Upper Deschutes Watershed Council
Monitoring Program
Technical Report

Whychus Creek Restoration Monitoring Plan
Upper Deschutes Model Watershed Program
Deschutes River Basin, Oregon

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Model Watershed Program
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1.0 Introduction and Background

The Upper Deschutes Model Watershed Program ("Program") was formalized in 2006 as a partnership between the Bonneville Environmental Foundation, Upper Deschutes Watershed Council, Crooked River Watershed Council, Deschutes Land Trust and Deschutes River Conservancy. The Program includes a 10-year, monitoring-intensive effort to evaluate changes in watershed conditions in Whychus Creek, the Metolius River and the Crooked River. The Program includes the collaborative work of numerous partners and relies on the commitments, expertise, support, funding and knowledge of the organizations, agencies, businesses and others discussed in this Monitoring Plan (see Reeve *et al.* 2006 or http://www.b-e-f.org/watersheds/ for additional background on the Model Watershed Program).

The Upper Deschutes Watershed Council leads the Program in Whychus Creek. We work with our partners to develop restoration goals and objectives, establish a monitoring plan and implement the coordinated monitoring effort over the duration of the Model Watershed Program.

As the local leader of the Program, we have led the development of the Whychus Creek Monitoring Plan (the Plan). The Plan outlines how we intend to compile, evaluate, integrate and report upon the conditions in Whychus Creek. It highlights physical and biological indicators of watershed conditions, outlines who will collect data on these indicators, and suggests how we can use these data to communicate about restoration efforts.

Under the Plan, we will compile, organize and evaluate information provided by a network of monitoring partners. We will not collect or process most of the data for the indicators discussed in this plan. Instead, we will rely on the expertise, capacity and knowledge of our monitoring partners for data collection and processing. We will synthesize this information and, most importantly, communicate it out to our funding partners, restoration practitioners, and local communities.

This approach emphasizes that, in most cases, we are not the identified experts in the monitoring of specific indicators, but rather the generalists tasked with compiling and translating the information prepared by our monitoring partners. Given the long history of collaboration in the Deschutes Basin and the proven capacity of our partners, we are confident that this approach will result in a robust monitoring program for Whychus Creek (Figure 1).

1.1 Study Area

The Whychus Creek watershed includes approximately 162,000 acres and 40 stream miles in Deschutes and Jefferson Counties in Central Oregon. The watershed extends from the crest of the Cascade Mountains to the creek's confluence with the Deschutes River, approximately three miles upstream of Lake Billy Chinook (formed by the Pelton Round Butte dams). Elevations range from 10,358 feet at the peak of South Sister to 2,100 feet at the confluence with the Deschutes River (Figure 2, Figure 3).

Surface water in Whychus Creek is sourced from springs and snow/glacial melt systems with a small amount from direct precipitation (USFS 2006). A significant amount of water moves

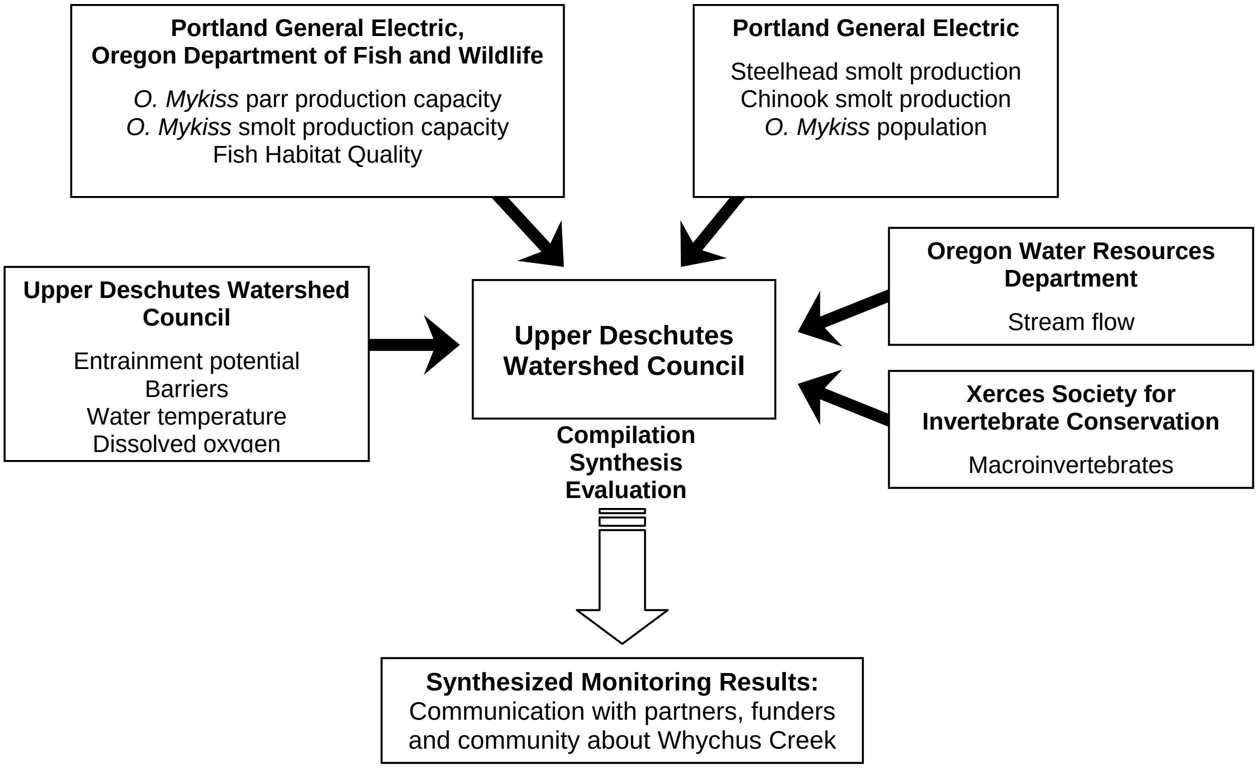

Figure 1. Organization of the Whychus Creek Restoration Monitoring Program

through the system as groundwater due to the highly permeable surface materials of the landscape (Gannett *et al*. 2004). Tributaries include Snow Creek, Pole Creek, and Indian Ford Creek with its tributary Trout Creek. A series of springs, including the Camp Polk springs complex and the Alder Springs complex, contribute a significant amount of flow to the system (UDWC 2000).

Key watershed restoration issues in the Whychus Creek watershed include:

Low Stream Flow / Poor Water Quality

The first irrigation diversions began in Whychus Creek in 1871 and, by 1912, summer flows in portions of Whychus Creek were entirely diverted for irrigation use (Nehlsen 1995). For the next three generations, there was little effort to keep water in the creek during the hot summer months. Up until the mid 1990s, there were many years when reaches of Whychus Creek ran dry.

