitoring stations (see Table 10). BLM, PGE, DEQ, and the City of Bend collect data at these stations. The reach contains an additional six historic stations. Water quality monitoring in the upper Deschutes River meets current needs.

Table 10. Water quality monitoring in the upper Deschutes River

Station	River	Location	CM	G	T
DR 164.75	Deschutes River	u/s Riverhouse Hotel	X	X	X
DR 165.75	Deschutes River	First St. Rapids		X	X
DR 166.00	Deschutes River	u/s Portland Ave. Bridge		X	X
DR 166.75	Deschutes River	Drake Park footbridge	X	X	X
DR 167.25	Deschutes River	Columbia Park footbridge		X	X
DR 168.00	Deschutes River	Columbia St. Bridge		X	X
DR 169.00	Deschutes River	u/s end Mill Log Pond		X	X
DR 172.00	Deschutes River	Southern UGB	X	X	X
DR 173.00	Deschutes River	USFS Meadow Camp		X	X
DR 181.50	Deschutes River	Benham Falls footbridge			X
DR 191.75	Deschutes River	Harper Bridge		X	X
DR 192.75	Deschutes River	u/s Little Deschutes River			X
DR 199.00	Deschutes River	d/s General Patch Bridge			X
DR 207.25	Deschutes River	Big Tree			X
DR 217.25	Deschutes River	Pringle Falls Experimental Station	X	X	X
DR 226.75	Deschutes River	d/s of USGS gaging station d/s Wickiup	X	X	X
DR 237.50	Deschutes River	d/s Browns Crossing	X	X	X
DR 243.75	Deschutes River	Cow camp			X
DR 246.75	Deschutes River	d/s Deschutes bridge at pullout by mm 42			X
DR 250.50	Deschutes River	d/s Little Lava Lake			X

Source: UDWC 2006

Upper Deschutes watershed; middle Deschutes River

The middle Deschutes River contains 16 active water quality monitoring stations (see Table 11). BLM, PGE, UDWC, DEQ, and the City of Bend collect data at these stations. The reach contains an additional six historic stations. As the City of Bend grows, both non-point source groundwater and surface water pollution has the potential to increase. Groundwater and surface water are intimately connected in this region, so future monitoring efforts may need to focus on monitoring groundwater quality as well.

Table 11. Water quality monitoring in the middle Deschutes River

Station	River	Location	CM	G	T
DR 117.37	Deschutes River	Deschutes River arm at bridge		X	
DR 119.23	Deschutes River	Deschutes River inflow		X	X
DR 120.00	Deschutes River	USGS gaging station u/s Lake Billy Chinook		X	X
DR 123.00	Deschutes River	d/s Squaw Creek			X
DR 123.25	Deschutes River	u/s Squaw Creek			X
DR 127.75	Deschutes River	u/s Steelhead Falls			X
DR 133.50	Deschutes River	Lower Bridge	X	X	X
DR 141.00	Deschutes River	Tetherow Crossing			X
DR 146.00	Deschutes River	u/s Cline Falls State Park			X
DR 158.50	Deschutes River	d/s end Tumalo State Park		X	X
DR 159.50	Deschutes River	Tumalo Bridge		X	X
DR 160.00	Deschutes River	d/s Tumalo Boulder Field	X	X	X
DR 160.25	Deschutes River	u/s Tumalo Creek	X	X	X
DR 163.25	Deschutes River	Firerock footbridge		X	X

Source: UDWC 2006; Cambell, pers. comm. 2006

Tumalo Creek watershed; Tumalo Creek

Tumalo Creek contains 6 active water quality monitoring stations (see Table 11Table 12). UDWC, USDA, and the City of Bend collect data at these stations. The reach contains six additional inactive stations upstream of the confluence with Bridge Creek. As in other reaches, most of the monitoring on Tumalo Creek focuses on temperature. Water quality monitoring in Tumalo Creek meets current needs.

Table 12. Water quality monitoring in Tumalo Creek

Station	River	Location	CM	G	T
TC 000.25	Tumalo Creek	Mouth		X	X
TC 003.25	Tumalo Creek	d/s Tumalo Feed Canal gauge			X
TC 004.75	Tumalo Creek	Shevlin Park covered bridge			X
TC 007.50	Tumalo Creek	u/s 4606 Rd		X	X
TC 014.50	Tumalo Creek	d/s Skyliner bridge			X
TC 017.25	Tumalo Creek	d/s Bridge Creek			X

Source: UDWC 2006b

Whychus Creek watershed; Whychus Creek

Whychus Creek contains eleven active water quality monitoring stations (see Table 13). UDWC, USDA Forest Service, and the BLM collect data at these stations. The reach contains three additional inactive stations. Water quality monitoring efforts in Whychus Creek have historically focused on temperature, but monitoring has expanded within the last few years. Current and expected future monitoring efforts in Whychus Creek are adequate to meet current needs.

Table 13. Water quality monitoring in Whychus Creek

Station	River	Location	CM	G	T
SC 000.25	Whychus Creek	Mouth		X	X
SC 001.50	Whychus Creek	d/s Alder springs		X	X
SC 003.00	Whychus Creek	u/s Alder springs			X
SC 006.00	Whychus Creek	u/s Rd 6360		X	X
SC 009.00	Whychus Creek	Rim Rock Ranch	X	X	X
SC 018.25	Whychus Creek	d/s end DBLT property		X	X
SC 019.50	Whychus Creek	d/s Camp Polk Bridge on DBLT property		X	X
SC 024.25	Whychus Creek	City Park, d/s gauge		X	X
SC 026.00	Whychus Creek	Rd 4606 footbridge			X
SC 030.25	Whychus Creek	USGS gauge	X	X	X
SC 038.00	Whychus Creek	Rd 1514		X	X

Source: UDWC 2006

Lower Crooked subbasin; lower Crooked River

The lower Crooked River is outside of the domain of the UDWC Water Quality Monitoring Program. DEQ maintains one ambient water quality monitoring station in the lower Crooked River as well. The Crooked River Watershed Council (CRWC) has monitored water quality in the past and expects to monitor water quality in the near-future. (see Table 14). While they have not do any continuous multi-parameter monitoring, they do collect both grab samples and temperature data. USGS, DEQ, and BLM have also monitored water quality in this reach.

No coordinated, multi-jurisidictional approach to monitoring occurs on this reach, but parties monitoring the lower Crooked River do communicate with each other and a coordinated approach may be developed in the future. Currently, funding is a factor limiting water quality monitoring efforts in this reach. Next steps in the lower Crooked River could involve building capacity and providing for further coordination between local municipalities and agencies.

Table 14. Water quality monitoring in the lower Crooked River

Station	River	Location	CM	G	T
CR 008.10	Crooked River	Above Opal Springs at Carcass Trail		X	
CR 008.30	Crooked River	Above Opal Springs at Pink Trail		X	X
CR 013.50	Crooked River	Below Osborne Canyon at Gage		X	X
CR 016.50	Crooked River	at Grasslands Trail		X	
CR 021.25	Crooked River	Canyons Ranch			X
Not Available	Crooked River	at Smith Rocks footbridge	X	X	
CR 030.00	Crooked River	Lone Pine Road Bridge		X	X
Not Available	Crooked River	u/s Dry Canyon	X	X	X
CR 042.50	Crooked River	Elliot Road Bridge		X	
CR 044.78	Crooked River	City Wastewater Irrigated Field Site Below Creeks			X
CR 044.75	Crooked River	d/s McKay Cr			X
CR 045.75	Crooked River	Rim Rock Road wastewater lagoon		X	X
Not Available	Crooked River	u/s Ochoco Cr			X
Not Available	Crooked River	600 ft d/s Prineville WWTP outfall	X	X	
Not Available	Crooked River	at Hwy 126 bridge		X	
CR 047.25	Crooked River	Les Schwab Park	X	X	X
CR 049.50	Crooked River	u/s end Les Schwab Park		X	
Not Available	Crooked River	u/s Stearns Dam		X	X
CR 063.50	Crooked River	Just Above BLM Boundary (Castle Rock)		X	X
Not Available	Crooked River	d/s Bowman Dam	X	X	X

Source: CRWC, pers. comm. 2006; Lamb, pers. comm. 2006; McSwain, pers. comm. 2006

Lower Deschutes subbasin; lower Deschutes River

The lower Deschutes River reach contains 14 active water quality monitoring sites (see Table 15). Portland General Electric and DEQ monitor a variety of parameters at each site, depending on the reason for monitoring at each site. Two of these sites, DR 096.80 and DR 001.00 are part of the DEQ's ambient water quality monitoring program.

Table 15. Water quality monitoring in the lower Deschutes River

Station	River	Location	CM	G	T
DR 001.00	Deschutes River	Deschutes Park Boat Ramp		X	
DR 001.24	Deschutes River	Rockpile Campground		X	X
DR 024.22	Deschutes River	Mack Canyon		X	X
DR 044.71	Deschutes River	Sandy Beach		X	X
DR 057.75	Deschutes River	Nena		X	X
DR 078.87	Deschutes River	Kaskela		X	X
DR 092.53	Deschutes River	Dry Creek		X	X
DR 096.80	Deschutes River	Hwy 26		X	
DR 099.36	Deschutes River	Disney Riffle		X	X
DR 099.98	Deschutes River	Reregulating Dam tailrace	X	X	X
DR 102.47	Deschutes River	Pelton Dam tailrace		X	X
DR 103.09	Deschutes River	Pelton Dam forebay		X	X
DR 110.54	Deschutes River	Round Butte Dam tailrace	X	X	X
DR 111.16	Deschutes River	Round Butte Dam forebay		X	X

Source: Cambell, pers. comm. 2006

Metolius River watershed; Metolius River

Water quality monitoring in the Metolius River consists of both continuous temperature and grab sampling. The reach contains three active monitoring stations and three inactive monitoring stations (see Table 16). USDA Forest Service collects temperature data at these three stations, and DEQ collects grab samples at MR 030.25. Water quality monitoring in this reach meets current needs.

Table 16. Water quality monitoring in the Metolius River

Station	River	Location	CM	G	T
MR 030.25	Metolius River	Bridge 99		X	X
MR 037.00	Metolius River	Gorge Campground			X
MR 040.00	Metolius River	d/s tract C bridge			X

Source: UDWC 2006; Lamb, pers. comm. 2006

5.3 Reach Status

Regulated flows in seven of the eight reaches differ from their natural hydrographs, and in a number of cases markedly so. Irrigation storage and diversions are the primary factors causing these differences. The Little Deschutes River, the upper Deschutes River, and the Crooked River experience seasonal flow and water quality impairments due primarily to storage operations. In contrast, Tumalo Creek, Whychus Creek, and the middle Deschutes River experience flow and water quality impairments due primarily to irrigation diversions. Any flow alterations in the lower Deschutes River are likely due a combination of activities in the lower Deschutes Basin and activities in the upper Deschutes Basin.

Flow alteration contributes to water quality impairments in these reaches. In some cases, discharge patterns are the primary factor causing water quality impairments. For example, sections of each reach are listed on the state's 2002 303(d) or the proposed 2004 303(d) list for exceeding temperature criteria. Stream discharge is one of the primary factors that moderates stream temperature, and discharge has a strong influence on peak daily stream temperatures (Gu 2002). Altered discharge patterns have likely been a major factor causing temperature impairments in these reaches. Other impairments, such as sedimentation, are reach specific and will be discussed in the following sections.

Each of the reaches has certificated or pending instream flow rights based on fish needs. ODFW determined these rights based on monthly or bi-weekly discharge needs. Stakeholders working in the reaches have not agreed on flow targets for each reach, so this paper uses these certificated or pending instream flow rights as preliminary instream flow targets.

The following sections outline the status of instream flows in each of the reaches. Each section briefly describes the drivers for flow restoration in each reach, summarizes historic or current discharges in the reach, and lists tools that could be applicable to instream flow restoration in the reach.

5.3.1 Little Deschutes subbasin, Little Deschutes River

The DWA's goal for instream flow restoration in the Little Deschutes River is to meet instream flow targets and to improve water quality in this reach. The following studies have identified flow alterations as a limiting factor in the Little Deschutes River:

- Little Deschutes River Subbasin Assessment (UDWC 2002)
- Deschutes Subbasin Plan (NPCC 2004)

Irrigation needs drive flows in the Little Deschutes River to a lesser extent than they drive flows in the upper and middle Deschutes Rivers. Releases from two lakes regulate discharge in the Little Deschutes River and its tributaries. Releases from Crescent Lake also affect discharge in the Little Deschutes River. Crescent Lake stores water for Tumalo Irrigation District and modulates flows in Crescent Creek, a major tributary to the Little Deschutes River. Reservoir operations contribute to high irrigation season flows and low winter flows in Crescent Creek and in the Little Deschutes River.

Releases from Paulina Lake generally do not affect discharge in the the Little Deschutes River, but do affect discharge in one of its tributaries. Paulina Lake stores water for multiple purposes and modulates flows in Paulina Creek. ODFW works with OWRD to maintain water levels in the lake that balance storage, irrigation releases, and recreation and fisheries objectives in the lake (Marx, pers. comm. 2006). Its operation does not actively increase or decrease flows in the Little Deschutes River, since flows in Paulina Creek below the dam do not always reach the Little Deschutes River (UDWC 2002).

Fisheries are the first driver for restoring instream flows in the Little Deschutes River. The Little Deschutes River does not currently support any ESA listed fish populations. Bull trout historically spawned in the Little Deschutes River and its tributaries, but they have been extirpated from this reach. However, other fish populations may be impacted by flow alterations. The Deschutes Subbasin Plan (NPCC 2004) identified a loss of riparian habitat and a reduction in instream habitat complexity as factors limiting fish production in the Little Deschutes subbasin. Flow alterations have likely contributed to these problems.

Water quality is the second driver for restoring instream flows in the Little Deschutes River. The majority of this reach is listed for temperature and dissolved oxygen (DO; see Table 17). Flow alterations due to storage and diversions contribute to these listings. The proposed 2004 303(d) list suggests additional impairments on the Little Deschutes River. It proposes listing the Little Deschutes River for temperature from the mouth to RM 92.4 and for DO from the mouth to RM 68.8. As described earlier, discharge is a major factor moderating stream temperatures and likely contributes to these listings. Consequently, discharge likely contributes to DO listings as well . High temperatures are one factor that can cause low DO concentrations in streams.

A further impetus for restoring instream flows in the Little Deschutes River is the prospect that flow protected and restored in the Little Deschutes may also be protected further downstream through the middle Deschutes portion of the river.

Table 17. 303(d) listed sections of the Little Deschutes River

River	**River Mile**	**Criteria**	**Season**	**Year Listed**
Little Deschutes River	0 to 54.1	Dissolved Oxygen	September 1 - June 30	2002
Little Deschutes River	0 to 54.1	Dissolved Oxygen	July 1 - August 31	2002
Little Deschutes River	54.1 to 78	Temperature	Summer	1998
Little Deschutes River	54.1 to 78	Temperature	September 1 - June 30	2002

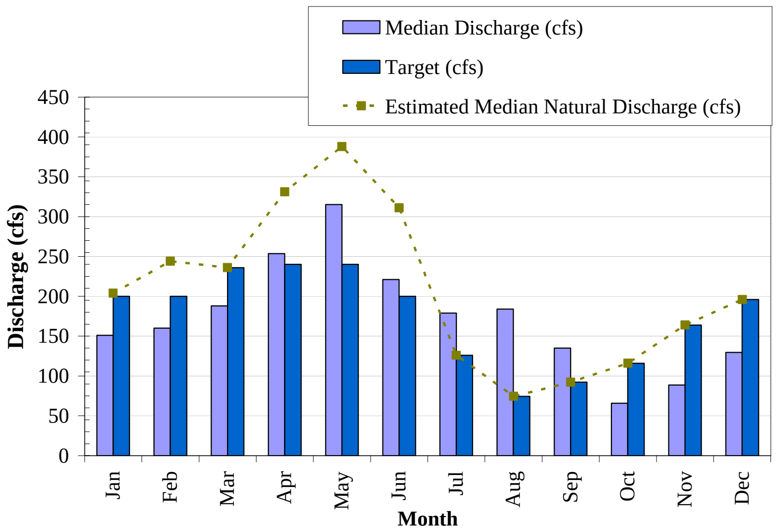
Source: DEQ 2002

Certificated instream water rights exist for the Little Deschutes River and some of its tributaries. The instream water rights for the Little Deschutes River follow the optimum flows recommended by ODFW for January through July. They are less than the optimum flows recommended by ODFW for August through December. The certificated water rights vary between 75 cfs and 200 cfs. Instream rights have priority dates of 1990 or 1993 and are junior to other surface water rights in the Little Deschutes subbasin (see Appendix A). They serve as targets for flow restoration

As mentioned earlier, this study uses data from the LAPO gage to determine instream flow needs in the Little Deschutes River. The LAPO gage is below the confluence of the Little Deschutes River and Crescent Creek, and discharge patterns above Crescent Creek may be very different than discharge patterns below Crescent Creek.

