Chapter 3
Physical Environment

© Ed Bustya

Chapter 3 Physical Environment

3.1 Climate

3.1.1 General Climate

Tualatin River National Wildlife Refuge (the refuge) is located in Washington and Yamhill Counties in northwestern Oregon (see Appendix P, Map 3). The refuge is located at the northern end of the Willamette Valley in the Tualatin River watershed, between the Coast Range mountains and the Willamette River (see Appendix P, Map 1). Much of the refuge lies within the Tualatin River floodplain. Major tributaries that drain into the refuge include Chicken and South Rock Creeks in the Sherwood Units (see Appendix P, Map 6), and Wapato, Hill, Ayers, Harris, and Scoggins Creeks at the Wapato Lake Unit (see Appendix P, Map 7). Many smaller perennial and ephemeral streams also drain into the basin. Elevation within the Sherwood Units ranges from about 105 feet to 300 feet. Elevation at the Wapato Lake Unit varies from about 160 to 240 feet, with the majority of the lake bed at about 170 feet. The Tualatin River Valley consists of low foothills, terraces, alluvial fans, and floodplains. The floodplains are subject to frequent flooding during winter and spring. However, changes due to agriculture, urbanization, and flood control projects have altered historic flooding patterns.

Photo 3-1. Frozen wetlands on the Atfálat'i Unit, January 2008. Peter Schmidt/ USFWS.

The northern Willamette Valley exhibits a general maritime climate with cool, wet winters and warm, dry summers. Temporal patterns of climate variability in Oregon are primarily influenced by the Pacific Ocean, namely the El Niño/Southern Oscillation (Oregon Climate Change Research Institute [OCCRI] 2010). Precipitation averages about 42 inches per year (Table 3-1) and occurs mainly from November through March. Average temperatures are lowest from December through February and highest on average during July and August (Table 3-1). Severe weather events are rare

but may include summer temperatures above 100°Fahrenheit (F), winter snow and ice storms, flooding of the Tualatin River and tributaries, high winds, and periods of subfreezing weather. Flooding of the river and tributaries typically occurs during December and January when the ground has become saturated and rainfall increases (Figure 3-1).

Table 3-1. Monthly High, Low, and Average Temperatures; Monthly Rainfall April 2008-March 2009

Month	Average Temperature*	Average Precipitation**
January	40.0	6.74
February	41.3	3.63
March	45.3	4.36
April	48.5	2.95
May	58.9	2.59
June	61.8	1.15
July	68.8	0.21
August	69.6	0.74
September	65.2	1.01
October	53.5	3.62
November	49.2	7.12
December	37.5	8.23
Total		42.35

* National Oceanic and Atmospheric Administration (NOAA) National Weather Service for Portland, Oregon.