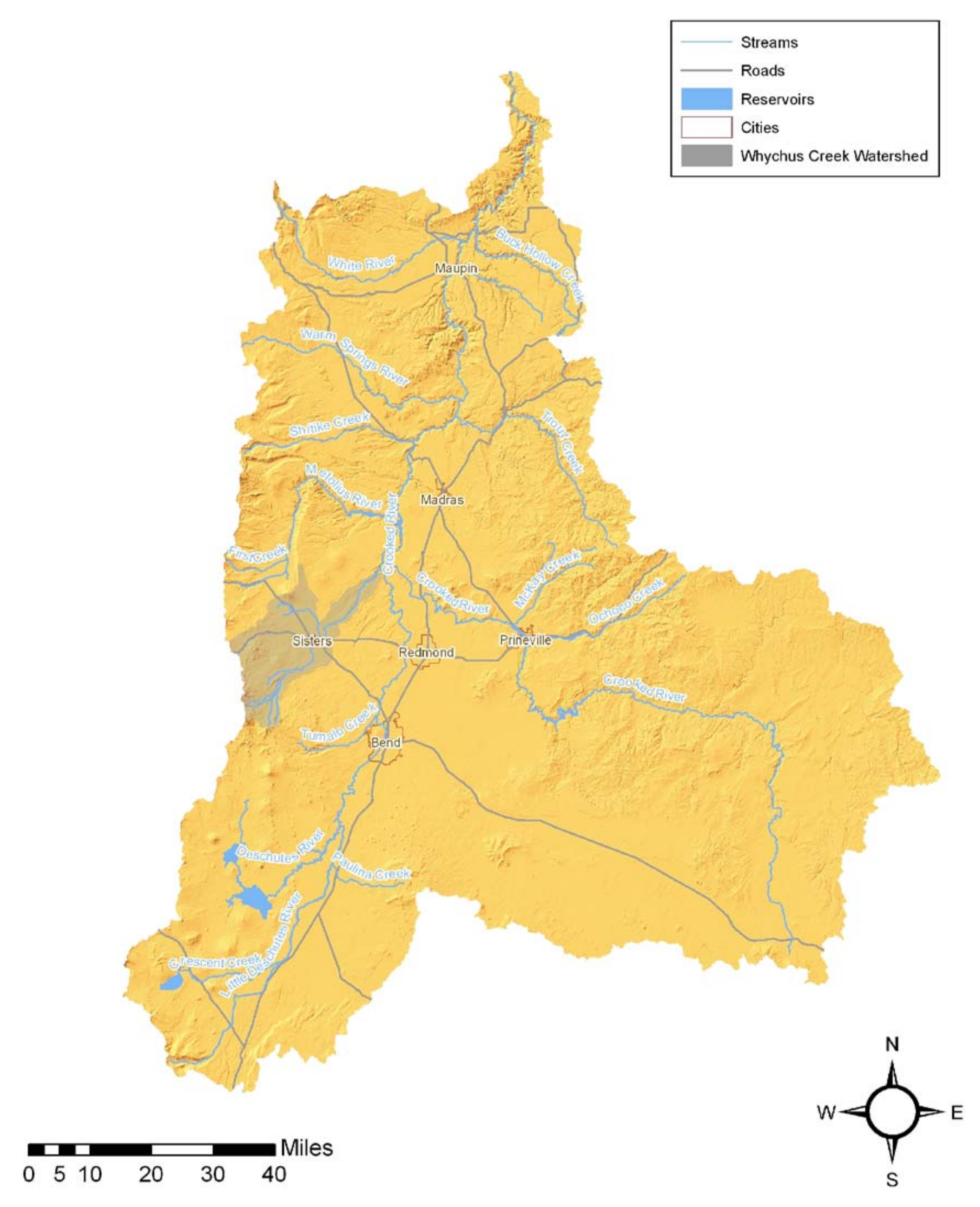

Figure 2. Whychus Creek location map

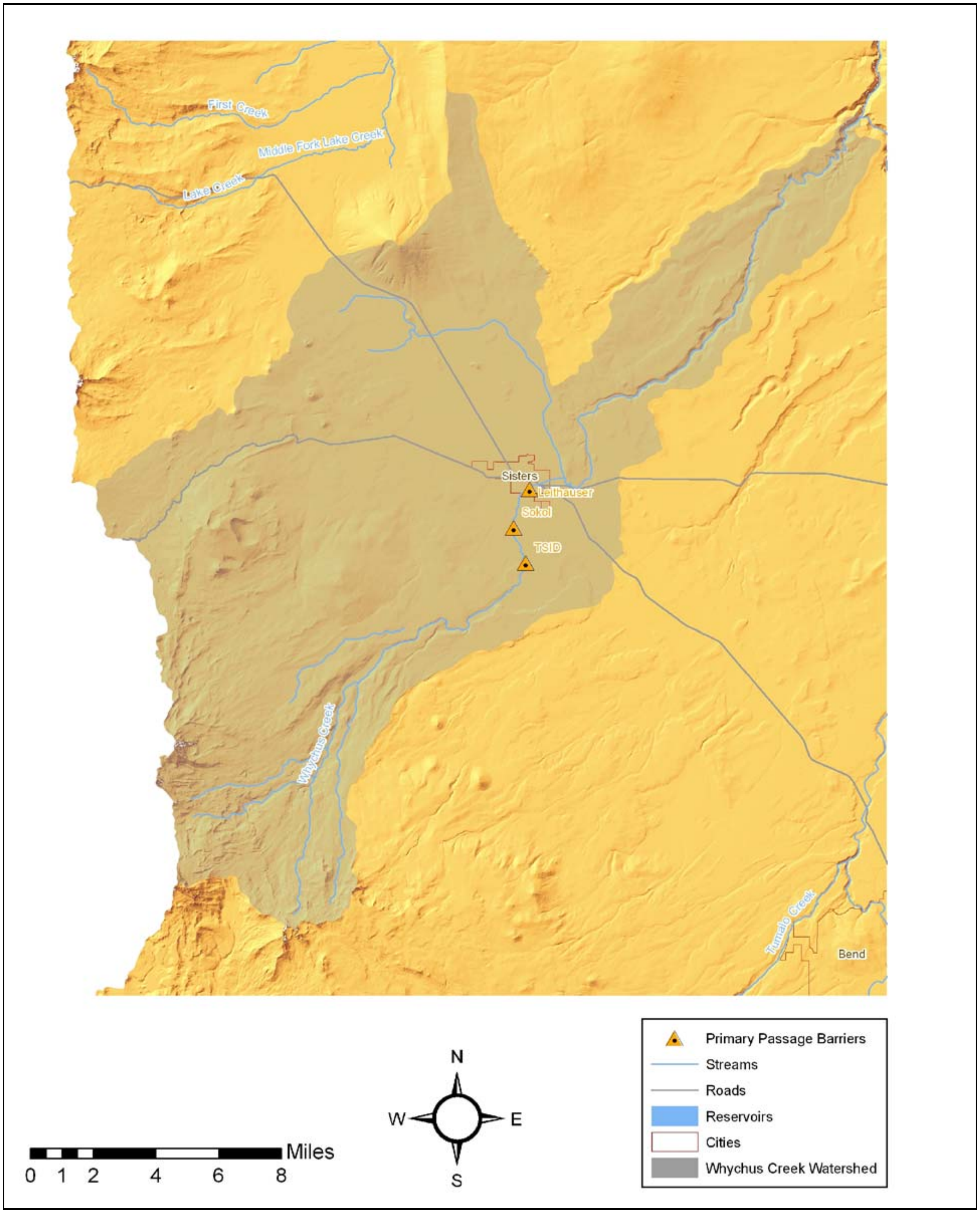

Figure 3. Whychus Creek watershed map

Today, irrigators reduce portions of Whychus Creek to a trickle as they divert almost 90% of the water upstream of Sisters. Irrigation diversions result in a highly modified stream flow regime that varies greatly depending upon the reach. For example, in an average July, one might observe the following along the creek (OWRD Date Unknown; Golden *pers. comm.*):

- 179 cubic feet per second (cfs) flowing in the Deschutes National Forest upstream of Sisters (above any diversions);
- 15 cfs flowing in the Sisters City Park (after most of the diversions); and
- 115 cfs flowing at the mouth (after Alder Springs has added cold, clean water).

Low stream flow affects many aspects of ecological function in Whychus Creek, including physical and biological parameters. Temperatures in the creek have been recorded as high as 24°C / 75°F, which is well above the 18°C / 64°F maximum temperature standard established by the State of Oregon to protect native fish (Jones *in preparation*, Watershed Sciences 2007, Watershed Sciences 2008). Reduced water availability in the summer may hamper growth of riparian vegetation, thus reducing habitat for terrestrial and aquatic wildlife and contributing to increased erosion along the stream banks. These changes in vegetation patterns and bank stability can, in turn, alter spawning and rearing habitat, streamside wetlands and other components of the ecosystem.

Habitat Degradation

Land use and land change has impacted fish habitat along Whychus Creek since the early European settlers moved into the area. Livestock grazing, urban development, irrigation diversions and other activities have all gradually affected fish habitat quality. In addition, the channelization of 18 miles of creek in the 1960s severely damaged specific reaches (USFS 1998).

Channelization, riparian vegetation removal and stream flow modification have reduced the availability of pools, shade, in-stream structure and other important habitat components. While not all reaches of Whychus Creek have been affected, 2007[1] HabRate habitat modeling results indicate that, of the 35.2 miles of potential spawning habitat for steelhead trout, there are 0.0 miles of ‘good’, 28.4 miles of ‘fair’ and 6.8 miles of ‘poor’ quality habitat (Spateholts 2008).

The Camp Polk site exemplifies some of the most devastating effects of channelization. Restoration partners have conducted extensive research at this site and have begun to move forward with a comprehensive stream restoration plan. Channel straightening and berm construction eliminated important habitat features like pools, oxbows, side channels and riparian vegetation. In addition, the straightened channel has increased flow velocities and accelerated erosion. These changes have resulted in channel instability many years after the bulldozers have left the creek. At one specific site, for example, the creek banks remain so unstable that more than 13 feet of bank erosion was measured during one month in 2007 (Senkier *pers. comm.*).

Fish Passage Barriers and Unscreened Diversions

At the close of 2008, six permanent or seasonal fish passage barriers blocked upstream fish passage in Whychus Creek from approximately river mile 15 through river mile 24. These fish

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[1] 1997 habitat survey data analyzed using 2007 HabRate model.

barriers isolate upstream resident fish populations and will limit the amount of habitat accessible to anadromous fish.

Several ongoing projects will improve conditions at these diversions. Restoration partners expect to retrofit the Three Sisters Irrigation District diversion, responsible for more than 80% of the water diverted, with fish passage and screening within the next two years. We are also considering retrofitting several smaller diversions in the coming years.

1.2 Restoration Efforts

Prior to construction of the Pelton Round Butte dams on the Deschutes River in the late 1960s, salmon and steelhead returned from the ocean to spawn in upper Deschutes Basin streams including Whychus Creek, the Crooked River, and the Metolius River. Whychus Creek was historically one of the most important steelhead spawning streams in the upper Deschutes Basin, with an estimated 1,000 adults returning to the creek during the last run in 1953 (Nehlsen 1995).

The Pelton Round Butte dams were built with fish passage facilities in place, but attempts to provide for downstream passage of outmigrating smolts were hampered by swirling currents created by the mixing of the colder waters of the Metolius River with the warmer waters of the Deschutes and Crooked Rivers. Eventually, the Oregon Fish Commission decided to abandon the passage program and requested that Portland General Electric, the owner of the dams at the time, construct a hatchery to offset the loss of the upper Deschutes Basin runs.

When Federal Energy Regulatory Commission re-licensing efforts began in 1995, restoring fish passage at the dams was a primary topic of discussions. Over several years of negotiations, the Confederated Tribes of the Warm Springs Reservation of Oregon, Portland General Electric, the Oregon Department of Fish and Wildlife, and other partners worked to address the issue of downstream fish passage. Now, as an outcome of the relicensing process, the Confederated Tribes of the Warm Springs Reservation of Oregon and Portland General Electric have committed more than $200 million for a comprehensive anadromous fish restoration program. This investment includes new facilitates at the Pelton Round Butte dams for upstream and downstream migration as well as significant restoration funding and support in watersheds upstream of the dams, including Whychus Creek. Fisheries managers introduced the first cohort of more than 200,000 steelhead fry into Whychus Creek in 2007. Additional releases occurred in 2008 and will continue for the foreseeable future.

While the long term success of reintroduction remains uncertain, it is clear that the commitment to restore passage has brought increased attention and resources to restoring watersheds in the upper Deschutes Basin over the next decade. In those areas that historically supported anadromous fish, the proposed reintroduction has prompted significant efforts to restore the habitat needed to support all native salmonids, including resident redband trout.

A suite of local, state, and federal agencies and organizations have coalesced around restoration in Whychus Creek to help make the reintroduction effort successful and to restore conditions for resident fish. Restoration partners coordinate their activities to ensure that their actions are as effective as possible without being redundant. In addition, many local and regional funding partners, including Pelton Round Butte Fund, Oregon Watershed Enhancement Board, Bonneville Environmental Foundation and others have joined to help support the restoration needed to make reintroduction successful. These agencies and organizations have complementary roles, as outlined below.

1.2.1 Partner Organizations

Bonneville Environmental Foundation

The Bonneville Environmental Foundation began working with local partners in the Whychus Creek watershed in 2004 and formally initiated a Model Watershed Program in 2006. The Model Watershed Program makes strategic, long-term investments in designing, implementing, and monitoring the effectiveness of watershed restoration activities. The Bonneville Environmental Foundation provides funding and technical assistance to support the Whychus Creek Monitoring Program.