Discharge in the Little Deschutes River meets targets least often during the winter months particularly October and November (see Figure 4 and Table 18). The median discharge exceeded the instream water right during the irrigation season. Discharge does not meet targets as often in October, this could be due to either decreased water availability or increased storage after the irrigation season ends. Instream targets were met most often during August (see Appendix B). As revealed below, instream flows in the Little Deschutes River approach targets more closely than instream flows in other reaches in the Deschutes Basin.

Figure 4. Instream flows in the Little Deschutes River, 1973 – 2002



Data from LAPO gage

Table 18. Target attainment in the Little Deschutes River, 1973-2002

Month	Percentage of Days Meeting Target
Jan	27%
Feb	38%
Mar	37%
Apr	54%
May	58%
Jun	58%
Jul	80%
Aug	94%
Sep	72%
Oct	19%
Nov	18%
Dec	29%

Data from LAPO gage

As in other reaches of the Deschutes Basin, instream flows in the Little Deschutes River vary inter-annually based on available water resources. During wet periods, discharge is generally higher than during dry periods. August median daily flows varied between under 50 cfs and over 300 cfs between 1973 and 2002. November median daily flows varied between under 50 cfs and over 200 cfs during the same period. This inter-annual variation means that meeting instream flow targets will require restoring different amounts of water to the river on an annual basis.

Table 19. Annual differences in volume between storage season* discharge in the Little Deschutes River and instream flow targets

Storage year	Sum of Difference Between Daily Discharge and Target (AF)
1973	18,963
1974	6,786
1975	12,023
1976	7,640
1977	39,347
1978	14,584
1979	25,901
1980	17,500
1981	21,884
1982	7,470
1983	7,702
1984	1,434
1985	6,986
1986	15,580
1988	25,967
1989	30,953
1990	33,047
1991	34,419
1992	33,144
1993	45,022
1994	36,348
1996	6,100
1997	2,877
1998	8,241
1999	10,363
2000	9,320
2001	37,601
2002	37,086
Median	16,540
Average	19,796

Data from LAPO gage
*the storage season is estimated to be October 16 through March 31

Improving the Little Deschutes River hydrograph will require restoring and protecting water instream primarily during the storage season. One alternative would be to lease storage from or alter storage patterns in Crescent Lake, allowing stream flow restoration to occur without permanently protecting water instream. The amount of water required to meet discharge targets 100% of the time during the storage season, when they are least likely to be met under current conditions, varies annually (Table 19).

Other approaches could be used to protect baseflow during the irrigation season. While discharge meets targets more often during the summer than the winter, low irrigation season discharge is still an issue during some years. Potential regulatory approaches include the federal Wild and Scenic Rivers Act and the Endangered Species Act. Sections of the Little Deschutes River are listed under the federal Wild and Scenic River program, protecting the river against further flow degradation. The Endangered Species Act potentially provides a second regulatory method to restore flow to the Little Deschutes River; bull trout re-introduction could bring ESA issues to the Little Deschutes River. While it is highly unlikely that these approaches will be applied to restore flows in the river, they should be acknowledged.

Cooperative, market-based approaches provide the most potential to restore flows in the Little Deschutes River. Instream leases have been used to protect water during the irrigation season in the Little Deschutes River and its tributaries. In 2005, the Deschutes River Conservancy protected up to 10 cfs of water in the Little Deschutes River and through instream leases. Instream leasing improves summer baseflow in the Little Deschutes River and brings flows closer to meeting targets during years when less water is available. As in other reaches, these flows support aquatic ecosystems but do not fully restore ecosystem processes. No permanent instream transfers or conserved water projects have occurred in the Little Deschutes watershed, although there is one transfer pending at OWRD. None of these tools have been used yet to restore winter flows to the Little Deschutes River.

5.3.2 Upper Deschutes watershed; upper Deschutes River

The DWA's goal for instream flow restoration in the upper Deschutes River is to meet instream flow targets and to improve water quality in this reach. The following studies have identified flow as a limiting factor in the upper Deschutes River:

- Upper Deschutes River Basin Water Conservation Study (Reclamation 1997)
- Upper Deschutes Subbasin Assessment (UDWC 2003)
- Deschutes Subbasin Plan (NPCC 2004)
- Upper Deschutes River Subbasin Fish Management Plan (ODFW 1996)

The operations of Crane Prairie and Wickiup reservoirs for winter storage and summer irrigation releases have altered flow patterns in this reach. Flows are lower in the winter and higher in the summer. These flow alterations negatively impact aquatic and riparian ecosystems.

While flow alterations affect more than fisheries, fisheries have been one of the primary drivers for flow restoration in the upper Deschutes River. Low winter flows and high summer flows reduce available fish spawning and rearing habitat and negatively affect riparian vegetation (UDWC 2003, ODFW 1996). The upper Deschutes River historically supported healthy bull trout and redband trout populations, but modifications to the river have eliminated bull trout and reduced redband trout populations (NPCC 2004). USFWS listed bull trout as threatened under the ESA in 1998 (NPCC 2004).

Water quality is the second factor driving flow restoration in the upper Deschutes River. Sections of this reach are listed for exceeding water quality standards for six criteria (see Table 20). The relationships between discharge, temperature have been discussed in earlier sections of this paper. In the upper Deschutes River, discharge patterns also lead to sedimentation and turbidity problems (City of Bend 2004). Daily and seasonally fluctuating flows lead to increased bank erosion below Wickiup Reservoir (USDA 1996a). This bank erosion increases turbidity and sedimentation. The river transports and deposits sediment as it flows from Wickiup Reservoir to the City of Bend, where the river slows and deposits additional sediment. The shallow waters caused by sediment deposition create a substrate for plant and algal growth, contributing to pH and chlorophyll-a impairments (City of Bend 2004).

Table 20. 303(d) listed sections of the upper Deschutes River

River	River Mile	Parameter	Season	Year Listed
Deschutes River	162.6 to 168.2	pH	Summer	1998
Deschutes River	162.6 to 168.2	Temperature	Summer	2002
Deschutes River	162.6 to 168.2	Temperature	September 1 - June 30	2002
Deschutes River	168.2 to 189.4	Chlorophyll a	June 1 - September 30	2002
Deschutes River	168.2 to 189.4	Dissolved Oxygen	July 1 - August 31	2002
Deschutes River	168.2 to 189.4	Dissolved Oxygen	September 1 - June 30	1998
Deschutes River	168.2 to 189.4	Sedimentation	none stated	1998
Deschutes River	168.2 to 189.4	Temperature	September 1 - June 30	2002
Deschutes River	168.2 to 189.4	Turbidity	Spring/Summer	1998
Deschutes River	189.4 to 222.2	Turbidity	Spring/Summer	1998
Deschutes River	189.4 to 222.2	Dissolved Oxygen	September 1 - June 30	1998
Deschutes River	189.4 to 222.2	Sedimentation	none stated	1998

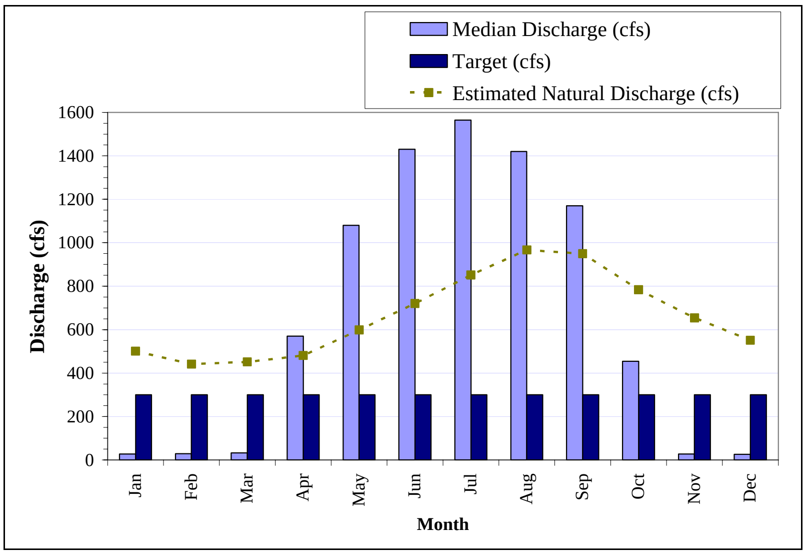
Source: DEQ 2002

Several reaches in the Upper Deschutes watershed, including the upper Deschutes River, have certificated instream rights that serve as preliminary restoration targets (see Appendix A). The upper Deschutes River has junior instream water rights for 300 cfs year round with 1983 priority date. These water rights are based on ODFW's recommended minimum flows below Wickiup Reservoir. To provide for minimal protection of flows below Wickiup in the winter, the State has also imposed a 20 cfs minimum flow requirement on the operations of the reservoir at all times.

Under unregulated conditions, the upper Deschutes River would have extremely stable flows. The basin's porous volcanic soil allows surface water to infiltrate into the subsurface and recharge groundwater aquifers. A majority of this water surfaces lower in the basin from springs, recharging surface waters during periods of lower flow (Gannet and others 2001; USDA 1996a). This connectivity aids in maintaining a stable flow regime.

Regulated discharge in the upper Deschutes River differs markedly from the estimated natural hydrograph. Discharge exceeds targets during the summer irrigation season and falls short of targets during the winter storage season. The greatest difference between discharge and targets appears from June through August, when flows are much higher than targets.   In contrast, discharge meets targets lease often from November through March (see Appendix B).

Figure 5. Instream flows in the upper Deschutes River, 1968 – 1997



Data from WICO gage

Table 21. Target attainment in the upper Deschutes River 1968-1997

Month	Percentage of Days Meeting Target
Jan	29%
Feb	30%
Mar	34%
Apr	72%
May	99%
Jun	99%
Jul	100%
Aug	100%
Sep	100%
Oct	60%
Nov	12%
Dec	23%

Data from WICO gage

As in other reaches, consensual approaches offer the greatest opportunities for stream flow restoration. Improving the upper Deschutes River hydrograph will involve releasing stored water during the winter and may require innovative strategies connecting irrigation season leasing, transfers, and conservation with winter storage releases.

Table 22. Annual differences in volume between daily storage season discharge* in the upper Deschutes River and instream flow targets

Storage Year*	Discharge in Excess of Target (AF)	Difference Between Daily Discharge and Target (AF)
1968	0	97,014
1969	0	93,992
1970	0	92,027
1971	0	92,374
1972	59,599	4,640
1973	68,449	1,884
1974	0	90,036
1975	80,904	4,424
1976	65,869	8,894
1977	14,385	23,754
1978	0	100,247
1979	0	94,389
1980	0	96,080
1981	0	96,120
1982	0	96,235
1983	63,678	17,288
1984	67,172	135
1985	83,718	7,845
1986	23,852	48,734
1987	7,510	54,755
1988	0	91,420
1989	0	101,734
1990	0	94,407
1991	0	94,296
1992	Not Available	Not Available
1993	0	96,596
1994	0	81,029
1995	Not Available	Not Available
1996	Not Available	Not Available
1997	119,926	7,623
Median		91,420
Average		62,517

Data from WICO gage
*the storage season was estimated to be October 16 through March 31

Just one project – a partnership between North Unit Irrigation District and the DRC – has successfully restored instream flows to the upper Deschutes River. This conserved water project calls on North Unit and the OWRD to release 0.76 cfs below Wickiup Reservoir during the storage season. As federal regulations governing Wickiup Reservoir allocations do not recognize instream flow as an authorized use, this water is not yet legally protected instream.

Meeting flow targets in the upper Deschutes River will require restoring additional flow to the river during winter storage months. As in the Little Deschutes River, the amount of additional water needed to meet these rights will vary each year depending on hydrologic conditions (Table 22). During some storage years, discharges exceed flow targets on some days and fall short of flow targets on other days. The average amount of water required to meet instream flow targets on each day during the storage season is just over 62,500 AF/year. While the actual figure would vary year to year this amount reflects the long-run amount of water that would need to be acquired for stream flow restoration in this reach. Further discussion on these targets and potential opportunities are found in the companion DWA Issues Paper on *Reservoir Management*.

5.3.3 Upper Deschutes watershed; middle Deschutes River

The DWA's goal for instream flow restoration in the middle Deschutes River is to meet instream flow targets and to improve water quality in this reach. The following studies have identified flow alterations as a limiting factor in this the middle Deschutes River:

- Upper Deschutes River Basin Water Conservation Study (Reclamation 1997)
- Upper Deschutes River Subbasin Fish Management Plan (ODFW 1996a)
- Deschutes Subbasin Plan (NPCC 2004)

Irrigation needs drive flow regimes in the middle Deschutes River. The operations of upstream reservoirs and diversions by six irrigation districts have altered flow and water quality in the middle Deschutes River below Bend. As a result, the river does not meet flow targets during the summer months or water quality standards during both summer and winter months

Fisheries restoration is one driver for instream flow restoration in the middle Deschutes River. In contrast to the upper Deschutes River, the upstream sections of the middle Deschutes River do not support ESA listed fish populations. However, the lower portions of this reach and of Whychus Creek do support bull trout. Historically, the entire middle Deschutes River supported larger and more geographically broad populations of bull trout than it currently supports. The middle Deschutes River below Big Falls also supported steelhead salmon and spring Chinook (NPCC 2004).

Seasonal flow fluctuations have reduced the quantity and quality of instream habitat in the middle Deschutes River (NPCC 2004). Seasonal flow reductions have reduced cover, spawning habitat, and habitat connectivity in this reach. In addition, fish passage at Steelhead Falls varies with flow (NPCC 2004).

As in other reaches, the second driver for instream flow restoration in the middle Deschutes River is water quality. Sections of this reach are listed for exceeding water quality standards for two criteria (see Table 23). As discussed earlier, flow alterations contribute to temperature and pH impairments in Deschutes Basin waterways (see Sections 5.3 and 5.3.2).