**Average from refuge rain gauge 2003-2010.

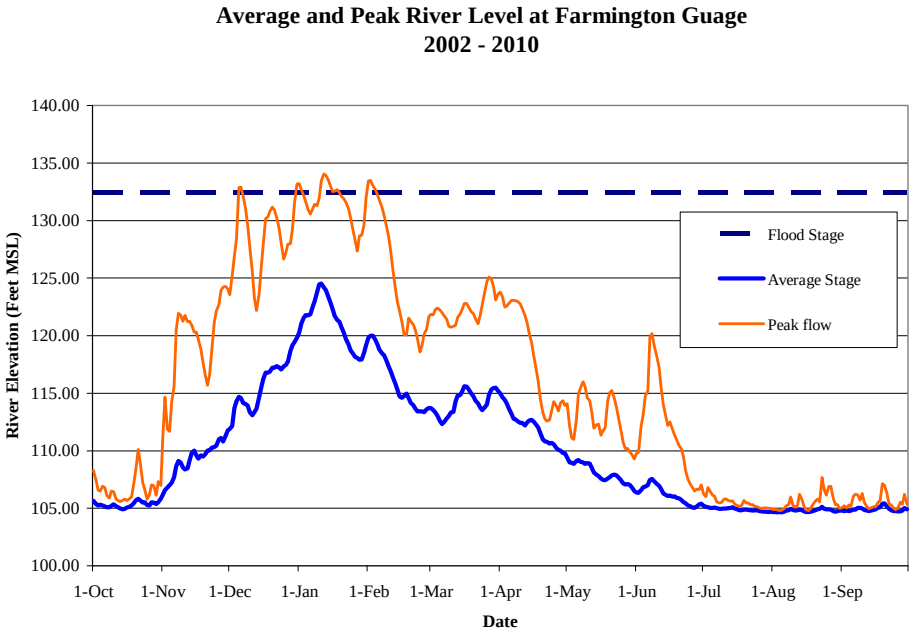

Figure 3-1. Average and peak river levels measured in feet above mean sea level (MSL) at Farmington gauge approximately 8 miles upstream from the westernmost parcel in the Sherwood Units.

3.1.2 Climate Change

As stated in U.S. Department of the Interior (USDOI) Secretarial Order 3226 (USDOI 2009) and the Service's climate change strategic plan (USFWS 2010c), the Service considers and analyzes climate change in its decisions, long-range plans, and other activities. Also, refuge efforts contribute to carbon sequestration through habitat restoration and protection efforts. A 1999 U.S. Department of Energy report, *Carbon Sequestration Research and Development* (U.S. Department of Energy 1999), concluded that ecosystem protection is important to carbon sequestration and may reduce or prevent loss of carbon currently stored in the terrestrial biosphere. The report defines carbon sequestration as "the capture and secure storage of carbon that would otherwise be emitted to or remain in the atmosphere."

Greenhouse gases (GHG) occur naturally in the Earth's atmosphere, but are also added by human activities. This happens primarily through the burning of fossil fuels, such as coal, oil, and natural gas, which releases carbon dioxide into the atmosphere. Over the past century, atmospheric carbon dioxide (as measured from ice cores) has increased due to human activities, and the average Earth temperature has increased approximately 0.7°Celcius (C) or about 1.3°F (NOAA 2011a; OCCRI 2010) (Figure 3-2), and it continues to increase.

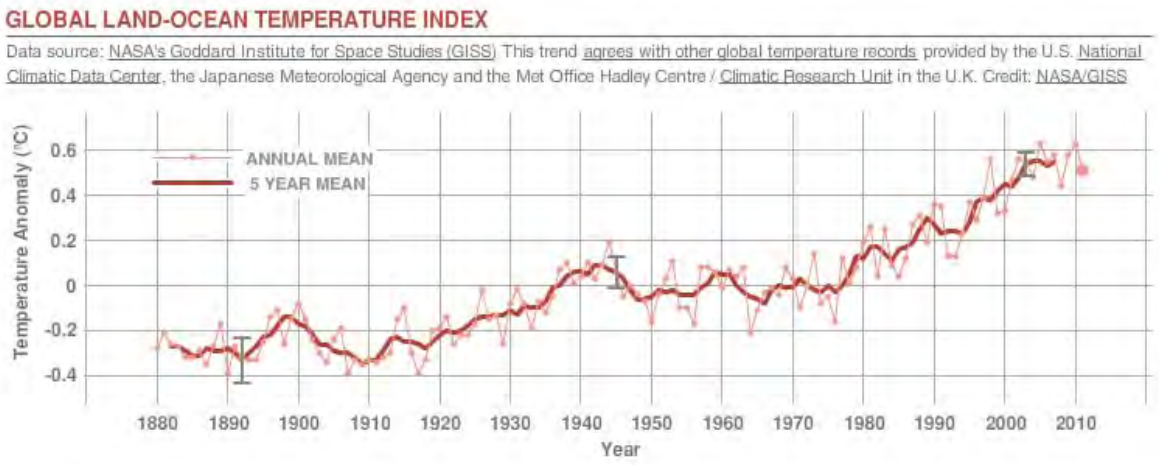

Figure 3-2. Global surface temperature (NASA 2012).