Upper Deschutes Watershed Council

The Upper Deschutes Watershed Council is the local lead for the Model Watershed Program in Whychus Creek, responsible for communicating with Bonneville Environmental Foundation, coordinating local partners and managing the implementation of the Program. We have historically focused on instream and riparian restoration, watershed education and water quality monitoring. With the adoption of the Model Watershed Program, we are now expanding our monitoring beyond water quality to include more holistic indicators of conditions, as outlined in this Plan.

Deschutes River Conservancy

The Deschutes River Conservancy is a restoration partner. They focus on restoring stream flow to Whychus Creek through collaborative, market-based approaches. The Deschutes River Conservancy also has a role in basin-wide water resource planning.

Deschutes Land Trust

The Deschutes Land Trust is a restoration partner. They protect, restore, and steward upland and riparian areas through land conservation. The Deschutes Land Trust owns Camp Polk and holds a conservation easement on Rimrock Ranch, two ecologically important properties along Whychus Creek. The Deschutes Land Trust also owns Indian Ford Meadow, an ecologically important property along Indian Ford Creek.

Oregon Department of Fish and Wildlife

The Oregon Department of Fish and Wildlife leads the reintroduction process. They coordinate the reintroduction effort between Portland General Electric, the Confederated Tribes of the Warm Springs Reservation, the Sisters Ranger District and others. They partner with restoration funding, technical support and monitoring data collection.

Portland General Electric / Confederated Tribes of the Warm Springs Reservation

Portland General Electric and the Confederated Tribes of the Warm Springs Reservation co-operate the Pelton Round Butte hydroelectric project. They are collaborators in the reintroduction process and are responsible for restoring fish passage at the hydroelectric project. These two entities partner on restoration funding (through the Pelton Round Butte Fund) and technical assistance, co-lead in monitoring data collection and house the Native Fish Team discussed in this Plan.

United States Forest Service, Sisters Ranger District

The Sisters Ranger district is a restoration partner for the reintroduction effort. They partner with other agencies and organizations to actively restore in-channel and riparian areas and to collect monitoring data.

Oregon Water Resources Department

The Oregon Water Resources Department maintains stream gages along Whychus Creek. They publish near-realtime provisional stream data and corrected annual data on their website.

Oregon Department of Environmental Quality

The Oregon Department of Environmental Quality has been instrumental in supporting the water quality monitoring conducted in Whychus Creek since the late 1990s. They provide funding and technical support, and they have been a key partner in water quality monitoring and modeling in Whychus Creek (see Watershed Sciences 2007, Jones *in preparation*).

United States Fish and Wildlife Service

The United States Fish and Wildlife Service plays an important role in providing technical assistance, funding and support for a variety of local restoration projects. They also help streamline regulatory approvals for restoration work and are involved in local Habitat Conservation Planning for steelhead trout.

National Oceanic and Atmospheric Administration Fisheries / National Marine Fisheries Service

NOAA Fisheries / National Marine Fisheries Service supports local restoration efforts through technical assistance, funding and the Habitat Conservation Planning for steelhead trout.

2.0 Monitoring Approach

Researchers bemoan the dearth of monitoring associated with river and watershed restoration. They have highlighted the lack of monitoring (Bash and Ryan 2002, O'Donnell and Galat 2008, Souchon *et al*. 2008), identified potential metrics (Carignan and Villard 2002, Palmer et al. 2005, Ryder and Miller 2005, Woolsey *et al.* 2007) and provided monitoring guidelines and frameworks (Reeve *et al.* 2006, Roni 2005, Souchon *et al*. 2008). So, why are so few restoration practitioners monitoring?

Experiences in the Deschutes Basin suggest that the traditional project-based funding model grossly underfunds monitoring. Project-based restoration funding available through grants typically offers little, if any, opportunity for long-term monitoring. Grants are short-term, focused on immediate results and driven by political cycles (*e.g*., budget years) rather than ecological processes. This funding model leads those practitioners to focus on project implementation instead of monitoring results. This limitation exists in other areas of the Pacific Northwest as well. A survey of 85 restoration project managers in Washington identified limited resources as the primary barrier to restoration project evaluation (Bash and Ryan 2002). The activities in this Plan attempt to reduce this barrier by leveraging existing resources and capabilities. They build upon the work of existing monitoring efforts rather than creating a new monitoring program.

Restoration monitoring encompasses several categories of activities. Roni (2005) builds on MacDonald *et al*. (1991) and identifies several of these categories as follows: *Baseline* monitoring characterizes existing conditions. *Status* and *trend* monitoring characterizes conditions at any given time and tracks how conditions change over time. *Implementation* monitoring identifies whether a project was completed as planned. *Effectiveness* monitoring determines if actions had the intended effects. *Validation* monitoring determines whether any hypothesized cause and effect relationships were correct.

In an ideal watershed restoration scenario, restoration practitioners would hypothesize about how individual restoration activities would affect the stream structures and functions or lead to responses in target species. Practitioners would then design each restoration activity as an experiment and evaluate their hypotheses using controls, statistical tools and other standard experimental practices. This validation monitoring would inform restoration practitioners as to cause and effect relationships between each individual restoration action and its corresponding physical and/or biological response.

While this scenario may appear to be ideal, it is not possible, practical, or desirable in Whychus Creek for three reasons. First, the multiple restoration actions occurring simultaneously along the creek make it difficult to verify cause and effect relationships between specific actions and changes in physical and biological conditions. Practitioners are interested in better understanding these relationships, but we believe that the benefits of this approach would not outweigh its tremendous cost. The effects of most restoration actions in Whychus Creek can be safely assumed (*e.g*., increased flow contributes to decreased temperature based on much empirical data and well tested models) yet the costs of fine-scale validation that accounts for natural variability can be extremely expensive and time consuming. We believe it is not worth the investment to attempt to tease apart the many interrelated factors that confound discrete measurements of ecosystem processes.

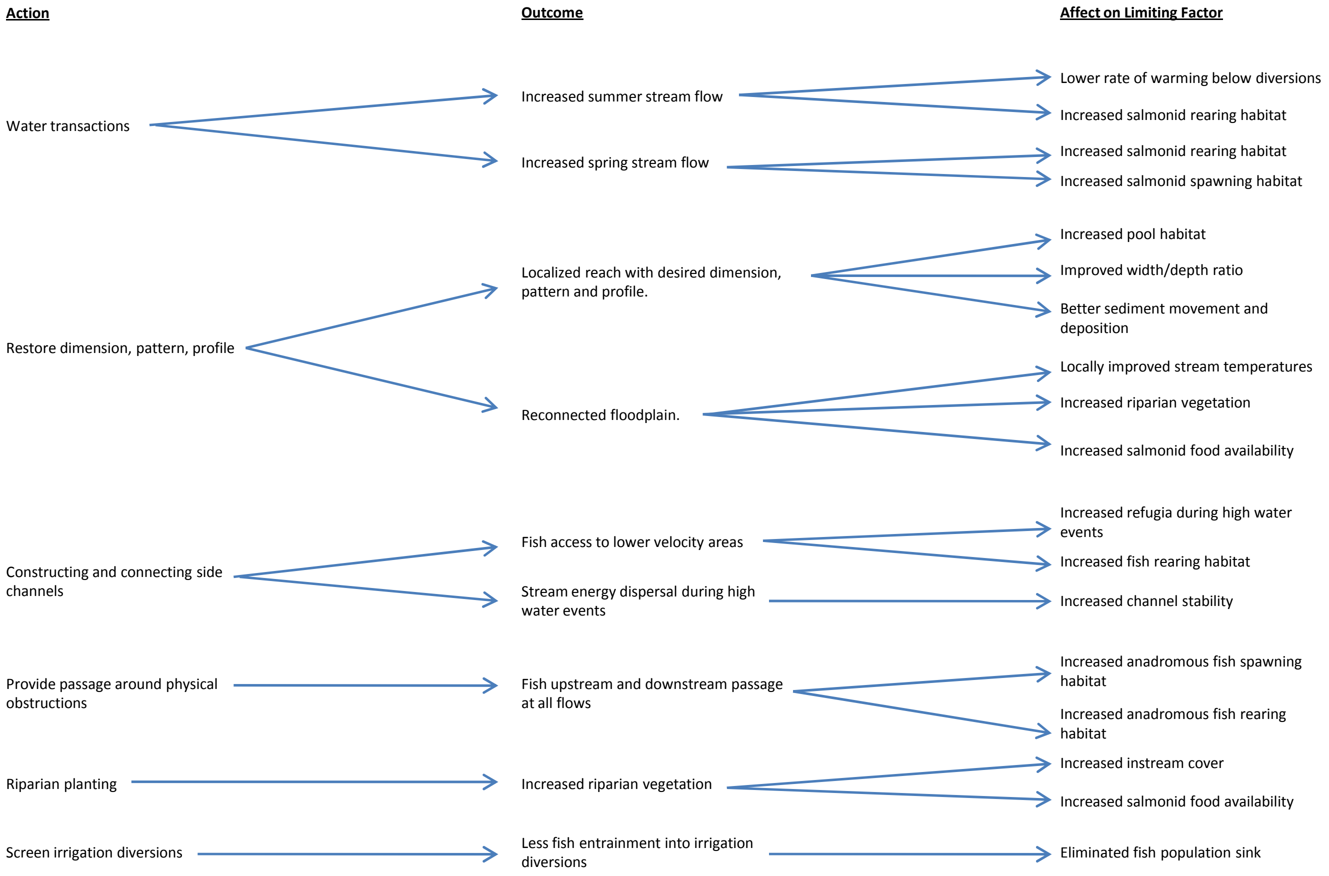
Second, the multiple agencies and organizations managing and restoring Whychus Creek work under different mandates set by local, state or federal regulations, community interests or other factors. Each entity must work on somewhat independent timelines toward their own goals and objectives. These different mandates make it impractical to establish controls for the rigorous experimental designs necessary for validation monitoring.

Finally, there are very limited resources available for monitoring in Whychus Creek. Therefore, from a practical standpoint, any monitoring must be completed as efficiently as possible by using existing data. This data may not be suitable for rigorous statistical analysis. The reliance on existing data inherently limits the types of analyses and the conclusions that can be developed. In addition, because of the limited resources, monitoring must begin at the basic level of understanding status and trends before moving into more complex and expensive efforts of validation.