Table 23. 303(d) listed sections of the middle Deschutes River

River	River Mile	Parameter	Season	Year Listed
Deschutes River	126.4 to 162.6	pH	Winter/Spring/Fall	2002
Deschutes River	126.4 to 162.6	pH	Summer	1998
Deschutes River	126.4 to 162.6	Temperature	September 1 - June 30	2002
Deschutes River	126.4 to 162.6	Temperature	Summer	1998
Deschutes River	162.6 to 168.2	pH	Summer	1998
Deschutes River	162.6 to 168.2	Temperature	Summer	2002
Deschutes River	162.6 to 168.2	Temperature	September 1 - June 30	2002

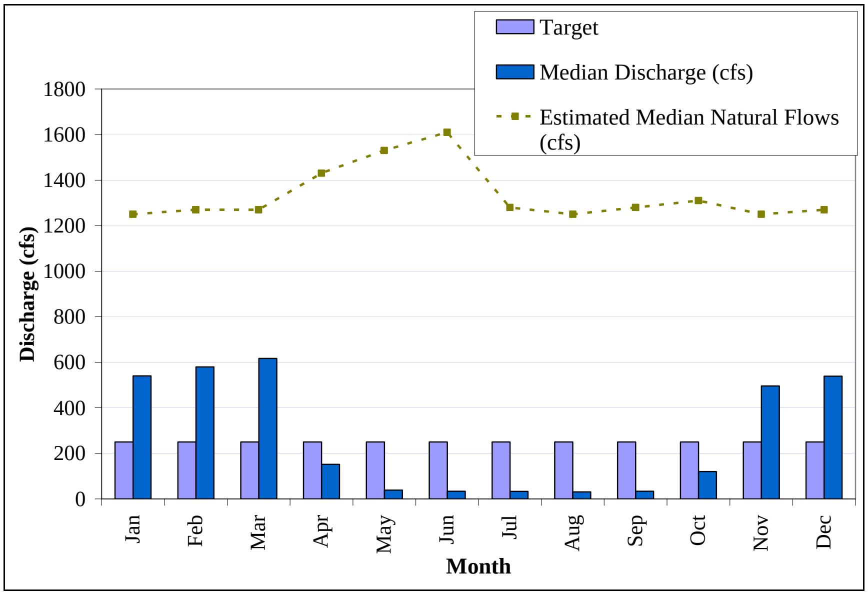
Source: DEQ 2002

ODFW has an application for a year-round instream water right of 250 cfs from North Canal Dam to Round Butte Reservoir (see Appendix A). The application was contested and is not yet approved by OWRD. If approved, this instream right would be junior to other rights and rarely met during summer months. The 250 cfs water right is based on ODFW's recommended optimum flow for fish.

In coordination with the state, Central Oregon Irrigation District, Arnold Irrigation District and North Unit Irrigation District agreed in 1962 to leave 30 cfs at the upstream end of the middle Deschutes River, below North Canal Dam, to support fisheries (Rogers 1962). This "Gentlemen's Agreement" provides instream flow below North Canal Dam but it does not legally protect water downstream of the dam.

Flows in the middle Deschutes River fall far short of flow targets during the summer irrigation season (see Figure 6 and Table 24). Flow targets are met least often during July, and the greatest difference between median flows and target flows appear from June through August. Flows ranged from a low of 13 cfs in July to a high of 2,200 cfs in January during the period of record used in this paper (see Appendix B).

Figure 6. Instream flows in the middle Deschutes River, 1968 – 1997



Data from DEBO gage

Table 24. Target attainment in the middle Deschutes River, 1968-1997

Month	Percentage of Days Meeting Target
Jan	95%
Feb	97%
Mar	95%
Apr	43%
May	4%
Jun	3%
Jul	0%
Aug	2%
Sep	7%
Oct	41%
Nov	90%
Dec	93%

Data from DEBO gage

Median flows in the middle Deschutes River often exceed certificated instream water rights during the winter. This discharge come mostly from tributary and spring inputs in the Upper Deschutes watershed, as Wickiup Reservoir typically releases less than 30 cfs during the winter storage season. Winter flows below Bend, at 500 to 600 cfs, remain less than half of natural flow.

Flow alterations in the middle Deschutes River have resulted primarily from the use of water by irrigation districts. While other users, including municipalities and private entities, use water from the middle Deschutes River and its tributaries, irrigation district activities have the greatest affect on flow patterns in the middle Deschutes River.

Federal regulatory, state regulatory, and consensual approaches may all influence future water management in the middle Deschutes River. The river supports ESA listed bull trout and may support anadromous salmon within a few years, and the ESA may provides some impetus for improving instream flows. As in other reaches, the Clean Water Act and the TMDL program also provides a motivation, although not an imperative, for action. However, consensual approaches offer the greatest opportunities for instream flow restoration.

Table 25. Differences between historic monthly discharge and instream flow targets in the middle Deschutes River, 1968-1997

Month	Difference Between 80% Exceedance Discharge and Target (cfs)*	Difference Between Minimum Discharge and Target (cfs)
Jan	-145	148
Feb	-161	216
Mar	-183	222
Apr	214	236
May	220	234
Jun	221	234
Jul	222	235
Aug	223	237
Sep	223	236
Oct	218	235
Nov	-87	228
Dec	-130	229

Data from DEBO gage
*negative values indicate discharge in excess of target

The Deschutes River Conservancy has worked with water users and used Oregon's legal framework to protect water instream in the middle Deschutes River. Permanent water transfers of acquired or conserved irrigation water to instream uses have protected up to 5 cfs of 'paper' water instream in the middle Deschutes River. Another 6.5 cfs of applications for permanent instream rights are pending at OWRD. The Deschutes River Conservancy's instream leases have protected up to an additional 67 cfs of paper water in this reach. These leases and transfers protect water instream during the irrigation season, when the disparity between certificated instream rights and actual instream flows is greatest.

In the Little Deschutes River and the upper Deschutes River, where winter stream flow restoration will depend on storage releases, the volume of water restored instream can be flexible and vary each year. Protecting water instream in the middle Deschutes River does not involve releasing stored water. It involves the transfer and lease of district rights and the implementation of conserved water projects. The resulting instream rights will largely be defined by the originating rights and must be acquired in fixed amounts. There is little room to shape these rights as the volume of water available under the right is generally sufficient to meet the seasonal rates. There is therefore less year-to-year flexibility in water acquisitions that do not rely on storage releases, and restoring water to the middle Deschutes River will generally require permanently protecting water instream.

In the middle Deschutes, then, the instream flow need can be expressed as the discharge rate needed to meet targets during the irrigation season. District rights, which make up the majority of the water rights from conservation projects and instream transfers, will have lower rates during the first and last 45 days of the irrigation season as flows are ramped up and down in accordance with the water rights. Correspondingly, the rights acquired for meeting flow targets in the peak summer months may be insufficient to meet targets early and late in the irrigation season. A potential solution to filling this short-term need would be releases from storage or split-season leases might also be employed to close this gap.

Another consideration in the middle Deschutes River is the 30 cfs of discharge provided by the Gentleman's Agreement. Districts have provided this water instream on a reliable basis, but there is no guarantee that this water will continue to remain instream as district needs change. This paper does not include the Gentleman's Agreement when it considers water already protected instream on a permanent basis.

The middle Deschutes River, with a target of 250 cfs and 11.5 cfs of senior instream water rights already protected or in process, will require 238.5 cfs to meet targets. If 20 cfs is restored to Tumalo Creek, which enters the middle Deschutes just downstream from the DEBO gage and is discussed in the following section, this need is reduced to 218.5 cfs.

5.3.4 Tumalo Creek watershed; Tumalo Creek

The DWA's preliminary goal for instream flow restoration in Tumalo Creek is to meet instream flows targets in this reach. The following studies have identified flow alteration as a limiting factor in this reach:

- Deschutes Subbasin Plan (NPCC 2004)
- Upper Deschutes River Subbasin Fish Management Plan (ODFW 1996a)

As in other reaches in the Deschutes Basin, irrigation needs drive discharge in Tumalo Creek. The Tumalo Irrigation District diverts water at RM 3 during the irrigation season. Municipal use also contributes to flow alterations in this reach. The City of Bend diverts water from Bridge Creek, a headwater tributary of Tumalo Creek, at RM 17 to meet its water needs (UDWC 2006). These diversions reduce instream flow and potentially impact water quality in Tumalo Creek.

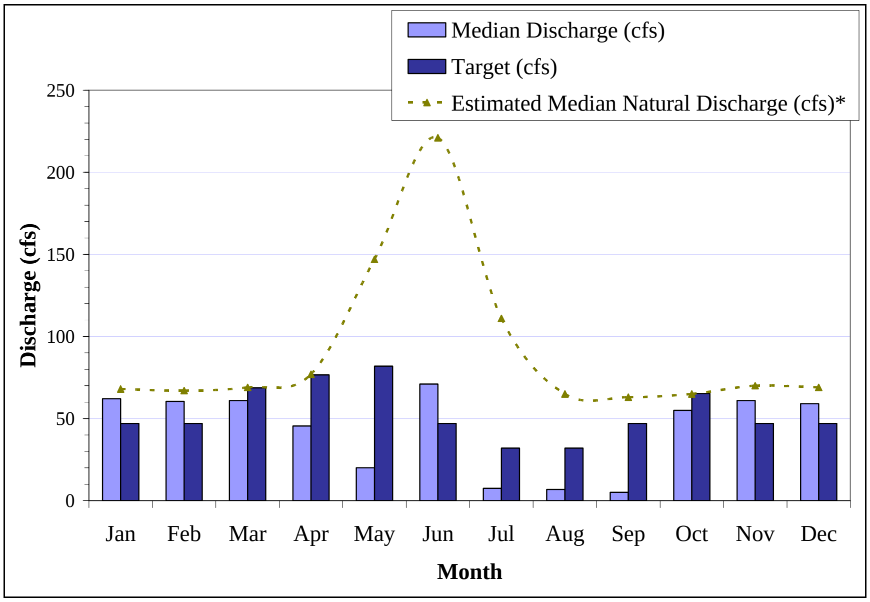
The primary driver for instream flow restoration in Tumalo Creek is fisheries. Historically, Tumalo Creek supported a large redband trout population that migrated from the Deschutes River (NPCC 2004). Physical and water quality changes associated with water diversions have fragmented habitat in this reach and reduced its ability to support redband trout.

In contrast to the majority of reaches examined in this paper, water quality in Tumalo Creek is relatively good. The reach is not 303(d) listed yet, but summer temperatures do remain a concern (NPCC 2004). Water quality monitoring by the UDWC in Tumalo Creek has resulted in a better understanding of water quality issues, and the Creek has been included on the proposed 2004 303(d) list (Lamb, pers. comm. 2006).

The Tumalo Creek instream water right, as applied for by ODFW, has a priority date of 1990 (see Appendix A). This water right protects water from the S. Fork of Tumalo Creek to the mouth and is based on ODFW's recommended optimum flow. The right varies considerably throughout the year, from a low of 32 cfs in July and August to a high of 82 cfs in May. During the period of maximum snow melt and runoff in June the right is just 21% of natural flow. However, in August and September the right makes up 49% and 75% of the natural flow respectively.

The period of record used to summarize flows in Tumalo Creek includes years where the Deschutes River Conservancy's activities have restored flows to the creek. Even so, irrigation diversions still drive flow patterns: discharge in Tumalo Creek often exceeds targets during the winter months, but does not meet targets during much of the summer irrigation season. The greatest differences between median discharge and targets appear early in the season in April and May and from July through September (see Figure 7 and Table 26). Targets are met least often during September, when targets are met on 1% of the days, and during August, when targets are met on 7% of the days.

Figure 7. Instream flows in Tumalo Creek, 2000 – 2005



Data from TUMO gage

Table 26. Target attainment in Tumalo Creek, 2000 - 2005

Month	Percentage of days meeting ISWR
Jan	95%
Feb	84%
Mar	33%
Apr	25%
May	21%
Jun	67%
Jul	21%
Aug	7%
Sep	1%
Oct	41%
Nov	88%
Dec	80%

Data from TUMO gage

Restoring aquatic and riparian conditions in Tumalo Creek will require restoring instream flows during the irrigation season, particularly during July, August and September; but also early in the season in April and May. Federal and state regulatory approaches are limited in their application in Tumalo Creek. In over-allocated reaches, such as Tumalo Creek, voluntary, market-based approaches provide water instream while benefiting existing water rights holders. In Tumalo Creek this involves working with the two primary water right holders: Tumalo Irrigation District and the City of Bend.

The Deschutes River Conservancy and Tumalo Irrigation District have partnered on a number of projects to restore instream flows in Tumalo Creek. In 1997, Tumalo Irrigation District transferred its diversion from the Columbia Southern Canal to the Tumalo Feed Canal. This transfer moved the point of diversion approximately 8.5 miles downstream and improved instream flows in a large section of the creek.

The DRC and the Tumalo Irrigation District partnered on the Bend Feed Canal Piping project to further improve instream flows in Tumalo Creek and the middle Deschutes River. This conserved water project was completed and the conserved water was final ordered in 2005. The project resulted in up to 13.6 cfs of water instream in Tumalo Creek, of which 5.8 cfs are senior rights. DRC and Tumalo Irrigation District have also partnered for a number of years on instream leasing. In 2005, the Deschutes River Conservancy worked with Tumalo Irrigation District customers to lease up to 9.8 cfs of water instream in this reach.

The analysis of water needs in Tumalo Creek differs from analyses in the middle Deschutes River and Whychus Creek because Tumalo Creek is not as over-appropriated relative to natural flow. In addition, Tumalo Creek's flow target is a greater portion of the available flow than the target are in other reaches.

There are two measures of the remaining instream flow need in Tumalo Creek relative to the target: the historic availability of water to meet the target, or the difference between the senior instream water right and the target. The lower of these two values provides information on restoration needs in Tumalo Creek on a monthly basis (see Column C of Table 27).

During June, March and April, the difference between the flow target and the monthly discharge that occurs 80% of the time dictates restoration needs. Available water typically exceeds diversion demands during peak snow melt in June. The amount of water instream 80% of the time exceeds the amount required to meet senior instream rights by 12 cfs (see Table 27). The creek is not fully appropriated by out-of-stream uses at this time, and junior instream water right is partially filled. A similar situation occurs in March and April. However, for the remainder of the irrigation season natural flow is fully appropriated and the target flow less the senior right provides the best estimate of flow needs to reach the target.

Table 27. Water availability, use and instream flow need in Tumalo Creek

Month	A. Difference between 80% Exceedance and Target (cfs)*	B. Difference between Senior Rights and target	C. Flow need to meet Target - min of A & B (cfs)	D. Flow for Social Uses - Median Natural Discharge less Median Discharge (cfs)	E. Need as % of Use - C/D (cfs)
Jan	-6	47		6	
Feb	-5	47		7	
Mar	13	69	13	8	159%
Apr	68	71	68	32	215%
May	77	76	76	127	60%
Jun	29	41	29	150	19%
Jul	28	26	26	104	25%
Aug	28	26	26	58	45%
Sep	45	41	41	58	71%
Oct	19	60	19	10	193%
Nov	-3	47		9	
Dec	1	47	1	10	10%

These results suggest that restoration needs vary considerably on a monthly basis (see Column C of Table 22). During some months, the target suggested by the junior instream water rights may not be socially feasible. The difference between the estimated median natural discharge and the median discharge at the TUMO gage provides a rough approximation of monthly water use (see Column D of Table 27) City of Bend water use is reflected in the non-irrigation season uses, while Tumalo Irrigation District is largely reflected in the irrigation season uses. During some months, a large portion of the water currently consumed would need to be restored instream to meet targets based on existing junior instream water rights (see Column D of Table 27).

The amount of current use that would need to be foregone to meet targets during the early and late portions of the irrigation seasons is quite high, 60% in May and 71% in September, is quite hight because the junior instream water right is set close to the estimated median natural discharge. During the peak summer months, a smaller portion of current use would need to be foregone to meet targets (see Table 27).

The feasibility of achieving the junior instream water rights in Tumalo Creek may be low given the existing social and economic uses of diverted water. The preliminary target may meet the ecological needs of salmon and trout in Tumalo Creek, but achieving that target will not allow for consumptive uses of the creek.

In considering the relative magnitude of the instream right in relation to natural flow and the demands on water during the irrigation season, the Deschutes River Conservancy chose to adopt an instream flow target of 20 cfs throughout the summer months. This target more closely mirrors the instream flow target in Whychus Creek, which flows through an adjacent watershed and has a similar hydrograph to Tumalo Creek. Further research could identify to what extent a 20 cfs target would contribute to ecological needs in Tumalo Creek.

If the DWA adopted a preliminary instream flow target of 20 cfs for Tumalo Creek, there would be a difference of 14.2 cfs between existing senior instream water rights and the target. This difference warrants further analysis of transactional opportunities, particularly the opportunity to exchange Deschutes River water for Tumalo Creek water through the Bend Feed pipe, in order to better assess the feasibility of achieving the instream flow target.