This Plan focuses on tracking the status and trends of key physical and biological indicators. We selected these indicators based on our conceptual model of salmonid production in Whychus Creek (Figure 4). We developed this model based on locally available data, literature research and professional judgment to illustrate the key influences in each life cycle stage of resident and anadromous salmonids in Whychus Creek. We expect that the ongoing restoration actions will affect the limiting factors identified in the conceptual model. Ideally, our selected indicators will respond to changes in these limiting factors. We will be able to understand if we have achieved our goal of restoring the physical and biological conditions necessary to support healthy salmonid populations in Whychus Creek as described below in Section 1.03.0.

The monitoring approach employed under this Plan relies upon the work that is already being completed by our network of partners. Therefore, the data and metrics utilized in this Plan will be generated by the local partners that have, will or expect to collect monitoring data. Although this design lowers monitoring costs, it also limits which questions the plan includes and which metrics it uses to answer them as discussed throughout this Plan. We anticipate that this approach may change as additional resources become available over time and this Plan is adapted accordingly.

Figure 4. Conceptual model for restoration in Whychus Creek.



3.0 Restoration and Monitoring Goals, Objectives, and Indicators

The partners working to restore Whychus Creek each have slightly different goals and objectives. For some, such as the Deschutes River Conservancy and Portland General Electric, legal agreements or government authorizations define these goals. For others, such as the Watershed Council, Boards and constituencies define these goals. However, for the purposes of this plan, we have selected the broad goal of *restoring the stream conditions and processes necessary to support chinook salmon, redband trout, and steelhead trout and bull trout*.[2] We expect that the monitoring design outlined in this Plan will allow us to track progress towards this goal. However, this Plan will not explicitly focus on bull trout because data are not and/or will not be readily available from local partners. Bull trout are currently located only in the lowest reaches of Whychus Creek and many of the conditions necessary to support steelhead trout, redband trout and chinook salmon are somewhat similar to those necessary for bull trout. We will adapt this plan accordingly if more information becomes available in the future.

Our monitoring design has four general objectives. First, the design will allow restoration partners to *track* the status and trends of selected indicators. Second, the design will encourage partners to *compare* observed trends to expected trends and observed values to desired target values. Restoration partners will use these results to *evaluate* their progress and *learn* more about how the Whychus Creek system works. Finally, we will communicate our observations to our restoration partners, their funding partners, and the local community.

We have selected both biological and physical *indicators* to monitor progress towards our goals. Niemi and McDonald (2004) define indicators as measurable characteristics of the structure, composition, or function of an ecosystem. We believe that the selected indicators will reveal how the creek does or does not respond to various management actions. While the indicators will not identify which specific actions cause which specific response, they will reveal overall ecosystem trends and conditions as restoration progresses. We selected specific *metrics* for each indicator. These metrics help us to assess changes in the status and trends of our selected indicators.

3.1 Biological Indicators

Although we will not be able to assess whether specific changes to physical conditions have directly resulted in specific biological responses, we will monitor several key biological indicators to understand the status and trends in resident and anadromous fish production as well as the macroinvertebrate communities. These indicators will provide critical information about the overall biological conditions in Whychus Creek.

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[2] Although each organization and agency has their own specific goals and objectives, enhancing the biological and physical conditions that affect native fish populations generally drives restoration funding and underlies the efforts of most partners so our goal is consistent with most local partners.

3.1.1 Resident and Anadromous Fish

Whychus Creek currently supports native redband trout, mountain whitefish, dace, bridgelip suckers, chiselmouth, northern squawfish and sculpins. The creek also supports introduced brown trout and brook trout (ODFW 1996). Although these resident species play important roles in Whychus Creek, restoration partners and restoration funders have coalesced around re-introducing anadromous fish to Whychus Creek while simultaneously improving conditions for native resident trout.

Given that most of their investments focus on anadromous fish reintroduction, restoration partners have generally focused their monitoring efforts on anadromous fish populations. Are anadromous fish good indicators of ecosystem function? Yes and no. Anadromous fish respond to different stressors across their life cycle. For example, juveniles will respond to local hydrologic conditions but adults will respond to ocean conditions (Quinn 2005). Natural variability in anadromous populations makes trend assessment difficult (Dent *et al*. 2005; Roni *et al*. 2005). Any analysis of indicator data needs to account for this natural variation (IMST 2007). Given these limitations, anadromous fish have the potential to be acceptable indicators of ecosystem function.

Resident redband trout could be better indicators of local habitat conditions than anadromous fish, but restoration partners need get over one significant hurdle: *Oncorhynchus mykiss* could follow anadromous (*i.e*. steelhead trout) or resident (*i.e*. redband trout) life history patterns. Currently, fisheries researchers cannot distinguish between resident and anadromous juvenile *O. mykiss*. Portland General Electric's Native Fish Team experimented with a dye as one tool to sort artificially and naturally produced *O. mykiss.* Fish did not retain the dye in the stream and the team is now looking for other techniques to distinguish between artificially and naturally produced fish (Hill *pers. comm*.).

This monitoring plan builds on existing monitoring activities currently being implemented by our restoration partners. The activities outlined in the Plan will tell restoration practitioners whether *O. mykiss* population composition has changed between 2006 and 2020. The activities will also reveal whether anadromous production characteristics changed between 2010 and 2020. We hope to see increased complexity in both local juvenile populations and outmigrants.

The specific monitoring activities outlined here draw on Portland General Electric's existing fish monitoring in Whychus Creek. Current efforts focus on monitoring resident and reintroduced *O. mykiss* and reintroduced spring Chinook salmon (*Oncorhynchus tshawytscha*) populations. The Native Fish Team currently monitors these populations at four locations between the City of Sisters and Alder Springs (Table 1). The data collected at these locations may not represent conditions across all of Whychus Creek; creek-scale population estimates will require additional study sites. We support expanding these monitoring efforts upstream of the Three Sisters Irrigation District Diversion and between this diversion and Camp Polk.

The Native Fish Team will conduct mark-recapture electrofishing surveys at each of the four sampling locations. They will follow the Oregon Department of Fish and Wildlife's stream survey protocols as identified by Moore *et al*. (2006). The Native Fish Team standardized their survey protocols in 2006. They suggested that pre-2006 survey methods and 2006 survey results were not adequate to provide reliable population estimates (Hill and Quesada 2007).

Table 1. Biological Indicators: Fish

									Data Collection							Data Analysis		
Question	**Expectation**	**Metrics**	**Target**	**Monitoring Task**	**Where?**	**Location Description**	**Location Coordinates**	**Who's Responsible**	**Protocol**	**When?**	**Other Monitoring Plan?**	**Historic Data Format**	**Historic Data Location**	**Who's Responsible?**	**Data Analysis?**	**Data Summary/Report**	**Notes**	
Has anadromous fish production changed between 2010 and 2020?	Juvenile anadromous fish outmigrant characterstics will change in the degraded reach.	Steelhead trout smolt numbers, size range, and outmigration timing	To Be Determined by Fisheries Managers	Screw trap	One site upstream from Alder Springs on lower Whychus Creek	Road 6360	10T 0628910E:4920560N	PGE Native Fish Team	To Be Determined by Fisheries Managers	2002-Future	PGE Native Fish Monitoring Plan (in development)	Excel	PGE Madras	PGE Native Fish Team	To Be Determined	Native Fish Monitoring Report (April 1 Annually)	PGE has not determined how will normalize results based on the number of fish stocked	
		Chinook salmon smolt numbers, size range, and outmigration timing	To Be Determined by Fisheries Managers	Screw trap	One site upstream from Alder Springs on lower Whychus Creek	Road 6360	10T 0628910E:4920560N	PGE Native Fish Team	To Be Determined by Fisheries Managers	2002-Future	PGE Native Fish Monitoring Plan (in development)	Excel	PGE Madras	PGE Native Fish Team	To Be Determined	Native Fish Monitoring Report (April 1 Annually)	PGE has not determined how will normalize results based on the number of fish stocked	
	Local abundance of Chinook salmon will increase.	Chinook salmon population	To Be Determined by Fisheries Managers	Snorkel surveys	Four locations between Sisters and Alder Springs	Alder Springs Road Crossing Camp Polk Sisters	10T0631685E:4992598N 10T0628910E:4920560N 10T0619560E:4908817N 10T0631684E:4922591N	PGE Native Fish Team	Hill and Quesada (2008)	2002-Future	PGE Native Fish Monitoring Plan (in development)	Excel	PGE Madras	PGE Native Fish Team	To Be Determined	Native Fish Monitoring Report (April 1 Annually)		
Have *O. mykiss* population sizes changed between 2006 and 2020?	Local abundace of *O. mykiss* will increase.	*O. mykiss* population sizes	To Be Determined by Fisheries Managers	mark-recapture electrofishing in early Fall	Four reaches between Sisters and Alder Springs	Alder Springs Road Crossing Camp Polk Sisters	10T 0631685E 4992598N 10T 0628910E 4920560N 10T 0619560E 4908817N 10T 0631684E 4922591N	PGE	Hill and Quesada (2008) adapted from Moore et al. (2006), Sheerer et al. (2007), and Temple and Parsons (2006)	2002-Future	PGE Native Fish Monitoring Plan (in development)	Excel	PGE Madras	PGE Native Fish Team	Hill and Quesada (2008)	Native Fish Monitoring Report (April 1 annually)	No targets as of October 2008.	
Are anadromous fish spawning in habitat opened up by fish passage restoration?	Chinook salmon will spawn in reopened habitat.	Chinook salmon presence	Chinook present upstream of Three Sisters Irrigation District Diversion	Snorkel surveys	Locations to be determined	Locations to be determined.	To be determined.	No entity currently responsible. Recommend that UDWC funds and PGE coordinates monitoring	To be determined.	Monitoring should start as soon as passage is restored above each barrier.	None	Not Applicable	Not Applicable	To Be Determined.	To Be Determined	Dependent on responsible entity.	Surveying for fish presence or absence above each diversion is outside of the scope of work of existing organizations and agencies.	