5.3.5 Whychus Creek watershed; Whychus Creek

The DWA's preliminary goal for instream flow restoration in Whychus Creek is to meet instream flow targets and remove the 303(d) listings for this reach. The following studies have identified flow alterations as a limiting factor in this reach:

- Deschutes Subbasin Plan (NPCC 2004)
- Sisters/Whychus Watershed Analysis (USDA 1997)
- Upper Deschutes River Subbasin Fish Management Plan (ODFW 1996a)
- Squaw Creek Watershed Action Plan (UDWC 2002)

Irrigation diversions have heavily impacted flows in Whychus Creek. Irrigation withdrawals by the Three Sisters Irrigation District at RM 23 and by non-district water rights holders dewatered the creek for approximately twenty miles between Sisters and Alder Springs for much of the 20th century. Groundwater discharge in the vicinity of Camp Polk and Alder Springs increases the amount of water in the creek as it flows towards the Deschutes River.

Fisheries provide the primary driver for flow restoration in Whychus Creek. The creek historically supported both summer steelhead and spring Chinook (USDA 1997). Whychus Creek currently supports redband trout, bull trout, and kokanee. Redband trout live throughout Whychus Creek, and bull trout and kokanee have been sighted downstream of Alder Springs (USDA 1997).

Dewatering has had obvious effects on fish habitat. Physical and water quality barriers created by dewatering and by dams have eliminated steelhead and Chinook populations and have reduced the geographic extent of the salmon and trout populations that are still present (USDA 1997). Flow alterations have also contributed to unstable stream backs and altered stream morphology (USDA 1997).

Portland General Electric and the Confederated Tribes of Warm Springs plan to re-introduce anadromous fish to Whychus Creek by 2010. Flow restoration in Whychus Creek will help to provide the habitat necessary to support current and re-introduced fish populations, as it will likely increase both physical habitat availability and water quality.

Water quality provides the second driver for flow restoration in Whychus Creek. Sections of Whychus Creek are listed for not meeting water quality standards for temperature (see Table 28). Flow alterations are a major factor contributing to temperature impairments in this reach.

Table 28. 303(d) listed sections of Whychus Creek

River	River Mile	Parameter	Season	Year Listed
Whychus Creek	0 to 1.6	Temperature	September 1 - June 30	2002
Whychus Creek	1.6 to 21	Temperature	Summer	2002
Whychus Creek	1.6 to 21	Temperature	September 1 - June 30	2002

Source: DEQ 2002

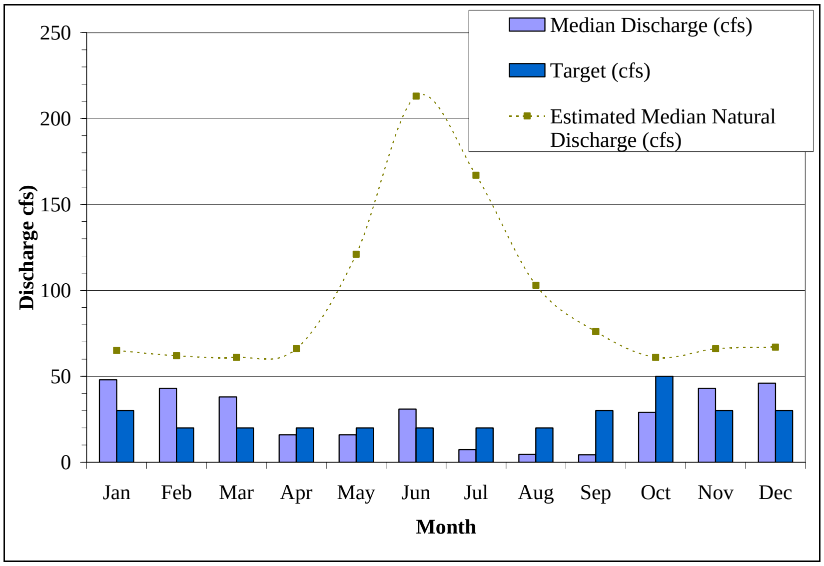
Whychus Creek and its primary tributary, Indian Ford Creek, have certificated instream flows rights that serve as preliminary restoration targets (see Appendix A). These instream flow rights, with priority dates of 1990, are intended to provide the instream habitat conditions necessary to support fish populations. They are based on ODFW's recommended optimum flows and protect water instream from the South Fork of Whychus Creek to Indian Ford Creek. A second instream water right protect higher discharge rates from Indian Ford Creek to the mouth.

In Whychus Creek, water rights with priority dates of 1895 are only partially met during the typical water year and rights junior to 1895 are not met outside of the snow melt period in late spring (see Appendix C). The degree of over appropriation in Whychus is extreme, with approximately 210 cfs in water rights allocated for a stream that has a base flow of around 60 cfs (see Figure 8). Anecdotal reports support the contention that historically flows in Whychus Creek were drastically reduced or eliminated for approximately 20 miles downstream of the town of Sisters. The absence of flow data to confirm this does not detract from the argument that, given the over-appropriation of water rights, the creek most likely went dry each summer.

The period of record used to summarize flows in Whychus Creek includes years in which stream flow restoration activities have restored flows to the reach. Current monthly flow trends in Whychus Creek still reflect the extent of irrigation withdrawals from the creek. Flows are relatively high during late fall and winter but fall short of instream targets during the summer irrigation season.

Targets selected for this paper were based on existing instream water rights designed to support fish populations. These rights protect water from the South Fork of Whychus Creek to Indian Ford Creek. Additional water rights protect water instream between Indian Ford Creek and the mouth of Whychus Creek; these downstream rights are higher than the targets selected for this paper. The greatest discrepancies between median discharge and targets occur in April, May, July, and August (see Figure 8 and Table 29). Instream flow rights were met less than 1% of the days during August and September of the study period, during 5% of the days during July, and during 6% of the days during October (see Appendix B).

Figure 8. Instream flows in Whychus Creek, 2000 – 2005



Data from SQSO gage

Table 29. Target attainment in Whychus Creek, 2000 – 2005

Month	Percentage of Days Meeting Target
Jan	100%
Feb	100%
Mar	93%
Apr	29%
May	46%
Jun	60%
Jul	9%
Aug	3%
Sep	0%
Oct	7%
Nov	89%
Dec	100%

Data from SQSO gage

The instream water right in Whychus as applied for by ODFW has a priority date of 1990 and is therefore met only at the peak of flood flows in late May and early June. The right is for 20 cfs from February through August, rising to 30 cfs in September, 50 cfs in October and back down to 30 cfs through the end of January (see Appendix A). The Deschutes River Conservancy Board adopted a flat 20 cfs target. With reintroduction pending the DRC and the UDWC are working to assess whether 20 cfs will meet water quality standards and provide suitable habitat for steelhead and chinook salmon.

Restoring fish habitat and water quality in Whychus Creek will require restoring instream flows during the irrigation season. Given the abundance of and the early priority dates of senior water rights on Whychus Creek, junior water rights are not likely to improve flows during the summer irrigation season. As with other reaches, regulatory approaches such as the Endangered Species Act and the Clean Water Act motivate flow restoration efforts in Whychus Creek. While they help stakeholders to focus on the creek, they do not necessarily help to restore water instream

In a fully allocated stream like Whychus Creek voluntary, market-based approaches provide long term opportunities for restoring instream flows during the irrigation season. The Deschutes River Conservancy, the Oregon Water Trust, the Three Sisters Irrigation District, the Deschutes Basin Land Trust and the Deschutes Soil and Water Conservation District have participated in a number of transfers, conserved water projects and leases to restore stream flow.

Interest in instream leasing continues to grow. During the 2005 irrigation season, instream leases between landowners, the DRC and Three Sisters Irrigation District protected up to 9 cfs in Whychus Creek. However, permanent instream rights are the best measure for assessing the gap between the targets and current water rights available for instream use. Permanent instream transfers have protected up to 1.8 cfs of senior water and 0.4 cfs of junior water instream during the irrigation season. Conserved water projects approved by or pending with OWRD account for another 4.2 cfs of water protected instream. With a total of 6 cfs protected or pending protection instream, the remaining need is approximately 14 cfs.

5.3.6 Lower Crooked Subbasin; lower Crooked River

The preliminary goal of instream flow restoration in the lower Crooked River is to meet instream flow targets and remove the 303(d) listings for this reach. The following studies have identified flow alterations as a limiting factor in this reach:

- Deschutes Subbasin Plan (NPCC 2004)
- Crooked River Basin Fish Management Plan (ODFW 1996b)

Flows in the lower Crooked River vary with discharges from Prineville Reservoir, spring and tributary inputs, and irrigation diversions. During the winter, Ochoco Irrigation District (OID) stores water in Prineville Reservoir. During the spring, summer, and fall, OID releases water from Prineville Reservoir for downstream irrigation diversions. Operation of the dam results in a seasonally reversed hydrograph with high summer discharges and low winter discharges from Prineville Reservoir, at RM 70, to the Crooked River Feed Canal, at RM 56. Water temperatures in this reach are typically cooler than those in downstream reaches (NPCC 2004)

Irrigation diversions between RM 57 and Prineville withdraw 160-180 cfs of water during the irrigation season. The North Unit Irrigation District's Crooked River Pumps divert water at RM 28. A stipulation between the state and the district requires the district to maintain 10 cfs in the river below the pumps (State of Oregon 1969), and summer flows do drop to this minimum during the irrigation season.

Irrigation return flows from three Crooked River tributaries, Lytle Creek, Ochoco Creek, and McKay Creek, contribute to instream flows between Prineville and Highway 97 at RM 18. Additional diversions withdraw water downstream of Prineville. Springs between Highway 97 and Lake Billy Chinook typically increase flows in the lower Crooked River by 1,000 cfs (NPCC 2004). Flows in the lower Crooked River average 1,562 cfs when the river enters Lake Billy Chinook (NPCC 2004).

The greatest impacts from flow alterations come between the Crooked River Feed Canal, at RM 56, and Highway 97, at RM 18. Flow alterations impact both instream flows and water quality in this reach. Flow restoration in the lower Crooked River should focus on improving irrigation season flows in this section of river.

Fisheries protection and restoration is one of the drivers for instream flow restoration in the lower Crooked River. The lower Crooked River historically supported spring Chinook, summer steelhead, and bull trout. Portions of the lower Crooked River still support bull trout. Two tributaries to the lower Crooked River, Ochoco Creek and McKay Creek, historically supported summer steelhead (NPCC 2004). Portland General Electric and the Confederated Tribes of Warm Springs plan to re-introduce anadromous fish to McKay Creek by 2010. Improved instream flows in the lower Crooked River will support these re-introduced populations.

Instream habitat quality varies in the lower Crooked River. Low stream flow and channel alterations associated with flow alteration subbasin have reduced habitat availability and quality between the Crooked River Feed Canal and Highway 97. In contrast, the high volume of spring inputs downstream of Highway 97 contributes to instream habitat suitable for salmon and trout (NPCC 2004).

Water quality is the second factor driving instream flow restoration in the lower Crooked River. The lower Crooked River's system of dams and diversions creates different water quality issues in different locations. High discharges from Bowman Dam result in the river's exceeding water quality standards for total dissolved gasses immediately below the dam (NPCC 2004). In contrast, irrigation withdrawals and return flows result in the river's exceeding water quality standards for temperature, bacteria, and pH (see Table 30). The relationships between pH, temperature, and discharge have been discussed in earlier sections of this paper (see Sections 5.3 and 5.3.2).

Table 30. 303(d) listed sections of the lower Crooked River

River	River Mile	Parameter	Season	Year Listed
Crooked River	82.6 to 109.2	pH	Summer	1998
Crooked River	0 to 51	pH	Winter/Spring/Fall	1998
Crooked River	0 to 51	Fecal Coliform	Summer	1998
Crooked River	0 to 51	Temperature	Summer	1998
Crooked River	82.6 to 109.2	Temperature	Summer	1998
Crooked River	82.6 to 109.2	pH	Winter/Spring/Fall	1998
Crooked River	0 to 51	pH	Summer	1998
Crooked River	51 to 70	Total Dissolved Gas		1998

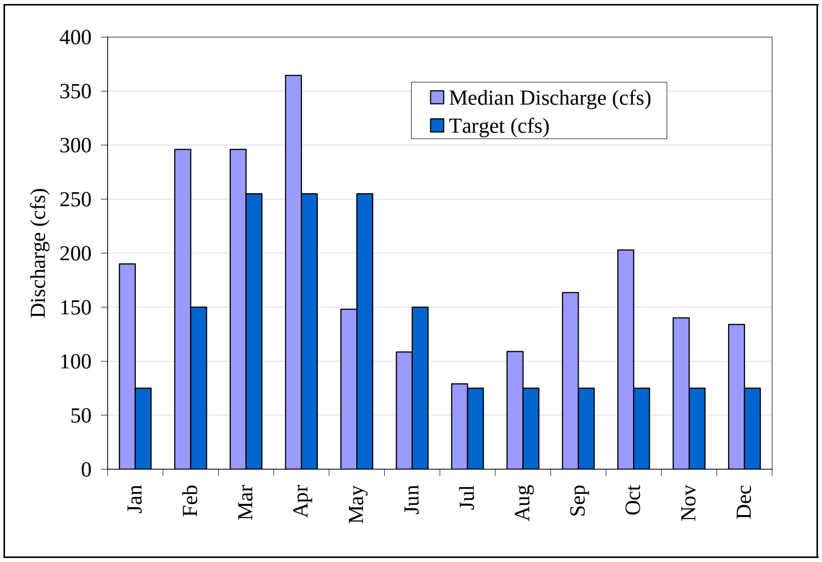
Source: DEQ 2002

Instream water rights have been certificated for several reaches in the Lower Crooked subbasin (see Appendix A). However, instream water rights developed to support fish populations in the lower Crooked River below Prineville Dam are still pending with OWRD. Concerns regarding these rights exist, particularly with respect to whether such flow rates are achievable under natural conditions. The pending rights are based on ODFW's recommended minimum flows.

The pending instream rights still serve as preliminary flow restoration targets, with the acknowledgement that they may change in the future. From July to January the rights call for 75 cfs. A higher rate of 150 cfs is set for February and June, with the remaining period from March to May set at 225 cfs (see Appendix A). The pending instream rights protect water from Bowman Dam to Lake Billy Chinook.

Discharge patterns in the lower Crooked River depend on storage releases, irrigation diversions, and natural discharge. The median monthly flow rate does not meet targets in May or June (Figure 9). Daily discharge meets targets least often during May and June as well (see Table 314). Median flow rates do not fully reflect water availability in the lower Crooked River; minimum flows during the irrigation season range from 1 to 10 cfs (see Appendix B). As in other reaches, annual water availability affects instream flows. No estimates of natural flow were available for the gage used in this paper.

Figure 9. Instream flows in the lower Crooked River, 1968 - 2004



Data from the CKKO gage

Table 31. Target attainment in the lower Crooked River, 1968-2004

Month	Percent of Days Meeting Target
Jan	100%
Feb	89%
Mar	58%
Apr	61%
May	35%
Jun	39%
Jul	54%
Aug	64%
Sep	82%
Oct	95%
Nov	100%
Dec	99%

Data from the CKKO gage

Federal and state regulatory authorities have the potential to affect instream flow allocation in the lower Crooked River. The Endangered Species Act, the Clean Water Act, and the Federal Wild and Scenic Rivers Act all apply to this reach. Two consensual approaches have already had important impacts on instream flows to the lower Crooked River. First, Reclamation has substantial authority to release unallocated water from Prineville Reservoir. Historically, Reclamation has released 75 cfs from the reservoir to provide some instream flow in the lower river during the irrigation season. Second, the Crooked River stipulation limits NUID's withdrawals from the river under Certificate 72283. NUID agreed to limit their withdrawals so as to maintain 10 cfs in the Crooked River below their diversion point (State of Oregon 1969).