The Native Fish Team will use the electrofishing data in three ways (Hill and Quesada 2007). First, they will describe *O. mykiss* populations at the four sites above and Chinook populations at yet to be determined locations.[3] They can estimate fish densities, size distributions, and population sizes. The Native Fish Team will likely develop tools to allow them to normalize their results based on how many fish were introduced, but the re-licensing agreement does not require them to develop these tools and results. Second, they will continue to evaluate their sampling methods. Finally, they will compare their population estimates to the population estimates predicted by the Unit Characteristic Model.[4] Initial research will yield population status at these sites. The Native Fish Team will most likely be able to identify any statistically significant trends with five to ten years of data (Hill *pers. comm*. 2008).

We initially selected fish densities as an indicator of environmental conditions at these four sites. Drawing any statistically significant trend data from this research will require at least five to ten years of data (Hill *pers. comm.*). We acknowledge that inter-annual variation affects anadromous and resident populations and that short- to medium-term monitoring may not reveal long-term trends. However, restoration partners and funding partners have focused their efforts and interest on restoring anadromous populations. Population status snapshots retain professional and social importance even if they do not reveal these long-term trends.

This plan does not include all of the potential fish-related monitoring activities that could occur in Whychus Creek. Initial reviews of this plan suggested that we should expand both the scope, including non-salmonids, and scale, including continuous snorkel surveys, of our monitoring activities.

Streams contain fish communities, not just salmonids. Monitoring efforts frequently overlook non-salmonids even though they are sometimes more sensitive to management activities than salmonids (Roni *et al*. 2005). Restoration partners have focused on salmon and trout habitat in Whychus Creek so this monitoring design does not include non-salmonids. Some indices, such as the Coldwater Index of Biological Integrity (Mebane *et al*. 2003), estimate stream conditions based on fish community metrics.

As described earlier, available resources currently limit our monitoring activities. We support the inclusion of non-salmonids into this plan as we move forward with our restoration projects. The Native Fish Team currently collects data on all the fish that they encounter during their electrofishing surveys. This data is not as high quality as the salmonid data, but it can be used to demonstrate changes in fish community metrics (Hill *pers. comm.*). We will incorporate non-salmonids into future monitoring efforts using a Coldwater Index of Biological Integrity or other appropriate metrics when resources become available.

Conditions in Whychus Creek vary spatially and temporally. Changing irrigation needs affect stream flow in the creek, and groundwater inputs affect local stream temperatures. Salmonids, particularly steelhead, move throughout the system to use different habitats has they become more or less suitable. Initial reviews of the Plan suggested that we incorporate continuous snorkel surveys to more fully document anadromous fish presence along Whychus Creek. We believe that this approach will improve both project planning and effectiveness monitoring, and we will explore using this approach as we move forward.

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[3] Chinook survey locations depend on where fisheries managers will outplant Chinook.
[4] See Habitat Quality components of this document for a description of the Unit Characteristic Model.

3.1.2 Macroinvertebrates

Macroinvertebrate monitoring can often help restoration practitioners overcome some of the challenges associated with monitoring ecological systems because macroinvertebrate communities respond quickly to changes in habitat conditions (Roni *et al.* 2005). We expect to see changes in macroinvertebrate communities that are of a greater magnitude and that occur sooner than changes in other biological indicators. The monitoring activities included here will identify whether or not Whychus Creek's macroinvertebrate community indicates an improvement in watershed conditions or not.

Small-scale habitat restoration projects may lead to small changes in macroinvertebrate communities. Natural processes may mask these changes so that monitoring may not reveal them (Roni *et al*. 2005 citing Weigel *et al*. 2001). However, restoration partners expect to alter habitat conditions across all of Whychus Creek through physical and hydrologic enhancements. Roni *et al*. (2005) suggest that large scale alterations have a greater affect on macroinvertebrate communities than small scale alterations. We and our partners have and will continue to implement both local and reach scale restoration projects, and we expect that our monitoring will pick up on any changes to these communities.

We have already partnered with the Department of Environmental Quality and the Xerces Society to collect baseline macroinvertebrate data along Whychus Creek. Data collection follows Department of Environmental Quality protocols, and data analysis identifies organisms to the genus level where possible. The Xerces Society first collected macroinvertebrate data in 2005, before any large scale habitat restoration and before some stream flow restoration. We expect the Xerces Society to collect data again in 2009, after large scale stream flow restoration but before intensive habitat restoration, and again in 2014, after both large scale stream flow restoration and intensive habitat restoration. Although we acknowledge that more frequent data collection would improve our understanding of Whychus Creek, funding constraints currently limit data collection and analysis.

The Xerces Society has analyzed this baseline data using the Predator multivariate model. The Predator model compares observed macroinvertebrate metrics to expected macroinvertebrate metrics and estimates stream condition based on this comparison. We will use the collected data in conjunction with the Predator model to understand if any changes have occurred in the Whychus Creek's macroinvertebrate community (Table 2).

Multivariate models provide one way to interpret macroinvertebrate data. Some restoration practitioners support the use of simple metrics or of multi-metric indices as opposed to multivariate models. We have initially selected a multivariate approach based on its historic use in the Whychus Creek watershed. We acknowledge that a simple or multi-metric approach may prove to be as valuable as the selected multivariate approach. Our data will allow us to incorporate such an approach in the future if the selected approach does not successfully inform our restoration efforts.

Table 2. Biological Indicators: Macroinvertebrates

														Data Analysis			
Question	**Expectation**	**Metrics**	**Target**	**Monitoring Task**	**Protocol**	**Where?**	**Location Description**	**Location Coordinates**	**Who's Responsible?**	**When?**	**Other Monitoring Plan?**	**Historic Data Format**	**Historic Data Location**	**Who's Responsible?**	**Data Analysis?**	**Data Analysis/Report**	**Notes**
Do macroinvertebrate populations indicate a change in watershed conditions between 2005 and 2020?	Macroinvertebrate indicators will show that conditons have improved	Observed:Expected Ratio	1:1	Macroinvertebrate sampling	Oregon DEQ (1999)	Ten locations between the upstream gage and the mouth of Whychus Creek.	RM 0.4 (RM 000.50)	10T 0632042E 4923953N	Xerces Coordinating with UDWC	2005, 2009, and 2014	None	Excel	UDWC	Xerces coordinating with UDWC	Xerces	The UDWC will summarize Xerces' data during the first two sampling years. The UDWC will publish a final report with conclusions following the final sampling year.	
							U/S Alder springs (RM 003.00)	10T 0630541E 4921451N									
							U/S Rd 6360 (RM 006.00)	10T 0627199E 4918000N									
							Rim Rock Ranch (RM 009.00)	10T 0626832E 4915827N									
							D/S Camp Polk (RM 018.25)	10T 0619669E 4909276N									
							D/S Camp Polk Bridge (RM 019.50)	10T 0618420E 4908327N									
							Perit Huntington Rd (RM 023.50)	10T 0617228E 4905206N									
							OWRD Gage at Sisters City Park (RM 024.25)	10T 0616341E 4904935N									
							Rd 4606 (RM 026.00)	10T 0615333E 4903280N									
							Upstream Gage (RM 030.25)	10T 0614445E 4898862N									

3.2 Physical Indicators

Most of the management actions proposed or initiated by restoration partners involve physical changes to Whychus Creek. Many management actions, such as stream flow restoration and floodplain reconnection, will directly and indirectly affect multiple components of Whychus Creek. We have selected physical parameters that we expect to change with the anticipated restoration actions. This monitoring design will not show causality, but it will identify any trends in these parameters.

3.2.1 Water Quality

The Oregon Department of Environmental Quality has identified and set water quality standards to support resident and anadromous fish. These standards vary based on location, species expected to be present, and season. Whychus Creek currently exceeds state standards for temperature (UDWC 2008), suggesting that the creek may not be optimal for resident and anadromous fish production during some times of the year. The Oregon Department of Environmental Quality has included Whychus Creek on its 303(d) list of water quality impaired streams due to these high stream temperatures. We have also collected data showing that Whychus Creek does not meet state standards for dissolved oxygen (Jones *pers. comm.*), another factor that potentially limits aquatic life. We expect that the Oregon Department of Environmental Quality will list Whychus Creek for not meeting dissolved oxygen standards in the near future.

This monitoring plan builds on existing monitoring activities. It will inform restoration practitioners as to whether water quality has changed in Whychus Creek between 1996 and 2020. As described below, the Plan will focus on metrics related to stream temperature and dissolved oxygen when outlining an approach to answer this question.

3.2.1.1 Temperature

Several management actions may improve stream temperatures in Whychus Creek. First, increasing stream flow may affect stream temperature (Caissie 2006, IMST 2004, Poole and Berman 2000). Both empirical data and water quality models suggest a strong relationship between stream flow and maximum stream temperatures (Jones *in preparation*, Watershed Sciences 2007). Second, channel rehabilitation may change surface-subsurface water exchange (Kasahara and Hill 2001) and alter temperature regimes (IMST 2004, Poole and Berman 2000). Finally, restoration that increases riparian vegetation may increase stream shading and reduce stream heating potential (IMST 2004, Poole and Berman 2004), although the effect is expected to be relatively small in Whychus Creek because much of the creek is already shaded.

Restoration partners will restore stream flow, alter channel morphology, and improve riparian cover along Whychus Creek. The monitoring activities included in this plan will reveal any changes in Whychus Creek's temperature regime, although the degree to which these changes may be influenced by restoration actions, climate change, natural variability and many other factors is not possible to tease apart in this Plan.

The Department of Environmental Quality has designated Whychus Creek for salmon and trout rearing and migration (ODEQ 2003a). Under this designation, the seven day moving average maximum temperature of the creek should not exceed 18°C / 64°F. Restoration partners have focused on achieving this standard throughout the creek with the acknowledgement that any improvements in temperature (*i.e.* decrease) will improve conditions for salmonids.

Oregon's Independent Multidisciplinary Science Review Team reviewed Oregon's temperature standards in 2004. The team concluded that Oregon's temperature standard was technically sound, and that the seven day moving average maximum temperature metric applied under Oregon's standard was appropriate for measuring stream conditions (IMST 2004). Salmonids can survive in streams that do not meet temperature standards due to a variety of reasons ranging from physiological adaptations to the availability of cold-water refugia (IMST 2004). We expect that, although higher temperatures have not eliminated salmonid populations, lower temperatures will be beneficial to existing and re-introduced populations.