Other voluntary approaches, particularly instream transfers and leases, have potential to improve instream flows in the lower Crooked River. Under the Crooked River stipulation, NUID already has to leave 10 cfs instream below their pumps. In general, water rights leased or transferred instream are not considered to be additive to this 10 cfs discharge. Thus, any restoration effort faces the hurdle of first replacing the stipulation water and then making headway towards the instream water right. The exception here would be projects undertaken directly with NUID. These projects, such as the one associated with Certificate 80966, are additive to the 10 cfs that NUID maintains in the river in order to prevent injury to downstream users and enlargement of NUID's water right. Conserved water projects with NUID would provide protect and restore instream flows below NUID's diversion point.

Watershed alterations have changed groundwater and surface water interactions, and these changes have potentially reduced summer base flows. For example, beaver dams historically maintained a high water table in the subbasin that supported springs and perennial streams. Some of these springs are now non-existent, and some of these streams are now intermittent (NPCC 2004). While watershed restoration is not within the scope of this paper, it may improve instream flows in the lower Crooked River and its tributaries.

Lower Crooked River discharge meets instream flow targets least often during May and June (see Table 25). Improving summer instream flows in the lower Crooked River could depend on changing reservoir operations to allow for additional storage releases or on reducing diversions from the lower Crooked River. Meeting targets depends on increasing the volume of water released from storage or on increasing the rate that is protected instream; this study considers targets for both of these measures.

Table 32. Differences between historic monthly discharge and instream flow targets in the lower Crooked River, 1968-2004 water years

Month	Difference between 80% Exceedance Discharge and Target (cfs)*	Difference between Minimum Discharge and Target (cfs)*
Jan	-51	-5
Feb	0	60
Mar	124	183
Apr	120	253
May	193	252
Jun	112	147
Jul	54	74
Aug	40	65
Sep	-7	65
Oct	-61	60
Nov	-46	-9
Dec	-35	10

Data from CKKO gage
*negative values indicate discharge in excess of target

Table 33. Annual differences in volume between daily discharge in the lower Crooked River and instream flow targets, 1968-2004 water years

Water Year	Additional Water Needed to Meet Target 100% of Days (AF)
1968	37,346
1969	6,712
1970	12,330
1971	1,975
1972	847
1973	33,896
1994	46,985
1995	13,389
1996	2,973
1997	5,957
1998	101
1999	3,020
2000	15,210
2001	43,431
2002	42,422
2003	35,331
2004	3,567
Mean	17,970
Median	12,860

Date from CKKO gage

Given the importance and availability of storage in the Crooked River system, though, efforts to meet targets are likely to be based on storage releases and not on permanent instream transfers. Under these conditions, estimates of the volume of water needed to meet targets are more instructive. On average over the period of record, restoring instream flows in the Crooked River will require restoring approximately 16,000 AF annually to the reach between Prineville Reservoir and Terrebonne (Table 33). While these numbers only provide approximate needs, they do indicate that meeting instream flow targets on a majority of the days may not require an extraordinarily large volume of water.

5.3.7 Lower Deschutes subbasin; lower Deschutes River

The DWA's preliminary goal of instream flow restoration in the mainstem lower Deschutes River is to minimize any impacts of upstream activities on flows in the river. A secondary goal is to improve instream flow rates and water quality by working in the lower Deschutes River and its tributaries. The following studies have identified flow alterations as a potential limiting factor in this reach:

- Deschutes Subbasin Plan (NPCC 2004)
- Lower Deschutes River Fish Management Plan (ODFW 1997)

Flows in the mainstem lower Deschutes River are naturally stable to due a high volume of groundwater discharge upstream of Lake Billy Chinook. Primary impacts to the lower Deschutes River come from the three dams that form the Pelton Round Butte Project. Additional impacts may come from irrigation withdrawals from surface waters and from groundwater withdrawals in the upper Basin.

Tributary conditions may have a role in moderating water quality and quantity in the lower Deschutes River, and land use changes have impacted these conditions. Land degradation has reduced floodplain and riparian functions in the subbasin, reducing the infiltration capacity of the soil and creating rapid runoff patterns in tributaries (NPCC 2004). Water quality and quantity impacts in tributaries may affect the mainstem lower Deschutes River.

The primary driver for instream flow restoration in the lower Deschutes River is fisheries. Several populations of ESA listed anadromous fish currently live or historically lived in the lower Deschutes River and its tributaries. Buck Hollow Creek, Bakeoven Creek, and Trout Creek historically supported spawning summer steelhead (NPCC 2004). The Warms Springs River, Shitike Creek, and the lower Deschutes River historically supported summer steelhead, Chinook salmon, redband trout, and bull trout (NPCC 2004). The lower Deschutes River currently supports fall Chinook, steelhead, and resident redband trout (NPCC 2004).

Flow alterations associated with irrigation and with land use change have affected flow patterns and habitat availibility in two ways. First, minor flow alterations potentially have disproportionately large affects on instream habitat availability. Shallow waters along the margins of the lower Deschutes River provide rearing habitat for juvenile salmon and trout, and minor flow reductions may reduce available habitat (NPCC 2004). Secondly, upland land use has reduced water retention and increased flow variability.

The second driver for instream flow restoration in the lower Deschutes River is water quality. The majority of the lower Deschutes River is listed for not meeting three water quality criteria (Table 34). Flow alterations due to the operation of the Pelton Round Butte Project and upstream irrigation and storage operations may contribute to these listings. Warmer water from upstream reservoirs does not necessarily moderate temperatures as well as cooler water would. In this case, increasing instream flows may not reduce temperature impairments during the irrigation season.

Table 34. 303(d) listed sections of the lower Deschutes River

River	River Mile	Parameter	Season	Year Listed
Deschutes River	0 to 46.4	pH	Summer	1998
Deschutes River	0 to 46.4	Temperature	September 1 - June 30	2002
Deschutes River	0 to 46.4	Temperature	Summer	1998
Deschutes River	46.4 to 99.8	Dissolved Oxygen	September 1 - June 30	1998
Deschutes River	46.4 to 99.8	pH	Winter/Spring/Fall	2002
Deschutes River	46.4 to 99.8	Temperature	September 1 - June 30	2002
Deschutes River	46.4 to 99.8	Temperature	Year Around	1998

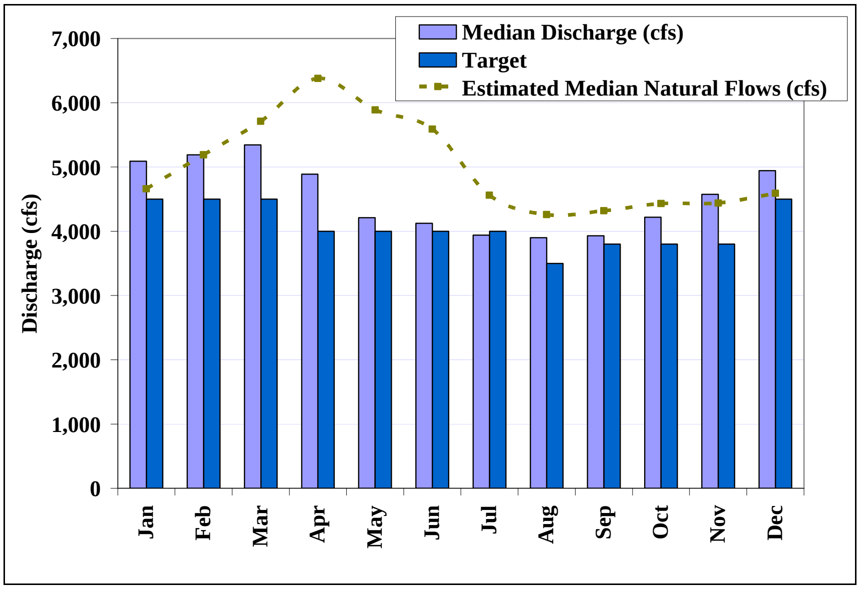
Source: DEQ 2002

Several reaches in the Lower Deschutes subbasin have certificated instream water rights that serve as instream flow restoration targets. Two separate instream flow rights exist for the lower Deschutes River. One instream flow right has a priority date of 1989, and the second instream flow right has a priority date of 1991 (see Appendix A). The 1991 rights are for higher flows than the 1989 rights, and these 1991 rights serve as flow targets for the lower Deschutes River.

The 1989 and 1991 rights are complementary but not additive to each other. For example, in January the 1989 rights certificate 3000 cfs instream and the 1991 rights certificate 4500 cfs instream. The first 3000 cfs in the lower Deschutes River are protected with a 1989 priority date and the next 1500 cfs are protected with a 1991 priority date. Instream rights exist for several other reaches in the subbasin as well (see Appendix A).

Median instream flows in the lower Deschutes River closely align with the 1991 minimum flow rights (Figure 10). Median instream flows actually exceed targets in 11 out of 12 months (see Appendix B). In this reach, though, median instream flows may not accurately represent flow needs.

Figure 10. Instreamflows in the lower Deschutes River, 1975 - 2004



Data from gage 14092500

Table 35. Target attainment in the lower Deschutes River, 1975-2004

Month	Percent of Days Meeting ISWR
Jan	71%
Feb	69%
Mar	84%
Apr	79%
May	62%
Jun	60%
Jul	72%
Aug	98%
Sep	84%
Oct	84%
Nov	99%
Dec	85%

Data from gage 14092500

The greatest challenge for the lower Deschutes River comes not from median flow rates but from variable flow rates; slight variations in winter discharge affect the availability of salmon and trout spawning habitat along the margins of the river (Aney and others 1967). While median flows resemble flow targets, they do not represent variation in discharge that affects habitat availability. Instream flow rights were only met during 71% of days during January and 69% of days during February (Table 35). Additionally, instream flow rights were only met during 62% of days during May and 60% of days during June. This data suggests that instream flows in the lower Deschutes River may not always provide for salmon spawning habitat.

As stated earlier, the base flow in this reach is relatively constant when compared to more highly impacted reaches in the Deschutes Basin. Improving hydrologic conditions in the lower Deschutes River will require reducing low flow events during late winter and early summer. Federal and state regulatory approaches that support the protection of instream flows and ameliorating flow-related water quality issues in the lower Deschutes River include the Endangered Species Act, the Clean Water Act, the Wild and Scenic Rivers Act, and the State Scenic Waterways Act.

Voluntary approaches will have little impact in the lower Deschutes River per se given the lack of water rights on this reach. However, water management in the upper Deschutes Basin can and will have an impact on lower Deschutes River discharge. The Deschutes Groundwater Mitigation Program has already been discussed as one element in an overall resource management strategy. That program aims to use a cap and trade system to prevent further impact from settlement and groundwater extraction on the lower Deschutes River.

Water management in the upper basin will be altered significantly if efforts to meet the future water resource needs of Central Oregon, including the instream needs discussed above, are to succeed. As described in Section 3 above, the complex interactions between storage and natural flow, groundwater hydrology and irrigation diversions it is difficult to asses the potential impacts of these changes on the lower Deschutes River. Modeling approaches employing surface water distribution and groundwater models will be necessary to explore the potential impacts of likely actions and assess the direction and potential order of magnitude of net impacts on the lower Deschutes River. However, it is at least possible that meeting upper Deschutes River targets below Wickiup Reservoir in the winter should have a corresponding impact on winter flow levels in the lower Deschutes River, helping to increase the frequency with which winter flow targets are met.

5.3.8 Metolius River watershed; Metolius River

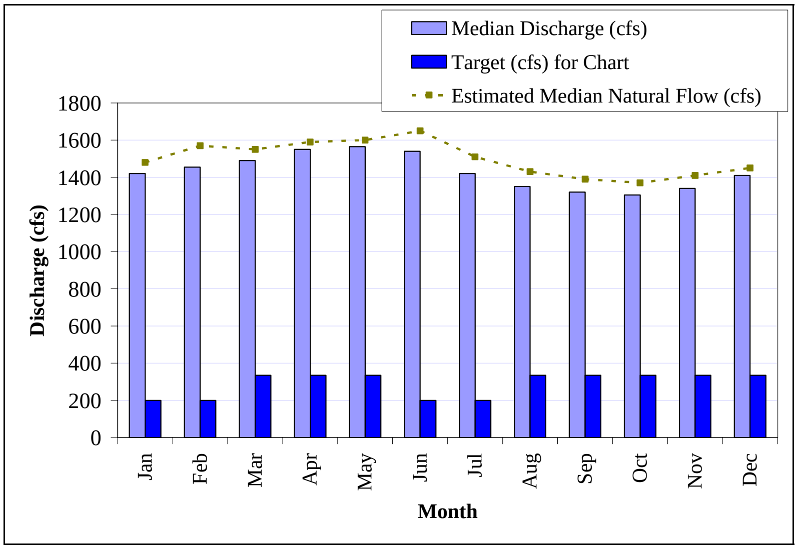
The primary goal of instream flow management in the Metolius River is instream flow protection, not instream flow restoration. No dam operations alter the flows of the Metolius reach, and flows in this reach closely resemble the natural hydrograph. Relatively small diversions on this reach and on tributary reaches do withdraw some water, and groundwater withdrawals may have some effect on flows in the Metolius River. Currently, the Metolius River does not appear on Oregon's 303d list of impaired streams. However, sections of the Metolius River appear on the 2004 proposed 303d list due to temperature impairments that potentially limit bull trout populations (Lamb, pers. comm. 2006).

Drivers for protecting instream flow in the Metolius River include protecting fisheries and maintaining water quality. The cold water of the Metolius River and its tributaries enables these sections of river to maintain three population complexes of bull trout (NPCC 2004). According to the FWS (NPCC 2004 citing FWS 2002), bull trout inhabit most of the streams in the Metolius basin. In addition, the river supports a migratory, adfluvial bull trout population that moves between tributaries and Lake Billy Chinook. The mainstem of the Metolius River historically supported spring Chinook spawning as well (NPCC 2004). PGE and the Confederated Tribes of Warm Springs plan to reintroduce anadromous salmon to Lake Creek by 2010, and protecting flows in the Metolius River will support these populations. Water quality is adequate to support fisheries in the Metolius River, but proposed 303(d) listings suggest that additional water quality improvements can be made.

Sufficient flow is not currently an issue during most years in the mainstem Metolius River. However, OWRD holds instream flow rights on the Metolius River and several tributaries (see Appendix A). In the Metolius River, these instream water rights serve as minimum flows that any future allocation of surface water rights cannot injure. They are based on ODFW's recommended optimum flows.

Discharge is relatively constant in the Metolius River (NPCC 2004). This section of spring-fed river has relatively few diversions and no reservoirs to regulate flow. As a result, the Metolius River has the seasonally steady hydrograph typical of spring-fed central Oregon rivers. Instream flows exceed targets during all months (see Figure 11). Estimates of natural flows for this reach and this location were not available.

Figure 11. Instream flows in the Metolius River near Grandview, 1975-2004



Source: gage 14091500

Median flows in the Metolius River exceed flow targets during all months of the year (see Appendix B). As a result, regulatory approaches focus on protecting current instream flows instead of restoring additional instream flow. A large portion of the Metolius River is listed as a federal Wild and Scenic River, providing some protection to instream flows (USDA 1996b). An additional method to protect current instream flows would be to work through the State Scenic Waterways Act. A portion of the Metolius River has been listed as a Scenic Waterway since 1988, and this listing requires the maintenance of instream flows. Another method would be for another state agency to apply for additional instream flows in the river, given that the instream water right is very low compared to current flows and the natural flow.

5.3.9 Reach Status Discussion

Aquatic, riparian, and floodplain ecosystems in seven out of the eight priory reaches mentioned above face water quality or quantity challenges due to flow alterations. Changes in flow regimes in the upper Deschutes River, middle Deschutes River, Tumalo Creek, Whychus Creek, lower Crooked River, and lower Deschutes River negatively impact aquatic ecosystems, reduce water quality, and limit fish production in the basin. Reducing these impacts will require improving instream flows.

The mechanisms for developing instream water rights in Oregon are clear and complete. The mechanisms for setting appropriate flow targets are not as clear. Certificated instream flows developed by ODFW and OWRD have been discussed here because they provide a constant baseline for comparison between reaches and between current conditions and desired future conditions. The DWA does not consider these flows as endpoints, but rather as targets that need to be adaptively managed. If water quality and habitat objectives are met short of the target in a reach, this information may inform flow restoration efforts. Likewise, if reaching a target in a reach does not adequately support aquatic and riparian species then further investment may be required. In either case, monitoring efforts will need to intensify in order to better document accomplishments along the way and the probability of success as targets are achieved.