Our Water Quality Monitoring Program will collect continuous temperature data from approximately ten sites located along Whychus Creek. These sites encompass reaches with different habitat and different hydrologic conditions. We expect to collaborate with Oregon State University researchers to use this temperature data in four ways. First, we will evaluate water quality status as it relates to state temperature standards. Second, we will use statistical approaches such as the exact sign test for trends to determine if any multi-year trends exist (Table 3). Finally, we will continue to evaluate the effectiveness of stream flow restoration as a tool to reduce instream temperatures. We expect Oregon State University researchers to fully develop their statistical tools by June 2009 (Jones *pers. comm.*).

Existing methods allow us to identify trends in the seven day moving average maximum temperature and trends related to meeting Oregon's 18°C standard. Salmonids are sensitive to prolonged high temperatures over periods as short as several hours, though, and the seven day moving average maximum temperature record will not reflect short duration, high temperature events.

We will publish an annual report summarizing these data. The report will summarize temperature status in Whychus Creek as it relates to state standards. It will also summarize any findings related to long-term trends in stream temperature.

The temperature monitoring included here does not account for the full range of interactions between temperature and salmonid production. It focuses on monitoring activities that use state standards and previously developed statistical methods. We acknowledge that salmonids are sensitive to prolonged high temperatures over periods as short as several hours. Oregon's temperature standard is adequate for measuring stream conditions, but it does not account for short term, high temperature events. Spring temperatures that exceed 12°C may affect egg growth, alevin development, and steelhead smoltification (Richter and Kolmes 2005). Temperatures that exceed 22°C to 24°C may block salmonid migration (Richter and Kolmes 2005 citing Fish and Hanavan 1948). As we implement the monitoring activities in the plan we expect to develop statistical approaches that account for short term, high temperature events as well.

3.2.1.2 Dissolved Oxygen

We expect that dissolved oxygen concentrations in Whychus Creek will change as stream flow and channel restoration moves forward in much the same way that temperature will likely change. Changes in dissolved oxygen may affect factors such as salmonid egg size (Geist *et al.* 2006) and fish behavior (Kramer 1987).

The Department of Environmental Quality applies different standards to different streams depending on their classification (ODWQ 2003b). Our Water Quality Monitoring Program applies one of two standards to different locations along Whychus Creek (Table 3).

We will collect continuous dissolved oxygen data from two sites located along Whychus Creek. Data from the first site, at the City of Sisters, will characterize conditions near the upper end of the water quality impaired reach. Data from the second site, at the Rd. 6360 crossing, will characterize conditions near the lower end of the water quality impaired reach (Table 3). We will work with Oregon State University researchers to use this data to evaluate water quality status as it relates to Oregon's dissolved oxygen standards. As with the temperature data, the UDWC and Oregon State University expect to fully develop their statistical tools by June 2009.

We will publish an annual report summarizing these data. The report will summarize water quality status in Whychus Creek as it relates state standards. It will also summarize any findings related to long term trends.

Table 3. Physical Indicators: Water Quality

Data Collection														Data Analysis			
Question	Expectation	Metrics	Target	Monitoring Task	Protocol	Where?	Location Description	Location Coordinates	Who's Responsible?	When?	Other Monitoring Plan?	Historic Data Format	Historic Data Location	Who's Responsible?	Data Analysis?	Data Analysis/Report	Notes
Has water quality changed between 1996 and 2020?	Temperature will show a decreasing trend.	7 day moving average maximum temperature	18°C	Continuous temperature monitoring (April-September)	UDWC 2005	Ten stations between the headwaters and mouth of Whychus Creek	Mouth (WC 000.25)	10T 632321E 4924249N	UDWC will collect data and perform QA/QC on their own data through 2008. UDWC will document statistically significant trends.	2003-2008	None	Excel	UDWC - Online	UDWC	Exact sign test for the establishment of trend.	Data and data summary published annually on UDWC website.	
							Diamondback Meadow (WC 001.00)	10T 631631E 4923389N									
							D/S Alder Springs (WC 001.50)	10T 631659E 4922621N									
							Road 6360 (WC 006.00)	10T 628460E 4919651N									
							Rimrock Ranch (WC 009.00)	10T 626832E 4915827N									
							D/S Camp Polk (WC 018.25)	10T 619669E 4909276N									
							D/S Camp Polk Bridge (WC 019.50)	10T 618420E 4908327N									
							D/S Hwy 20 Bridge (WC 023.50)	10T 617228E 4905206N									
							OWRD Gage at Sisters City Park (WC 024.25)	10T 616341E 4904935N									
							Rd 4606 (WC 026.00)	10T 615333E 4903280N									
							Upstream Gage (WC 030.025)	10T 614445E 4898863N									
							Rd 1514 (038.00)	10T 606774E 4894098N									
	Dissolved oxygen will move closer to target	Daily minimum dissolved oxygen concentration and % saturation	6.5 mg/L 90% saturation	Continuous dissolved oxygen monitoring (June - September)	UDWC 2005	Two stations between the TSID Diversion and the mouth of Whychus Creek	Road 6360 (WC006.00)	10T 0627199E 4918000N	UDWC will collect data and perform QA/QC on their own data. UDWC will document statistically significant trends.	2006-2008	None	Excel	UDWC - Online	UDWC	To Be Determined by Lesley Jones, Graduate Student	Data and data summary published annually on UDWC website.	
			8mg/L 90% saturation				OWRD Gage at Sisters City Park (WC 024.25)	10T 0616341E 4904935N									

3.2.1.3 Other Water Quality Parameters

The suite of restoration actions proposed by restoration partners may influence parameters other than temperature and dissolved oxygen. Our research suggests that instream and riparian restoration may affect total dissolved solids and pH. However, we expect that these parameters will not be as sensitive to management actions as temperature and are not likely to be limiting factors for salmonid populations. Therefore, we do not expect to monitor them in the long-term.

3.2.2 Stream Flow

Water drives stream ecosystems. The entire hydrograph, including stream flow magnitude, frequency, duration, timing and rate of change all affect what a stream looks like and how it functions (Poff *et al*. 1997). Changes in stream flow can affect biological characteristics such as macroinvertebrate assemblages (Konrad *et al.* 2008, James *et al.* 2008, Monk *et al.* 2008, Wills *et al*. 2006), fish communities (Xenopoulos *et al.* 2006, Decker e*t al.* 2008), and riparian vegetation (Stromberg *et al.* 2005). River restoration efforts across the Pacific Northwest have focused on restoring stream flow as one technique to restore ecological function to impaired rivers.

We have identified stream flow alterations as a major factor limiting fish production in Whychus Creek. Low fall, spring, and summer flows likely affect both the structure and function of the creek. Most flow restoration efforts in the Pacific Northwest have focused on restoring minimum flows. The Oregon Department of Fish and Wildlife has applied for and received water rights to support fish production in Whychus Creek. These water rights provide minimum flow targets for restoration partners. Minimum flow targets will provide for some habitat, but they will not fully restore stream function.

Actions under this monitoring plan will tell restoration partners if the existing hydrograph has moved towards desired future hydrograph. The restoration community has moved from a minimum flow approach towards a whole hydrograph approach. Under this newer approach, restoration partners design and work towards a hydrograph that supports a full range of ecosystem functions (*e.g.* Mathews and Richter 2006). The local community has not yet identified the desired hydrograph for Whychus Creek, although we anticipate that the Deschutes River Conservancy will work towards this goal in the near future.

The Three Sisters Irrigation District diverts the majority of irrigation water from Whychus Creek. The Oregon Water Resources Department maintains a stream gage downstream from this diversion. The Department publishes provisional data at near-realtime frequencies, and it publishes revised daily average data annually. We have used and will continue to use the data from this gage to monitor the status of and trends in stream flow conditions.

The Oregon Water Resources Department's stream flow data is adequate to use with multiple metrics. Olden and Poff (2003) identified 171 stream flow metrics from 13 published papers. Monk *et al.* (2007) built off of Olden and Poff and identified an additional 30 metrics. Olden and Poff (2003) categorized these metrics based on whether they measured the magnitude, frequency, rate of change, duration, or timing of flow events. Ideally, the desired hydrograph for Whychus Creek will include target values for indices in each of the above categories. We will work with local partners to develop this hydrograph and to identify the appropriate metrics.

However, until the community develops this hydrograph, daily average daily stream flow during the irrigation season will serve as an appropriate metric. The Oregon Water Resources Department regulates stream flow through and publishes annual data for this metric. The Deschutes River Conservancy will use this data to identify statistically significant trends in stream flow using the Seasonal Kendall Test (Table 4). As this target hydrograph is developed, we will incorporate additional metrics into this Plan. We will publish a graphic summary of the status and trends of the selected metrics annually.

3.2.3 Habitat Quantity and Quality

Resident and anadromous fish prefer or require certain habitat characteristics. Different ages and stages of fish prefer different habitat types. The quantity and quality of these habitat types contributes to the size and distribution of fish populations throughout a stream. The suite of restoration projects proposed and initiated along Whychus Creek will likely affect habitat quality and quantity.

3.2.3.1 Passage Barriers

Fish passage barriers currently limit available fish habitat in Whychus Creek. They prevent fish from moving along the stream and alter instream habitat. At the close of 2008, six permanent or seasonal fish passage barriers blocked upstream fish passage in Whychus Creek from approximately river mile 15 through river mile 24. We intend to provide passage at or remove each of these barriers by 2014.

Activities outlined under this monitoring plan will identify how much additional habitat has been opened to anadromous fish each year and whether anadromous fish are accessing that habitat. We will monitor both the biological and physical indicators associated with fish passage restoration. Earlier sections outline biological metrics (*i.e.*, whether or not fish are present upstream of the barriers [Table 1]) that could be associated with fish passage restoration. This section briefly outlines selected physical metrics associated with fish passage restoration (Table 5). Our objective is to increase the quantity of instream habitat accessible to anadromous fish. As we remove each successive barrier, we can easily tally the additional river miles accessible to fish. These additional river miles serve as a simple metric and it will allow us to effectively communicate stream conditions to restoration partners and the general community.

We will maintain geographic data that identifies each of these barriers and highlights when they restored passage at each barrier. We will use this data to determine the quantity of habitat accessible to anadromous fish each year and we will publish these data annually.

The location, seasonality, and physical characteristics of a passage barrier all change how that barrier affects a stream system. Cote *et al.* (2009) have developed an index to measure longitudinal connectivity in stream systems. Their index accounts for the number, passability, and placement of barriers in the system. We will explore using this or a similar index as we move forward with monitoring activities.