The driver for instream flow restoration in the Deschutes Basin has historically been fisheries restoration. The historical focus on fish populations and the current efforts to restore them in the Deschutes Basin highlights their social and economic importance in the basin. Fisheries restoration, including minimum instream flow restoration, may not result the restoration of upland, riparian, and aquatic ecosystem processes. However, fish populations provide a common baseline that engages communities, drives funding, and provides some indication of ecological success.

As stated earlier in this paper, the Oregon Method for determining instream flows is based on flow rates that will support salmon and trout populations. The instream water rights requested by ODFW and certificated by OWRD are based on the Oregon Method or the Instream Flow Incremental Methodology. These approaches to determining instream flows are appropriate for supporting fish populations but they are not necessarily appropriate for restoring aquatic ecosystem processes.

Acreman and Dunbar (2004) point out that instream flow standards in the United States have typically been based on the needs of sport fish, with the assumption that these fish are sensitive indicators of ecosystem health. Some research suggests that this theory is correct; Mobrand and others (1997) argue that streams that have the characteristics necessary to support salmon require healthy ecosystems. However, instream flows designed solely to support sport fish do not necessarily provide for fully-functioning aquatic, riparian, and upland ecosystems.

Palmer and others (2005) argue that stream restoration is ecologically successful only when it leads to a more dynamic, self-sustaining, and resilient stream ecosystem. Stream flow drives the processes that create functioning ecosystems. Poff and others (1997) identified five stream flow flow characteristics that affect ecological processes in stream ecosystems: the magnitude, frequency, duration, timing, and rate of change of discharge in a stream. For example, small changes in discharge amount and timing can have large spatial and temporal affects on the hydraulic characteristics of streams (Dyer and Thoms 2006). Each of the characteristics identified by Poff and others needs to be accounted for when designing instream flow regimes that support healthy stream ecosystems.

From this perspective, healthy rivers in the Deschutes Basin will have flow patterns that contribute to resilient, self-sustaining ecosystems. These flow patterns may not mirror historical flow patterns; minimum discharges may be lower than natural discharges in reaches with irrigation diversions, and median summer discharges may be greater than median natural discharges in reaches with storage releases. Under ideal conditions, discharge patterns will support rivers with functioning physical, biological and chemical processes while allowing for consumptive uses of water.

Where should the Deschutes Basin go from here? Restoring minimum flows to heavily managed reaches is a step towards healthy stream ecosystems. From an aquatic ecosystem perspective, minimum instream flows are better than no instream flows. However, future restoration efforts should take an approach that focuses on restoring stream processes (Wohl and others 2005). Fully-functioning stream ecosystems are dynamic systems (Ward and others 2001); they require periodic floods that connect the stream to its floodplain, support riparian habitat, reshape the channel, and move sediment along a stream corridor. Recreating these flows will require changing the flow regimes of rivers in the Deschutes Basin.

At least one case study has suggested that altering flow regimes to restore ecological processes will not require eliminating human uses of water. Hauer and Lorang (2004) examined the potential for restoration in the upper Snake River. The section of river is managed for winter storage and summer irrigation, like the Deschutes. They examined the hydrologic, geomorphic, and ecological characteristics of this reach and modeled various flow regimes. They determined flow regimes that would support ecosystem processes and modeled those flow regimes under various hydrologic conditions. Hauer and Lorang (2004) suggest that, in moderate and high flow years, there would enough water to support both ecosystem processes and irrigation demands. This case study suggests that further research could improve knowledge of instream flow needs in the Deschutes Basin and provide an impetus for reallocating flows for environmental purposes while still meeting irrigation and other needs.

6. Conclusions

This paper provides a comprehensive assessment of monitoring needs, instream flow and water quality status, and water resource use in the Deschutes Basin. It focused on instream flows, and associated water quality and quantity issues, in eight reaches of the Deschutes Basin. Given the extent of water resource development in the upper basin, streams in the upper basin and the lower Deschutes will never return to their pre-settlement conditions. The paper does, however, document how conditions in the seven highly regulated reaches may be improved and in the five reaches displaying the greatest degree of flow modification provides an estimate of the flow or volume of storage releases required to meet instream targets.

Water quantity and quality monitoring in each reach allow for an understanding of current status and historic trends with respect to water quantity and quality. Each reach discussed in this paper contains two or more gages operated by state or federal agencies, allowing for the analysis of both historic trends and current status. Several parties have suggested that an additional state approved gage on Whychus Creek will allow for a more comprehensive understanding of water resources in the Deschutes Basin.

Water quality monitoring stations exist on each of the reaches as well. The Upper Deschutes Watershed Council's (UDWC) Water Quality Monitoring Program provides a comprehensive approach to monitoring water quality in six of the eight reaches. Instituting a similar coordinated water quality monitoring program in the Crooked River and the lower Deschutes River will improve the ability to analyze trends in these reaches.

Irrigation diversions have reduced summer flows in six of the seven water quality impaired reaches. Most reaches experience low summer flows due to irrigation diversions. Sections of Whychus Creek and Tumalo Creek typically dried up during the irrigation season due to extensive diversion. The daily probability of reaching flow targets during each month appears below (see Table 36).

Table 36. Historic probability of meeting instream flow targets

Month	Probability of Meeting Instream Flow Target in Selected Reaches*							
	Little Deschutes River	Upper Deschutes River	Middle Deschutes River	Tumalo Creek	Whychus Creek	Lower Crooked River	Metolius River	Lower Deschutes River
Jan	Low	Low	Very High	Very High	Very High	Very High	Very High	High
Feb	Low	Low	Very High	Very High	Very High	Very High	Very High	High
Mar	Low	Low	Very High	Low	Very High	High	Very High	Very High
Apr	Medium	High	Medium	Low	Low	High	Very High	High
May	Medium	Very High	Very Low	Low	Medium	Low	Very High	High
Jun	Medium	Very High	Very Low	High	Medium	Low	Very High	High
Jul	Very High	Very High	Very Low	Low	Very Low	Medium	Very High	High
Aug	Very High	Very High	Very Low	Very Low	Very Low	High	Very High	Very High
Sep	High	Very High	Very Low	Very Low	Very Low	Very High	Very High	Very High
Oct	Very Low	High	Medium	Medium	Very Low	Very High	Very High	Very High
Nov	Very Low	Very Low	Very High	Very High	Very High	Very High	Very High	Very High
Dec	Low	Low	Very High	Very High	Very High	Very High	Very High	Very High

*period of record varies for each reach

Key to Table 36

Percent of Days Meeting Target	Historic Probability
80-100%	Very High
60-79%	High
40-59%	Medium
20-39%	Low
0-19%	Very Low

Federal and state regulatory approaches have the potential to affect instream flow allocation in the Deschutes Basin. Federal approaches include the Wild and Scenic Rivers Act, the Clean Water Act, and the Endangered Species Act. State approaches include the State Scenic Waterways Act and instream flow rights to support aquatic life.

However, voluntary, market-based approaches, enabled by the state legal framework, provide the greatest opportunity for restoring instream flows in the Deschutes Basin. Tools available include instream transfers, leases, storage leases, allocation of conserved water. The Deschutes River Conservancy, local irrigation districts and other partners have worked together to restore water to reaches by using these tools. In particular, Conserved Water projects offer an opportunity to restore stream flow. A relatively large portion of water enters the aquifer due to artificial aquifer recharge occurred during transport in canals; reducing this recharge could supply water for instream flows without changing consumptive use in the Deschutes Basin.

In some reaches, the amount of water required to restore instream flows and meet preliminary targets is relatively small. In reaches that depend on storage, storage re-allocation might provide a flexible, market based tool to meet instream flow needs on an annual basis. In other reaches, irrigation season leasing and permanent acquisitions could restore instream flows during highly impacted months (see Table 37).

Table 37. Analysis of instream flow needs in selected reaches

Reach	Storage Release Requirements (AF)	Conversion of Summer Irrigation Water Rights (cfs)
Upper Deschutes River	62,500	
Middle Deschutes River		218.5
Tumalo Creek		14
Wychus Creek		14
Lower Crooked River	18,000	

The instream flow targets selected for this paper are intended as preliminary targets only. The targets were set as minimum flows to support salmon and trout populations, and they may not be appropriate targets to restore aquatic and riparian ecosystem functions. Current research suggests that ecosystem processes depend on the volume and timing of stream discharges. Both high flow and low flow events are important in supporting these processes. Reaching these preliminary flow targets will provide important base flow, but it may not restore ecosystem processes that support healthy fish and wildlife populations.

The Deschutes Water Alliance (see foreword) intends to meet instream, agricultural and community needs for water resources. For the purposes of development of long-range planning scenarios for water management in the upper Deschutes Basin the findings of this paper can be used as preliminary assessment of instream flow demands in the most altered reaches (see Table 37). Scenarios for meeting these needs and those developed in the other DWA papers may then be subjected to further analysis to assess the nature of their impact on the lower Deschutes, with the expectation that flows in this reach may also be improved under the scenarios for restoring flows in upper basin reaches.

The total volume of water represented by these instream needs is just over 183,000 acre-feet. Over the course of a 214-day irrigation season this is equivalent to 430 cfs. Or to put it in a larger context it is 2% of total available water resources and 5% of unregulated blue water flow for the Groundwater Study Area portion of the upper Deschutes Basin. Yet, despite the relatively minor portion of overall water this need represents, the technical, operational and financial challenge will be significant. At approximate current average costs for large conservation projects and instream transfers of $600/acre-foot the total price tag for projects would reach $110 million. However, it is likely this cost will rise as more costly conservation projects are brought on line. Social coordination in terms of the collaboration between a wide range of groups and individuals in the basin will also require a major effort and implies additional costs.

The vision of the 2004 Deschutes Subbasin Plan describes “a healthy, productive watershed that sustains fish, wildlife and plant communities as provides economic stability for future generations of people” (NPCC 2004, ES-5). The voluntary, market-based approaches to restoring instream flow that have been described in this paper are one way to reach that vision.

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Appendix A. Instream Water Rights in the Deschutes Basin

Table A-1. Instream water rights in the Little Deschutes River and tributaries

Source	From	To	Certificate	Priority Date	Instream Rates (cfs)											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Little Deschutes R	Headwaters	Unnamed Trib	73228	10/11/1990	34	34	44.8	62.1	68	34	34	34	32.8	33.3	35.3	37.8
Little Deschutes R	Unnamed Trib	Cresent Creek	73227	10/11/1990	52.6	60	61.6	75	75	60	40	37.4	34.6	35.1	36.8	39.9
Little Deschutes R	Crescent Creek	Mouth	73226	10/11/1990	200	200	236	240	240	200	126	74.5	92.2	116	164	196
Crescent Cr	Crescent Lake	Mouth	73234	10/11/1990	75	75	125	125	125	75	50	50	50	50	108	125
Big Marsh Cr	Refrigerator Creek	Mouth	73236	10/11/1990	39.6	44.8	65.4	78	78	59	39.7	20.4	19.4	20.3	30.6	39.2
Basin Cr	Headwaters	Mouth	73261	04/05/1993	4.7	5.6	4.4	7	7	7	6.6	3.4	3.5	3.5	3.2	3.6
Hemlock Cr	Spruce Creek	Mouth	73262	04/05/1993	10.2	15	15	10	10	10	10	7	7.1	7.1	6.2	7.4
Spruce Cr	Rabbit Creek	Mouth	73263	04/05/1993	1.31	3.98	5.66	5	3.82	2.76	1.23	0.83	0.8	0.76	0.63	0.87

Table A-2. Instream water rights in the upper Deschutes River and tributaries

Source	From	To	Certificate	Priority Date	Instream Rates (cfs)											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Browns Cr	Unnamed Trib	Wickiup Reservoir		04/05/1993	25	25	32	32	32	25	25	25	32	32	32	32
Cultus Cr	Cultus Lake	Crane Prairie Reservoir	73259	04/05/1993	19.2	20	17.5	17.5	32	20	5	3.2	0.5	0.2	1.2	12.3
Cultus R	Corral Swamp	Crane Prairie Reservoir	73258	04/05/1993	48.6	47.3	49.4	50	50	50	50	50	63.1	63.7	59.7	51.5
Deschutes R	Little Lava Lake	Crane Prairie Reservoir	73232	10/11/1990	60	60	93.8	96.3	100	60	60	60	100	100	100	100
Deschutes R	Crane Prairie Reservoir	Wickiup Reservoir	73233	10/11/1990	130	130	130	130	130	130	130	130	130	130	130	130
Deschutes R	Wickiup Reservoir	Little Deschutes	59776	11/03/1983	300	300	300	300	300	300	300	300	300	300	300	300
Deschutes R	Little Deschutes	Spring River	59777	11/03/1983	400	400	400	400	400	400	400	400	400	400	400	400
Deschutes R	Spring River	North Canal Dam	59778	11/03/1983	660	660	660	660	660	660	660	660	660	660	660	660
Fall Cr	Green Lakes	Soda Creek	73255	04/05/1993	46	46	44.6	30	30	30	30	30	38.3	43.6	42	40.1
Fall R	Indina Creek	Mouth	73231	10/11/1990	100	100	142	151	155	100	70	70	70	147	144	143
Goose Cr	Headwaters	Sparks Lake	73256	04/05/1993	10	10	10	7	7	7	7	7	9.4	11.5	11.3	10.9
Link Cr	Blue Lake	Suttle Lake	73266	04/05/1993	50	50	51.9	55.8	66.8	49.5	33.6	29.9	28.9	30.3	46.6	50
Odell Cr	Odell Lake	Davis Lake	75917	09/24/1990	70	70	85	85	85	70	50	50	82	82	82	82
Quinn Cr	Sink Creek	Hosmer Lake	73257	04/05/1993	20.1	24	21.6	21.8	23	23	23	23	15.5	14.6	15.3	18.1
Snow Cr	Headwaters	Crane Prairie Reservoir	73225	10/11/1990	29.9	29.9	29.8	29.9	30.3	30	20	20	20	31.2	30.7	30.2
Soda Cr	Soda Springs	Sparks Lake	73254	04/05/1993	30	30	30	20	20	20	20	20	30	38	38	38
Spring R	Headwaters	Mouth	73264	04/05/1993	50	50	50	50	50	50	50	50	50	50	50	50

Table A-3. Instream water rights in the middle Deschutes River

Source	From	To	Certificate	Priority Date	Instream Rates (cfs)											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Deschutes R*	North Canal Dam	Round Butte Reservoir	Pending	09/24/1990	250	250	250	250	250	250	250	250	250	250	250	250
Deschutes R	CO Canal	Lake Billy Chinook	81612	10/31/1900	0	0	0	1.25	1.67/ 2.20	2.20	2.20	2.20	2.20/ 1.67	1.25	0	0
Deschutes R	CO Canal	Lake Billy Chinook	81612	12/2/1907	0	0	0	0	0.89	0.89	0.89	0.89	0.89		0	0
Deschutes R	North Canal Dam	Lake Billy Chinook	76687	09/01/1899	0	0	0	0.14	0.19/ 0.36	0.36	0.36	0.36	0.36/ 0.19	0.14	0	0
Deschutes R	Deschutes River	Lake Billy Chinook	80400	10/10/1903	0	0	0	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0	0
Deschutes R	North Canal Dam	Lake Billy Chinook	80856	10/31/1900	0	0	0	0.13	0.17/ 0.22	0.22	0.44	0.22	0.22/ 0.17	0.13	0	0
Deschutes R	Original POD	Lake Billy Chinook	81313	05/12/1944	0	0	0	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0	0
Deschutes R	Original POD	Lake Billy Chinook	81314	05/12/1944	0	0	0	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0	0
Deschutes R	Tumalo Creek	Lake Billy Chinook	81333	9/1/1900	0	0	0	5.82	5.82	5.82	5.82	5.82	5.82	5.82	0	0
Deschutes R	Tumalo Creek	Lake Billy Chinook	81333	12/8/1961	0	0	0	1.9	4.3	6.3	7.8	6.3	4.3	1.7	0	0
Deschutes R	North Canal Dam	River Mile 125	81509	10/31/1900	0	0	0	0.21	0.28/ 0.52	0.52	0.52	0.52	0.52/ 0.28	0.21	0	0
Deschutes R	River Mile 125	Mouth	81509	12/2/1907	0	0	0	0.07	0.17	0.17	0.17	0.17	0.17	0.07	0	0

*pending OWRD approval

Table A-4. Instream water rights in Tumalo Creek

Source	From	To	Certificate	Priority Date	Instream Rates (cfs)											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tumalo Cr	S. Fk Tumalo	Mouth	73222	10/11/1990	47	47	68.7	76.6	82	47	32	32	47	65.3	47	47
Tumalo Cr	Tumalo Feed Canal	Mouth	81332	12/8/1961	0	0	0	1.9	4.3	6.3	7.8	6.3	4.3	1.7	0	0
Tumalo Cr	Tumalo Feed Canal	Mouth	81333	9/1/1900	0	0	0	5.82	5.82	5.82	5.82	5.82	5.82	5.82	0	0

Table A-5. Instream water rights in Whychus Creek and tributaries

Source	From	To	Certificate	Priority Date	Instream Rates (cfs)											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Indian Ford Cr	Headwaters	Mouth	73229	10/11/1990	6	4	4	4	4	4	4	4	4	5.4	6	6
Indian Ford Cr			81007	12/31/1882	0	0	0	0	0	0.02	0.04	0.04	0.04	0.02	0	0
Indian Ford Cr			81009	12/31/1871	0	0	0	0	0	0.455	0.91	0.91	0.91	0.455	0	0
Indian Ford Cr			81009	12/31/1903	0	0	0	0	0	0.205	0.41	0.41	0.41	0.205	0	0
Indian Ford Cr			81008	12/31/1905	0	0	0	0	0	0.185	0.37	0.37	0.37	0.185	0	0
Three Cr	Three Creek Lake	Snow Creek	73265	04/05/1993	4.8	4.2	4.1	4.1	7.8	10	7	7	7.7	4.4	5.1	4.1
Three Cr	Three Creek Ditch	Snow Creek Ditch	80590	01/01/1885	0	0	0	0	0.61	0.61	0.61	0.61	0	0	0	0
Three Cr	Three Creek Ditch	Snow Creek Ditch	80590	01/01/1891	0	0	0	0	0.147	0.147	0.147	0.147	0	0	0	0
Whychus Cr	S. Fk Whychus	Indian Ford Creek	73224	10/11/1990	30	20	20	20	20	20	20	20	30	50	30	30
Whychus Cr	Indian Ford Creek	Mouth	73223	10/11/1990	33	33	50	50	50	33	33	33	33	33	33	33
Whychus Cr	Smith Ditch	Mouth	76797	12/31/1884	0	0	0	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0	0
Whychus Cr	Smith Ditch	Mouth	76797	1/1/1904	0	0	0	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0	0
Whychus Cr	Smith Ditch	Mouth	76932	12/31/1885	0	0	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	0	0
Whychus Cr	Smith Ditch	Mouth	76111	12/31/1885	0	0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0	0
Whychus Cr	Diversion on Whychus Creek	Mouth	81607	1/1/1895	0	0	0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0	0
Whychus Cr	Diversion on Whychus Creek	Mouth	81674	1/1/1885+1min	0	0	0	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0	0
Whychus Cr	Diversion on Whychus Creek	Mouth	81674	1/1/1900+1min	0	0	0	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0	0

Table A-6. Instream water rights in the lower Crooked River and tributaries

Source	From	To	Cerificate	Priority Date	Instream Rates (cfs) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Allen Cr	Fall Creek	Confluence with McKay Creek	73210	08/30/1990	3.1	7.9	9.3	9.5	5.9	1.8	0.3	0.1	0.1	0.1	0.4	1.7
Allen Cr	Unnamed Trib	Mouth	73201	08/30/1990	3.7	4.9	11.6	15	15	9	4.5	2	1	0.8	0.8	1.5
Brush Cr	Headwaters	Mouth	73209	08/30/1990	1.7	2.1	5.3	11	10.3	6	2.1	1	0.5	0.4	0.4	0.7
Canyon Cr	Kyle Creek	Mouth	73208	08/30/1990	3.1	4.6	5.6	13.7	10.1	5.9	1.4	1	0.4	0.3	2.3	3.1
Crooked R	N. Fork Crooked R.	Prineville Reservoir	75993	5/11/1990	50	50/75	113	113	113	75	50	47.8	50	50	50	50
Crooked R*	Bowman Dam	Lake Billy Chinook	Pending	05/11/1990	75	150	255	255	255	150	75	75	75	75	75	75
Crooked R	Original POD No. 1	Original POD No. 2	81584	1/1/1904 and 1/1/1910	0	0	0	0	0.431	0.431	0.431	0.431	0.431	0.431	0	0
Crooked R	Original POD No. 2	Lake Billy Chinook	81584	1/1/1898	0	0	0	0	0.856	0.856	0.856	0.856	0.856	0.856	0	0
Crooked R	Original POD No. 2	Lake Billy Chinook	81584	1/1/1910 and 1/1/1904	0	0	0	0	0.431	0.431	0.431	0.431	0.431	0.431	0	0
Crooked R	Original POD	Lake Billy Chinook	80966	9/18/1968	0	0	0	0	0.54	0.54	0.54	0.54	0.54	0	0	0
E Fk Mill Cr	Desolation Canyon Creek	Mouth	73207	08/30/1990	8	12	17.9	25	25	12	2.1	0.9	0.2	0.1	5.8	2.6
Little Mckay Cr	Hunt Springs	Confluence with McKay Creek	73202	08/30/1990	1.6	4.1	4.9	5	3.1	0.9	0.2	0.1	0.1	0.1	0.23	0.9
Marks Cr	Crystal Creek	Mouth	73212	08/30/1990	11	22.8	27.1	53.1	27.7	12.2	3.4	2	0.9	0.8	5.5	8.5
Mckay Cr	Little McKay	Allen Creek	73199	08/30/1990	5.6	14.6	17.3	17.6	10.9	3.27	0.59	0.19	0.19	0.26	0.82	3.16
Mckay Cr	Allen Creek	Mouth	73200	08/30/1990	11	26/ 28.4	33.7	34.4	21.2	6.4	1.2	0.4	1.6	6.2	6.2	11
Mill Cr	West Fk Mill	Mouth	73211	08/30/1990	17.2	35	41.4	45	45	24.9	2.9	1.4	0.4	0.2	9	11.4
Ochoco Cr	Headwaters	Canyon Creek	73194	08/30/1990	3.26	5/ 5.37	6.6	16	13.4	8	2	1.3	0.5	0.4	2.1	2.5
Ochoco Cr	Canyon Creek	Mark's Creek	73193	08/30/1990	17	17/ 25	35	35	35	25	7.04	4.82	1.93	1.67	9.86	14.3
Ochoco Cr	Marks Creek	Ochoco Reservoir	73215	08/30/1990	25	25/ 38	52	52	52	38	10.6	7.2	3.2	3.2	22.8	21.8
Ochoco Cr	Ochoco Reservoir	Mouth	73214	08/30/1990	23	32/ 35	45	45	45	35	14.7	6.3	6.5	6.9	8.6	23
W Fk Mill Cr	Harvey Creek	Mouth	73268	08/30/1990	2	4.7	5.9	6.5	3.7	1	0.2	0.1	0	0.1	0.3	1.1
Wolf Cr	Broadtree Creek	Mouth	73198	08/30/1990	5.5	9	12.3	14	14	9	2.2	1.6	3	4.2	4.2	5.5

*pending OWRD approval

Table A-7. Instream water rights in the lower Deschutes River and tributaries

Source	From	To	Certificate	Priority Date	Instream Rates (cfs) Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Antelope Cr	Grub Hollow Creek	Mouth	73241	08/12/1991	13.7	35.2	41.8	42.7	26.3	7.91	1.44	0.45	0.45	0.63	1.98	7.64
Badger Cr	Pine Creek	Little Badger Creek	73264	12/03/1991	17	17/25	34	34	34	25	17	16.4	15.7	15.6	16	17
Bakeoven Cr	Deep Creek	Mouth	73240	08/12/1991	8.3	24.3	27.9	21.2	2.97	1.16	0.58	0.59	0.59	0.8	1.52	3.77
Boulder Cr	Swamp Creek	Mouth	73247	12/03/1991	10	10/15	20	20	20	15	10	10	10	10	10	10
Buck Hollow Cr	Macken Canyon Creek	Mouth	73239	08/12/1991	25.1	52	54.8	56.8	19.5	3	0.7	0.2	0.2	0.5	2.6	11.4
Cedar Cr	Headwaters	Mouth	73245	12/03/1991	8	8/9.56	8.3	10.1	14.3	10.6	5.8	5.4	4.4	3.1	3.2	6.1
Clear Cr	Clear Lake	Mouth	73248	12/03/1991	21	21/32	36	36	36	32	21	21	21	21	21	21
Deschutes R	Pelton Dam	Mouth	73237	01/16/1991	4500	4500	4500/ 4000	4000	4000	4000	4000/ 3500	3500	3500/ 3800	3800	3800	3800/ 4500
Deschutes R	Pelton Dam	Mouth	73188	10/02/1989	3000	3000	3500	3500	3500	3500	3000	3000	3000	3000	3000	3000
Deschutes R	River Mile 125	Mouth	81509	12/2/1907	0	0	0	0.07	0.17	0.17	0.17	0.17	0.17	0.07	0	0
Frog Cr	Frog Lake Outlet	Mouth	73244	12/03/1991	10	10/15	21.6	24.7	25	15	10	10	10	8.5	8.2	10
Little Badger Cr	Headwaters	Mouth	73238	08/12/1991	8	8/12	14.7	15.9	19.8	12	7.45	6.22	5.58	4.2	4.07	7.87
Threemile Cr	Headwaters	Mouth	73242	08/12/1991	13	13/20	25	23.1	13.4	7.3	3	2	2.5	3	2.9	5.8
Trout Cr	Mouth of Clover Creek	Confluence with Antelope Creek	73190	05/09/1990	25	67/ 72.9	73	73	54.5	16.4	3	0.9	0.9	1.3	4.1	15.8
Trout Cr	Antelope Creek	Mouth of Trout Creek	73189	03/21/1990	25	67/73	73	73	73	33.5	6.2	1.9	1.9	2.8	9.7	25
Tygh Cr	Unnamed Trib	Jordan Creek	73251	12/03/1991	7.63	9.07	8.28	9.27	11.7	8.27	4.23	3.47	2.96	2.18	2.18	4.37
Tygh Cr	Jordan Creek	Badger Creek	73250	12/03/1991	22	22/33	48	47.2	39.4	24.3	11.2	8.4	8.5	8.1	8.1	16.4
Tygh Cr	Badger Creek	Mouth	73249	12/03/1991	40	40/60	95	95	95	60	38.6	32	30.8	29.1	29.4	40
White R	White River Falls State Wayside, Western Boundary	White River Falls State Wayside, Eastern Boundary	73267	12/16/1994	445	602	548	569	583	341	163	129	122	133	195	321
White R	Iron Creek	National Forest Boundary	73243	08/12/1991	28	28/40	62	62	62	40	12	12	12	12	12	28
White R	Mt. Hood Forest Boundary	Mouth of White River	64196	10/02/1989	60	100	145	145	145	100	60	60	60	60	60	60
White R	USGS Gage	Mouth	59751	01/10/1980	60	60/ 100	145	145	145	100	60	60	60	60	60	60
White R	USGS Gage	Mouth	59750	02/20/1962	60	60/95	95	95	95	95	60	60	60	60	60	60
Willow Cr	Coon Creek	Mouth	73197	08/30/1990	4	5/8	13	13	13	8	2.5	1.2	1	2.4	2.4	4

Table A-8. Instream water rights in the Metolius River and tributaries

Source	From	To	Certificate	Priority Date	Instream Rates (cfs)											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Abbot Cr	Unnamed Trib	Mouth	73235	10/11/1990	11.6	12	11.8	12.1	12.3	12	11.4	10.9	10.9	10.8	11	11.3
Candle Cr	Cabot Creek	Mouth	73217	09/19/1990	50	50	83	83	83	50	50	75.1	70.3	67.4	50	50
Canyon Cr	Bear Valley Creek	Mouth	73216	09/19/1990	50	50	83	83	83	50	50	50/ 79.6	76.9	75	78.4	83
Fly Cr	Meadow Creek	Mouth	73230	10/11/1990	4.5	20	24.7	18.5	5.1	1.2	0.2	0.1	0.1	0.1	0.3	2.2
Jack Cr	Unnamed Trib	Mouth	73218	09/19/1990	30	30	42.7	42.4	42.7	30	30	42.6	43.5	43.7	43.8	43.5
Jefferson Cr	Parker Creek	Mouth	73219	09/19/1990	60	60	73.1	89.6	100	60	60	89.9	77.6	72.8	73.2	60
Lake Cr	River Mile 5	Mouth	76416	10/11/1990	50	50	81.9	84	84	50	43.3	34.5	32.6	34.2	42.9	63.1
Lake Creek	Source	Mouth	59797	2/20/1962	20	20	20	20	20	20	20	20	20	20	20	20
Metolius R	Metolius Springs	Canyon Creek	73221	09/19/1990	110	110	185	185	185	110	110	185	185	185	185	185
Metolius R	Canyon Creek	Lake Billy Chinook	73220	09/19/1990	200	200	335	335	335	200	200	200/ 335	335	335	335	335

Appendix B. Instream flow summaries for selected reaches.