Table 4. Physical Indicators: Stream flow

								Data Collection							Data Analysis		
Question	**Expectation**	**Metrics**	**Target**	**Monitoring Task**	**Protocol**	**Where?**	**Location Description**	**Location Coordinates**	**Who's Responsible?**	**When?**	**Other Monitoring Plan?**	**Historic Data Format**	**Historic Data Location**	**Data Analysis?**	**Who's Responsible?**	**Data Analysis/Report**	**Notes**
Has existing hydrograph moved towards desired future hydrograph?	Daily average streamflow will increase during the summer irrigation season.	Daily average flow (cfs)	33 cfs at OWRD gage in Sisters	Continuous streamflow monitoring	OWRD protocol adapted from Rantz et al (1982)	One location downstream from the TSID diversion	OWRD Gage at Sisters Sisters City Park	10T 615685E 4904577N	OWRD will operate gage and publish daily average data.	2003-Future	None	Database	Online - OWRD	Seasonal Kendal Test	The DRC will analyze data.	None	

Table 5. Physical Indicators: Passage Barriers

Data Collection														Data Analysis			
Question	**Expectation**	**Metrics**	**Target**	**Monitoring Task**	**Protocol**	**Where?**	**Location Description**	**Location Coordinates**	**Who's Responsible**	**When?**	**Other Monitoring Plan?**	**Historic Data Format**	**Historic Data Location**	**Who's Responsible?**	**Data Analysis?**	**Data Summary/Report**	**Notes**
Has the amount of Whychus Creek accessible to anadromous fish changed between 2009 and 2020?	More habitat will be accessible in 2020.	Miles of stream accessible to anadromous fish.	Entire stream accessible to natural barriers.	Passage barrier surveys.	To Be Determined	Passage Barrier at RM 15 to TSID Diversion at RM 24.5	To Be Determined	To Be Determined	UDWC in coordination Oregon Department of Fish and Wildlife	Post-management activities, 2009-2020	None	None	None	UDWC will maintain geographic data.	To Be Determined.	UWDC will report annually after management activities (such as barrier removal).	

3.2.3.2 Habitat Quality

We intend activities outlined under this monitoring plan to identify whether physical habitat quality has improved for anadromous fish between 1997 and 2020. Each restoration project proposed for Whychus Creek will alter the physical habitat of the creek. Projects may increase the amount of usable spawning gravel, increase the number of pools in the stream, change channel dimensions, or affect any number of other possible elements of stream habitat. Although we could focus on individual indicators along the stream, we intend to adopt a more generalized approach that will save considerable costs. We have chosen to follow the work of Portland General Electric, Oregon Department of Fish and Wildlife and the Confederated Tribes of the Warm Springs Reservation and use models that rate habitat in relation to juvenile fish production potential.

The Oregon Department of Fish and Wildlife surveyed Whychus Creek in 1997. Portland General Electric contracted with them to survey the creek again in 2008 following standard methodology. They do not expect to survey the creek again for another ten years. We will seek additional funding for habitat surveys in 2013-2014 to document any improvements in stream conditions over the next five years. The two models described below estimate the habitat suitability and carrying capacity of Whychus Creek based on this habitat data.

HabRate

Fisheries managers have developed several systems to rate instream habitat quality. The Oregon Department of Fish and Wildlife developed the HabRate system to rate stream habitat suitability for salmon and steelhead in the Deschutes Basin. HabRate uses observed habitat data and identified physical habitat requirements to estimate habitat suitability at multiple spatial scales (Burke *et.al.* 2003).

HabRate focuses on habitat suitability for steelhead trout, chinook salmon, and sockeye salmon. It rates habitat suitability for up to three life history stages per species (see Table 6). The HabRate methodology builds off of field data collected using a continuous census design. Fisheries managers compile this habitat data and evaluate it using the HabRate desktop model.

Steelhead trout	Chinook salmon	Sockeye salmon
Spawning, incubation, emergence	Spawning, incubation, emergence	Spawning, incubation, emergence
Age 0+ summer rearing	Age 0+ summer rearing	Age 0+ summer rearing
Age 0+ overwintering	Age 0+ overwintering	Age 0+ overwintering
Age 1+ summer rearing		
Age 1+ overwintering		

Source: Burke *et.al.* 2003

Table 6. Life history stages evaluated by HabRate. HabRate uses observed habitat characteristics to rate habitat quality for three salmonid species at up to four life history stages.

HabRate developers have identified habitat requirements for each life history stage of each species using a combination of literature reviews and professional judgment (Burke *et al.* 2003). HabRate rates each observed habitat attribute as poor, fair, or good for each life stage of each species based on their previously derived habitat requirements. A list of these attributes appears in Appendix A. Under the HabRate model, habitat attributes with a ranking of “fair” are adequate for juvenile fish survival.

HabRate combines habitat attribute ratings to create categorical level ratings. These categorical level ratings account for habitat conditions that support or impair fish survival. HabRate uses the categorical level ratings to assign each reach an overall rating by life history stage (Burke *et al.* 2003). The lowest categorical level rating limits the overall reach rating, identifying reaches that are inadequate for different life history stages.

The HabRate analyses previously applied to Whychus Creek have been broad-scale, reach level habitat rankings. These analyses help fisheries managers focus on certain reaches for reintroduction. They may be too coarse to reveal restoration effectiveness. HabRate's methodology allows it to be used at the micro, macro, or meso scales (Burke *et al.* 2003). The Upper Deschutes Watershed Council intends to apply HabRate at the macro scale to understand how restoration activities have improved habitat conditions for different life stages of salmon and trout. Although current resources do not support these activities, we will seek additional funding to apply HabRate at a finer scale as restoration progresses.

Unit Characteristic Method

The Unit Characteristic Model (UCM), similar to HabRate, compiles and analyzes common stream habitat data. The UCM uses relationships between habitat attributes and fish production to estimate a stream's carrying capacity for steelhead trout. It focuses on habitat attributes typically measured during stream surveys and typically affected by restoration activities (Cramer and Ackerman In review). A list of habitat attributes considered by the UCM appears in Appendix B.

The UCM is sensitive to small-scale changes, like restoration activities, in a watershed. It uses habitat unit level characteristics to estimate how many juvenile steelhead a stream can support (Ackerman *et al.* 2007). It assigns a standard density of steelhead to each habitat unit, then scales that density up or down based on relationships between habitat conditions and expected steelhead density (see Figure 5). The UCM considers channel size, depth, cover, and productivity when estimating steelhead carrying capacity. It does not consider competition between species, competition between resident and anadromous fish, or water quality parameters such as pH and temperature (Cramer and Ackerman In review).

The suite of restoration actions slated for Whychus Creek should improve habitat conditions. Improved habitat conditions should increase the steelhead carrying capacity estimated by the UCM. We will use the UCM to identify whether habitat restoration has improved habitat carrying capacity for juvenile steelhead (Table 6).

The UCM estimates the carrying capacity for Age 1+ parr. To estimate smolt carrying capacity, it factors overwinter survival into parr estimates. It does not completely account for winter habitat use and conditions and their affects on steelhead carrying capacity (Cramer and Ackerman In review).

The Ecosystem Diagnosis and Treatment model used during the Northwest Power and Conservation Council's Subbasin planning process suggested that habitat in some portions of Whychus Creek was most limiting to parr and earlier life stages. We know that we need to monitor the creek's capacity to produce smolts as well as parr. Smolt production will determine how many fish outmigrate and, at the broadest level, how many have the potential to return.

$$\mathit{Capacity}_i = \left(\sum \mathit{area}_k \cdot \mathit{den}_j \cdot \mathit{chnl}_{jk} \cdot \mathit{dep}_{jk} \cdot \mathit{cvr}_{jk}\right) \cdot \mathit{prod}_i$$

Where:

Capacity = maximum number of age >1 parr supported under average environmental conditions.

I = stream reach. “Reach” is a sequence of channel units that compose a geomorphically homogenous segment of the stream network.

j = channel unit type

k = individual channel unit

area = effective area (m^2) of channel unit k

den = standard fish density (fish/ m^2) for species i in unit type j

chnl = discount scalar for extra long pools and portions of channel >12m from shoreline with expected value of 1.0.

dep = depth scalar with expected value of 1.0

cvr = cover scalar with expected value of 1.0

prod = Productivity scalar for the reach. Expected value of 1.0. This scalar combines the effects determined separately from nutrient concentrations, turbidity, fines and availability of riffles to produce drifting invertebrates.

Source: Ackerman *et al.* 2007

Figure 5. The Unit Characteristic Model. The UCM determines the stream carrying capacity for the most limiting life stage of steelhead. based on the quality and availability of different habitat types. Conditions for Age 1+ steelhead during the summer are typically most limiting. The UCM gives each habitat type a standard density of Age 1+ parr. The UCM then adjusts the density of Age 1+ parr in any given habitat unit based on the six variables listed above. It adjusts the scalars for each variable based on functions relating each variable to fish density (Ackerman *et al.* 2007; Cramer and Ackerman In Review).

Table 6. Physical Indicators: Habitat Quality

Data Collection														Data Analysis			
Question	**Expectation**	**Metrics**	**Target**	**Monitoring Task**	**Protocol**	**Where?**	**Location Description**	**Location Coordinates**	**Who's Responsible**	**When?**	**Other Monitoring Plan?**	**Historic Data Format**	**Historic Data Location**	**Who's Responsible?**	**Data Analysis?**	**Data Summary/Report**	**Notes**
Have habitat conditions improved between 1997 and 2020?	Habitat conditions will improve between 1997 and 2020.	*O. mykiss* parr production capacity, estimated with UCM	To Be Determined by Fisheries Managers	Habitat Surveys	Moore et al. (2007)	Mouth of Whychus Creek to upstream of TSID Diversion.	Not Applicable	Refer to GIS data for detailed location information.	Portland General Electric in coordination Oregon Department of Fish and Wildlife	1997, 2008, 2014 (recommended), 2018	Native Fish Monitoring Plan	Excel and GIS	Portland General Electric	Portland General Electric will run models. UDWC will communicate results.	Unit Characteristic Method (Ackerman et al. 2007)	Native Fish Monitoring Report, April 1 Annually (only included here in years when PGE samples/analyzes Whychus Creek)	Recommended that UDWC fund or advocate for 2014 habitat survey.
		O. mykiss smolt production capacity, estimated with UCM															
		Miles of habitat rated Good, Fair, or Poor for selected life stages.	To Be Determined by Fisheries Managers									Excel and GIS	Portland General Electric		HabRate (Burke et al. 2003)		

3.2.3.3 Fish Entrainment

Irrigation diversions can create two types of problems for fish. First, as described earlier, they potentially block fish passage. Second, unscreened diversions divert fish almost as effectively as they divert water. Roberts and Rahel (2008) found that unscreened diversions along a Wyoming stream acted as sinks for local fish populations, entraining an estimated 6,300-10,400 fish annually. Anecdotal evidence from the Three Sisters Irrigation District and the Sisters Ranger District suggests that irrigation canals along Whychus Creek also serve as population sinks.