Table B-1. Summary of instream flows in the Little Deschutes River, 1973-2002

Month	Median Discharge (cfs)	Mean Discharge (cfs)	Minimum Discharge (cfs)	Maximum Discharge (cfs)	St Deviation (cfs)	80% Exceedance Discharge (cfs)	Estimated Median Natural Discharge (cfs)	Target (cfs)	Difference Btw 80% Exceedance and Target (cfs)	Difference Btw Minimum Discharge and Target (cfs)	Percent of Days Meeting Target
Jan	151	192	13	1602	178	80	204	200	120	187	27%
Feb	160	193	13	1030	156	72	244	200	172	187	38%
Mar	188	225	13	710	130	112	236	236	124	223	37%
Apr	254	284	50	740	150	145	331	240	186	190	54%
May	315	336	34	805	187	157	388	240	231	206	58%
Jun	221	297	28	992	201	134	311	200	177	172	58%
Jul	179	213	38	608	109	126	126	126	0	88	80%
Aug	184	190	9	404	74	137	75	75	-62	66	94%
Sep	135	138	6	294	73	67	92	92	25	86	72%
Oct	66	82	9	266	50	42	116	116	74	107	19%
Nov	89	114	25	739	80	61	164	164	103	139	18%
Dec	129	171	21	914	136	75	196	196	121	175	29%

Data from LAPO gage

Table B-2. Summary of instream flows in the upper Deschutes River, 1968-1997

Month	Median Discharge (cfs)	Mean Discharge (cfs)	Minimum Discharge (cfs)	Maximum Discharge (cfs)	St Deviation (cfs)	80% Exceedance Discharge (cfs)	Estimated Natural Discharge (cfs)	Target (cfs)	Difference Between 80% Exceedance Discharge and Target (cfs)*	Difference Between Minimum Discharge and Target (cfs)*	Percent of Days Meeting Target
Jan	27	213	16	1214	299	22	501	300	278	284	29%
Feb	29	224	17	1107	303	23	441	300	277	283	30%
Mar	32	218	20	1106	260	25	452	300	275	280	34%
Apr	570	526	26	1430	336	118	481	300	182	274	72%
May	1080	1073	154	1960	313	780	599	300	-480	146	99%
Jun	1430	1371	236	2090	304	1160	720	300	-860	64	99%
Jul	1564	1551	476	2060	232	1399	851	300	-1099	-176	100%
Aug	1420	1405	718	1990	208	1250	967	300	-950	-418	100%
Sep	1170	1142	79	1720	256	921	949	300	-621	221	100%
Oct	454	438	15	1320	333	44	783	300	256	285	60%
Nov	27	117	12	915	163	21	654	300	279	288	12%
Dec	26	160	13	926	228	22	551	300	278	287	23%

Data from USBR gage WICO

*negative values indicate discharge in excess of target

Table B-3. Summary of instream flows in the middle Deschutes River, 1968-1997

Month	Median Discharge (cfs)	Mean Discharge (cfs)	Minimum Discharge (cfs)	Maximum Discharge (cfs)	St Deviation (cfs)	80% Exceedance Discharge (cfs)	Estimated Median Natural Flows (cfs)	Target (cfs)*	Difference Btw 80% Exeedance Discharge and Targe (cfs)^	Difference Btw Minumum and Target (cfs)	Percent of Days Meeting Target
Jan	540	706	102	2200	414	395	1250	250	-145	148	95%
Feb	580	740	34	2000	409	411	1270	250	-161	216	97%
Mar	617	764	28	1850	419	433	1270	250	-183	222	95%
Apr	152	352	14	1740	422	36	1430	250	214	236	43%
May	38	65	16	678	82	30	1530	250	220	234	4%
Jun	34	56	16	671	67	29	1610	250	221	234	3%
Jul	33	47	15	315	37	28	1280	250	222	235	0%
Aug	31	53	13	430	53	27	1250	250	223	237	2%
Sep	34	78	14	677	109	27	1280	250	223	236	7%
Oct	120	259	15	1420	298	32	1310	250	218	235	41%
Nov	496	539	22	1500	270	337	1250	250	-87	228	90%
Dec	539	632	21	1700	333	380	1270	250	-130	229	93%

*based on pending instream water right

^negative values indicate flow in excess of target

Data from DEBO gage

Table B-4. Summary of instream flows in Tumalo Creek, 1998-2003

Month	Median Discharge (cfs)	Mean Discharge (cfs)	Minimum Discharge (cfs)	Maximum Discharge (cfs)	St Deviation (cfs)	80% Exceedance Discharge (cfs)	Estimated Median Natural Discharge (cfs)*	Target (cfs)	Difference between 80% Exceedance and Target (cfs)*	Difference between Minimum Flow and Target (cfs)	Percent of Days Meeting Target
Jan	62	66	2	292	27	53	68	47	-6	45	95%
Feb	61	67	1	234	34	52	67	47	-5	46	84%
Mar	61	63	1	107	25	56	69	68.7	13	67	33%
Apr	46	52	2	254	47	9	77	76.6	68	75	25%
May	20	49	0	255	61	5	147	82	77	82	21%
Jun	71	84	3	266	65	18	221	47	29	44	67%
Jul	8	31	0	210	50	4	111	32	28	32	21%
Aug	7	11	0	109	17	4	65	32	28	32	7%
Sep	5	7	0	50	9	2	63	47	45	47	1%
Oct	55	56	1	142	22	46	65	65.3	19	65	41%
Nov	61	59	0	120	21	50	70	47	-3	47	88%
Dec	59	55	1	106	23	46	69	47	1	47	80%

Data from TUMO gage
*negative values indicate discharge in excess of target

Table B-5. Summary of instream flows in Whychus Creek, 2000-2005

Month	Median Discharge (cfs)	Mean Discharge (cfs)	Minimum Discharge (cfs)	Maximum Discharge (cfs)	St Deviation (cfs)	80% Exceedance Discharge (cfs)	Estimated Median Natural Discharge (cfs)	Target (cfs)	Difference between 80% Exceedance and Target (cfs)*	Difference between Minimum Flow and Target (cfs)*	Percente of Days Meeting Target
Jan	48	59	35	446	47	42	65	30	-12	-5	100%
Feb	43	50	23	289	30	38	62	20	-18	-3	100%
Mar	38	38	12	89	13	27	61	20	-7	8	93%
Apr	16	22	2	306	29	9	66	20	11	18	29%
May	16	29	1	241	38	4	121	20	16	19	46%
Jun	31	40	1	284	42	6	213	20	14	19	60%
Jul	7	10	2	57	10	4	167	20	16	18	9%
Aug	5	5	0	34	4	3	103	20	17	20	3%
Sep	4	5	1	12	2	3	76	30	27	29	0%
Oct	29	28	1	92	18	8	61	50	42	49	7%
Nov	43	42	14	171	15	35	66	30	-5	16	89%
Dec	46	49	36	115	11	42	67	30	-12	-6	100%

Data from SQSO gage
*negative values indicate flow in excess of target

Table B-6. Summary of instream flows in lower Crooked River, 1968-2004

Month	Median Discharge (cfs)	Mean Discharge (cfs)	Minimum Discharge (cfs)	Maximum Discharge (cfs)	St Deviation (cfs)	80% Exceedance Discharge (cfs)	Target (cfs)	Difference Btw 80% Exceedance Discharge and Target (cfs)*	Difference Btw Minimum Discharge and Target (cfs)*	Percent of Days Meeting Target
Jan	190	439	80	4260	681	126	75	-51	-5	100%
Feb	296	524	90	3260	574	150	150	0	60	89%
Mar	296	648	72	3720	805	131	255	124	183	58%
Apr	365	632	2	3220	599	135	255	120	253	61%
May	148	319	3	4260	424	62	255	193	252	35%
Jun	109	208	3	3700	435	38	150	112	147	39%
Jul	79	83	1	403	62	21	75	54	74	54%
Aug	109	109	10	336	68	35	75	40	65	64%
Sep	164	162	10	368	84	82	75	-7	65	82%
Oct	203	222	15	473	103	136	75	-61	60	95%
Nov	140	165	84	1420	121	121	75	-46	-9	100%
Dec	134	235	65	2760	321	110	75	-35	10	99%

Data from CKKO gage

*based on pending instream water right

^negative values indicate discharge exceeding target

Table B-7. Summary of instream flows in lower Deschutes River, 1974-2004

Month	Median Discharge (cfs)	Mean Discharge (cfs)	Minimum Discharge (cfs)	Maximum Discharge (cfs)	St Deviation Discharge (cfs)	80% Exceedance Discharge (cfs)	Target (cfs) for Chart	Estimated Median Natural Flows (cfs)	Target (cfs)	Difference Btw 80% Exceedance and Target (cfs)*	Difference Btw Minimum Discharge and Target (cfs)*	Percent of Days Meeting Target
Jan	5090	5248	3150	12800	1237	6080	4500	4660	4500	-1580	1350	71%
Feb	5190	5477	3010	17800	1676	4238	4500	5190	4500	262	1490	69%
Mar	5345	5677	3550	11400	1604	4290	4500	5710	4500/4000	210	950	84%
Apr	4890	5253	3510	9900	1439	3970	4000	6380	4000	30	490	79%
May	4210	4542	3460	9320	916	3820	4000	5890	4000	180	540	62%
Jun	4125	4293	3570	9490	659	3770	4000	5590	4000	230	430	60%
Jul	3940	4042	3270	5650	415	3710	4000	4560	4000/3500	290	730	72%
Aug	3900	3971	3370	5770	339	3690	3500	4260	3500	-190	130	98%
Sep	3930	4014	3390	5610	384	3690	3800	4320	3500/3800	110	410	84%
Oct	4220	4304	3390	7770	520	3840	3800	4430	3800	-40	410	84%
Nov	4575	4728	3330	8900	683	4170	3800	4440	3800	-370	470	99%
Dec	4945	5137	3470	10400	988	4320	4500	4590	3800/4500	180	1030	85%

Data from gage 14092500

Table B-8. Summary of instream flows in the Metolius River, 1975-2004

Month	Median Discharge (cfs)	Mean Discharge	Minimum Discharge (cfs)	Maximim Discharge (cfs)	St Dev Discharge (cfs)	Estimated Median Natural Flow (cfs)	80% Exceedance Discharge	Target (cfs)	Percent of Days Meeting Target
Jan	1420	1528	1100	4730	340	1480	1290	200	100%
Feb	1455	1623	1100	6580	529	1570	1330	200	100%
Mar	1490	1586	1150	2610	268	1550	1360	335	100%
Apr	1550	1571	1220	2630	222	1590	1380	335	100%
May	1565	1597	1240	2300	218	1600	1400	335	100%
Jun	1540	1591	1240	2330	229	1650	1390	200	100%
Jul	1420	1495	1190	2170	200	1510	1330	200	100%
Aug	1350	1412	1160	1980	164	1430	1280	200/335	100%
Sep	1320	1369	1150	1750	142	1390	1250	335	100%
Oct	1305	1346	1130	2330	144	1370	1230	335	100%
Nov	1340	1388	1140	3660	205	1410	1230	335	100%
Dec	1410	1500	1150	3920	324	1450	1270	335	100%

Data from USGS gage 14091500

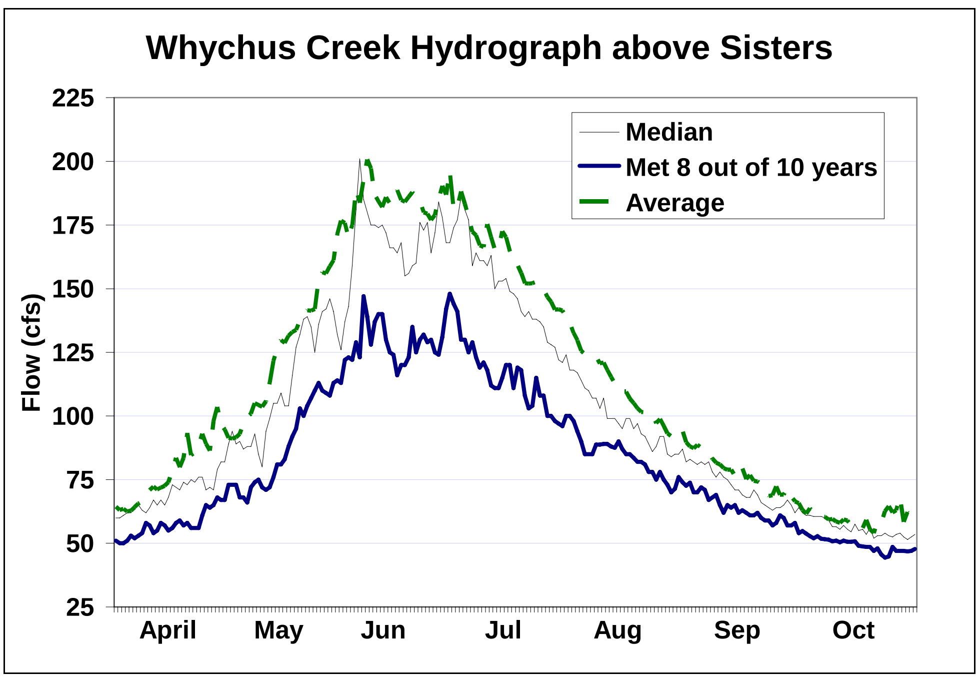
Appendix C. Water Availability in Whychus Creek: Analysis of Hydrology and Characterization of Water Rights

Basic Characteristics of Whychus Creek

Whychus Creek is a major west side tributary of the Middle Deschutes River. From its glacial headwaters on the flanks of Broken Top and the Three Sisters, the creek flows 35 miles first through forest and then sagebrush steppe before joining the Deschutes at river mile 123 (3 miles above Lake Billy Chinook). Whychus Creek flows are fed primarily by runoff from snow, glaciers, and rain, though springs do supplement flows below the town of Sisters and towards the confluence with the Deschutes. The cold, clear waters of Alder Springs (river mile 1.5) provide an important refuge for fish, including Bull Trout, listed as threatened under the ESA. Before the construction of the Pelton and Round Butte dams blocked passage in 1964, Whychus Creek was the primary spawning area for Steelhead in the upper basin. Whychus Creek's only major non-headwater tributary is the spring-fed Indian Ford Creek, which joins at river mile 20. Indian Ford creek runs dry due to irrigation diversions; although there is speculation that return flows and channel loss resurface as springs in Whychus Creek.

Whychus Creek Hydrograph

The natural hydrograph of Whychus Creek reflects consistent glacial runoff augmented by runoff in late spring. Fall and winter flows of 70 cfs rise to 200 cfs or more as snow melts in June. Rain on snow flood events can cause flood flows of over 1000 cfs. The median, 80% exceedance and average flows at the gage above Sisters (and irrigation diversions) are compared in the chart below.



Flow alterations due to irrigation diversions have occurred since the late 1800s in Whychus Creek. The stream is severely overallocated as rights have been issued authorizing diversion of more water than typically flows in the creek. Presently, Whychus Creek enjoys natural flows from its headwaters until around river mile 25, where a series of major irrigation diversions empty the creek of virtually all flow over a 3 mile stretch. By the time the creek reaches Sisters, it is largely dry. Below Sisters, springs and return flow gradually re-water the creek around river mile 20 (Camp Polk Road), though flows remain insignificant as compared to the natural hydrograph. Recent projects including source switches, instream transfers, instream deliveries, water leasing, and canal piping have put some water back in the creek through Sisters where it used to run dry. These projects are in various stages of completion and processing; when they are complete, a permanent flow of 7 cfs will be instream. Conservation projects and water leasing in Whychus Creek are a consensus priority, and the trend should be towards increasing flow in the future.

Water Right Priority Dates and Water Availability

On Whychus Creek, the hydrograph and distribution of irrigation water rights creates three categories of priority dates of importance in instream flow restoration.

- *Pre-1895 'Senior' Rights*. There is a relatively small quantity of pre-1895 water rights (approximately 20 cfs). Because the natural flow is always above 20 cfs, these rights are equivalent in terms of reliability, and are senior rights. Pre-1895 rights are therefore the highest priority for restoration activities. These rights can be taken at face value in the calculations of water protected instream upon transfer or lease of water instream.

- *1895 Rights.* The middle, pivotal group of water rights has a priority date of 1895. There are approximately 116 cfs of 1895 water right on Whychus Creek, of which 110 cfs are held by the Three Sisters Irrigation District. By the late summer, streamflow is likely to be adequate to serve only some of these rights. In practice, 1895 rights are typically served at approximately 50% in the late summer months (when the Creek historically went dry) and may receive roughly 70% water across the season (according to reports from TSID). These rights are therefore worth between 50 and 70% of the paper water right in assessing their contribution to instream flows.

- *Post-1895 'Junior' Rights.* Water rights with a post-1895 priority date are junior water rights on Whychus Creek. They will not be served unless there is more than 138 cfs of natural (pre-diversion) flow in the creek. In a typical year, this will mean that junior rights are only available during the period of high runoff in early summer. It is also noteworthy that during periods when junior rights are served, there is generally not a problem with stream dewatering near Sisters. For this reason, post-1895 rights are not likely to make a measurable contribution towards instream flow restoration in Whychus Creek. These rights are not considered as objects for acquisition in a streamflow restoration strategy in the Creek, however, in order to remove push-up dams in the creek it will be important to work with these water rights to cancel the rights or otherwise reduce their impact on creek habitat.

The analysis of irrigation rights also suggests that it is improbably that the very junior instream rights (priority date 1990) on Whychus will be filled at any time after the peak of the snow melt phase, if at all.

The figure below summarizes these relationships between supply (stream hydrology) and demand (water rights) for Whychus Creek above Camp Polk by superimposing Squaw Creek water rights on top of the median hydrograph. Where the hydrograph shows water available above a given band of water rights the water right can be satisfied. Where the hydrograph is located within a band of water rights, then the water rights are only partially filled. Where the hydrograph is located completely below a band of water rights, then the water rights may not be filled at all. Actually behavior by irrigators may of course vary across the season, in terms of whether they divert their full right. However, with rights in Squaw Creek typically having no volume or duty specified, and in some cases no season, irrigators are within their rights to turn on their rights when they wish and leave the water running as long as they wish.