Screening diversions with state and federally approved screens provides obvious benefits for fish populations by reducing fish entrainment. Gale *et al* (2008) found that fish screens reduced or eliminated fish entrainment in one heavily managed stream in Montana, Skalkaho Creek. They found inter- and intra-annual variations in the proportion of fish entering diversions, and they suggested that variations in the proportion of water diverted accounted for some of the inter-annual variations in the number of fish diverted.

We identified 16 unscreened diversions between river mile 9 and river mile 26 that have the potential to entrain fish. We expect to screen 13 of these diversions by 2014. By reducing the amount of water diverted through unscreened diversions, we will be decreasing the magnitude of one factor limiting fish populations.

We selected two simple metrics to estimate entrainment potential – the number of unscreened diversions and the proportion of water that they diverted relative to the total stream flow. We acknowledge that diversion timing, location, and structure design all change a diversion's fish entrainment potential. In the absence of detailed knowledge on the impacts of each diversion, though, we have selected these coarse metrics as cost-effective indicators of entrainment potential.

We will coordinate with the Oregon Water Resources Department to survey unscreened diversions annually. We will maintain geographic data that identifies each existing unscreened diversion (as of 2008), its capacity, and the date when it was screened. We will use this data to summarize and graphically display any changes in fish entrainment potential (Table 8).

Table 7. Physical Indicators: Fish Entrainment

Data Collection														Data Analysis			
Question	**Expectation**	**Metrics**	**Target**	**Monitoring Task**	**Protocol**	**Where?**	**Location Description**	**Location Coordinates**	**Who's Responsible**	**When?**	**Other Monitoring Plan?**	**Historic Data Format**	**Historic Data Location**	**Who's Responsible?**	**Data Analysis?**	**Data Summary/Report**	**Notes**
Has the potential for diversions to entrain fish changed between 2009 and 2020?	Entrainment potential will decrease.	Number of unscreened diversions.	No unscreened diversions	Diversion surveys	To Be Determined	Diversion at river mile 9 to diversion at river mile 26	To Be Determined	To Be Determined	UDWC	Post-management activities, 2009-2020	None	None	None	UDWC will maintain numeric and geographic data.	To Be Determined.	UWDC will report annually after management activities (such as diversion screening).	
		Diversion capacity of unscreened diversions	Zero														

4.0 Data Compilation and Reporting

A range of organizations, private corporations, and local, state, and federal agencies will complete the monitoring activities included in the Plan. The data collected by these entities normally remains in single silos maintained by one or more monitoring partners. Although there has been some degree of coordination in the past, we recognize that disparities in data quality, data archiving, and data availability have hindered past efforts to characterize conditions in Whychus Creek.

Under the Plan we will track the data collected by our monitoring partners to ensure that it can be used for current and future analyses. We will not store all of this data. Instead, we will collect and store our own data, summarize data availability for our partners' data, and compile and store our partners' data where appropriate. We will also work with our monitoring partners to summarize the status and trends of selected indicators.

There are inherent advantages and disadvantages to this approach. The most obvious advantage, which is a fundamental driver of the Plan, is that the use of existing data allows us to keep our monitoring costs low. Our severely limited monitoring budget requires low costs and leaves us with few options at this time. The primary disadvantages to our approach include our lack of control over where, when, and how our partners collect and disseminate their data. We will continue working with our partners to influence their monitoring activities and limit these concerns. As more monitoring funds become available over time, we will be able to increase our role in data collection and reduce the risks associated with relying on other partners.

Once we have compiled data from our partners, we will report annually on the status and trends of the selected metrics included in the Plan. We will identify the programmatic context for each metric and the methods used to collect and analyze each metric. Although monitoring partners may complete statistically rigorous evaluations of their data, we will provide simplified summaries of indicator status and trends. Restoration practitioners tend to focus on the technical aspects of their work, and their reports do not always speak to local communities. Our reports will summarize technical data so that the broader community understands any changes in the Whychus Creek system.

We anticipate that there may be times when the data present conflicting results. For example, physical indicators may suggest that conditions for fish are improving but biological indicators may suggest that fish production is actually decreasing. We will need to use any contradictions or unexpected results as opportunities for further refine our conceptual model, adjust the monitoring indicators and/or metrics and potentially establish specific controlled studies to examine specific cause and effect relationships.

5.0 Future Directions

The monitoring design presented in the in the Plan attempts to move beyond the single indicator / single partner approach taken previously in the Deschutes Basin. In addition, it draws on data collected by multiple partners in multiple collections and distills several indicators from those data. While the monitoring design will not validate the success of specific monitoring actions, it will reveal overall aquatic ecosystem trends and suggest overall restoration effectiveness and represent an important step forward in the monitoring of Whychus Creek.

This monitoring design does not include specific hypotheses or demonstrate cause and effect relationships, but future monitoring activities could be adapted to test causality. Effectiveness monitoring based on Before-After and Post-treatment designs can validate specific management actions (Roni 2005). Also, this monitoring plan purposefully uses metrics that represent overall ecosystem trends and conditions. Future monitoring efforts may focus on different metrics that relate more closely to individual management actions with the goal of improving future restoration effectiveness.

The trajectory outlined in this Plan is very different from the trajectory that that our monitoring program has followed in the past. Our past monitoring activities focused on water quality status and trend monitoring; we successfully housed, funded, and implemented the collaborative Water Quality Monitoring Program from 2001 through 2009 (expected). The rest of the activities included in this Plan go well beyond this approach.

With the implementation of this Plan, we will reach across organizations to establish a new coordinated Whychus Creek Monitoring Program beginning in 2009.

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Appendix A. HabRate Attributes

Table A-1. Reach attributes used to rate suitability for each life stage of spring chinook and salmon steelhead trout.

Spawning, Incubation, and Emergence	**Summer Rearing**	**Overwintering**
% Fines	% Fines	% Fines
% Gravel		
% Cobble	% Cobble and Boulders	% Cobble and Boulders
% Pools	% Pools	% Pools
Residual Pool Depth		
	Pool Complexity (Chinook only)	Pool Complexity
	Cover	
Gradient	Gradient	Gradient
Temperature	Temperature	
Flow	Flow	Flow

Source: Burke *et al.* 2003.

Table A-2. Interdependent reach attributes appearing in Table A-1.

Interdependent Reach Attribute	**Dependent Reach Attributes**
Pool Complexity	Average Scour Pool Depth per pool
	Average Large Woody Debris per pool
	Average % Undercut per pool
	Average % Boulders per pool
Cover	% Cobble and Boulders
	% Undercut
	Large Woody Debris / 100m
	Boulders > 0.5m diameter / 100m

Source; Burke *et al.* 2003.

Appendix B. Unit Characteristic Model Attributes.

Table B-1. Habitat attributes used as inputs for the Unit Characteristic Model.

Parameter/Function	**Value/Equation**
den (fish/m^2)	
Backwaters	0.05
Beaver Ponds	0.07
Cascades	0.03
Glides	0.08
Pools	0.17
Rapids	0.07
Riffles	0.03
chnl	
Glides	If W>24: (W-24)*0.35/W+24/W
Pools	If W>24: (W-24)*0.75/W+24/W; and
	If L>4*W: L=4*W
Riffles	If W>24: (W-24)*0.15/W+24/W
dep	
Pools	If D<0.10: 0.0*D
	If D is 0.10-0.80: (0.30*D-0.027)/0.17
	If D>0.80: 0.22/0.17
Riffles	If D<0.01: 0.0*D
	If D is 0.10-0.16: (0.5*D-0.050)/0.03
	If D is 0.16-0.30: (0.29*D-0.917)/0.03
	If D is 0.30-0.80: (0.25*(D-0.003)/0.03
	If D is 0.80-0.90: 0.20/0.03
	If D is 0.90-1.50: (-0.32*D+0.485)/0.03
	If D>1.5: 0
cvr	
Pools and Glides	If wood complexity = 1: 0.58
	If wood complexity = 2: 1.00
	If wood complexity = 3: 1.42
	If wood complexity = 4 or 5: 1.84
Boulders	If B_{Pr} < 0.25: 1.0
	If B_{Pr} is 0.25-0.75: 1+12*(B_{Pr}-0.25)
	If B_{Pr} > 0.75: 7.0
turb	
	If D_R < 0.3m: $10^{(2-(1+0.024*T)*0.1)}/10^{2-0.1}$
	If D_R is 0.3m-0.5m: $10^{(2-(1+0.024*T)*0.3)}/10^{2-0.3}$
	If D_R > 0.5m: $10^{(2-(1+0.024*T)*0.5)}/10^{2-0.5}$

drift	
	If $R_P < 0.5$: 1.0
	If $R_P >= 0.5$: $0.1+1.8*R_P$
fines	
	If $F_P < 0.1$: 1.0
	If $F_P >= 0.1$: $1.11-1.1*F_P$
alk	
	Alkalinity $(mgCaCO_3/l)^{0.45}/4.48$
winter	
	If $C_P < 0.15$: $0.20+(C_P)/0.15*0.8$
	If $C_P >= 0.15$: 1.0

W = wetted width of unit in meters.
L = length of unit in meters
D = depth in meters (maximum in pools; mean in riffles)
B_{Pr} = Proportion of substrate in riffles that is comprised of boulde
D_R = Mean depth of riffles within the reach
R_P = Proportion of surface area of reach comprised of riffle and ra
F_P = Proportion of substrate in riffles that is comprised of fines
C_P = Proportion of substrate in the stream comprised of cobbles

Source: Cramer and Ackerman In Review