The greenhouse effect is a natural phenomenon that assists in regulating and warming the temperature of our planet. Just as a glass ceiling traps heat inside a greenhouse, certain gases in the atmosphere, called greenhouse gases, absorb heat from sunlight. The primary GHGs occurring in the atmosphere include carbon dioxide, water vapor, methane, and nitrous oxide. Carbon dioxide is produced in the largest quantities, accounting for more than half of the current impact on the Earth's climate.

The terms "climate" and "climate change" are defined by the Intergovernmental Panel on Climate Change (IPCC). "Climate" refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (IPCC 2007b:78). The term "climate change" thus refers to a change in the mean or variability of one or more measures of climate (e.g., temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both (IPCC 2007b:78).

Scientific measurements spanning several decades demonstrate that changes in climate are occurring, and that the rate of change has been faster since the 1950s. Examples include warming of the global climate system, and substantial increases in precipitation in some regions of the world and decreases in other regions. (For these and other examples, see *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [IPCC 2007a:30] and *Technical Summary* [Solomon et al. 2007:35-54, 82-85].) In the Pacific Northwest, increased GHGs and warmer temperatures have resulted in a number of physical and chemical impacts. These include changes in snowpack, stream flow timing and volume, flooding and landslides, sea levels, ocean temperatures and acidity, and disturbance regimes such as wildfires, insects, and disease outbreaks (United States Global Change Research Program [USGCRP] 2009). All of these changes will cause major perturbations to ecosystem conditions, possibly imperiling species that evolved in response to local conditions.

Results of scientific analyses presented by the IPCC show that most of the observed increase in global average temperature since the mid-twentieth century cannot be explained by natural variability in climate, and is "very likely" (defined by the IPCC as 90 percent or higher probability) due to the observed increase in GHG concentrations in the atmosphere as a result of human activities,

particularly carbon dioxide emissions from use of fossil fuels (IPCC 2007b:5-6, Figures SPM.3 and SPM.4; Solomon et al. 2007:21-35). Further confirmation of the role of GHGs comes from analyses by Huber and Knutti (2011:4), who concluded it is extremely likely that approximately 75 percent of global warming since 1950 has been caused by human activities.

Looking toward the future, the University of Washington Climate Impacts Group (CIG) has projected changes in mean annual temperature and precipitation for the Pacific Northwest based on "statistical downscaling" an ensemble of 20 global climate models and two carbon emissions scenarios for each model run (Mote and Salathé 2009, 2010). The CIG also performed projections using two regional climate simulations with the same two emissions scenarios (Salathé et al. 2010). These two approaches provide the projected changes described below.

3.1.2.1 Temperature: Historical Trends and Projections

The Pacific Northwest experiences wide temperature variability based on geography (for example, the Olympic, Coast, and Cascade mountain ranges enhance a moderating maritime influence west of the Cascades) and seasonal and year-to-year variability (e.g., associated with the El Niño-Southern Oscillation) (Salathé et al. 2010). In the Pacific Northwest, regionally averaged temperature rose 1.5°F between 1920 and 2000, slightly more than the global average. Warming was largest for the winter months of January through March. Minimum daily temperatures have increased faster than maximum daily temperatures (Mote et al. 2005).

Historical climate data for Tualatin River National Wildlife Refuge are available from the United States Historical Climatology Network (USHCN), a high-quality data set of daily and monthly records of basic meteorological variables from 1,218 observing stations across the 48 conterminous states. The data have been corrected to remove biases or heterogeneities from nonclimatic effects such as urbanization or other landscape changes, station moves, and instrument and time-of-observation changes.

The USHCN Forest Grove, Oregon, station is the station closest to the refuge, and temperature data are shown in Figure 3-3. There has been a statistically significant increase of 1.36°F ($p = 0.001$) in average annual temperature from 1925 to 2010 at the Forest Grove station, similar to the regional average. Much of the increase is due to the increase in minimum temperature (increase of 1.53°F, $p = 0.000$) rather than maximum temperature (increase of 1.1°F, $p = 0.025$). In the past 30 years, temperature increases have been particularly pronounced during summer months (Table 3-2).

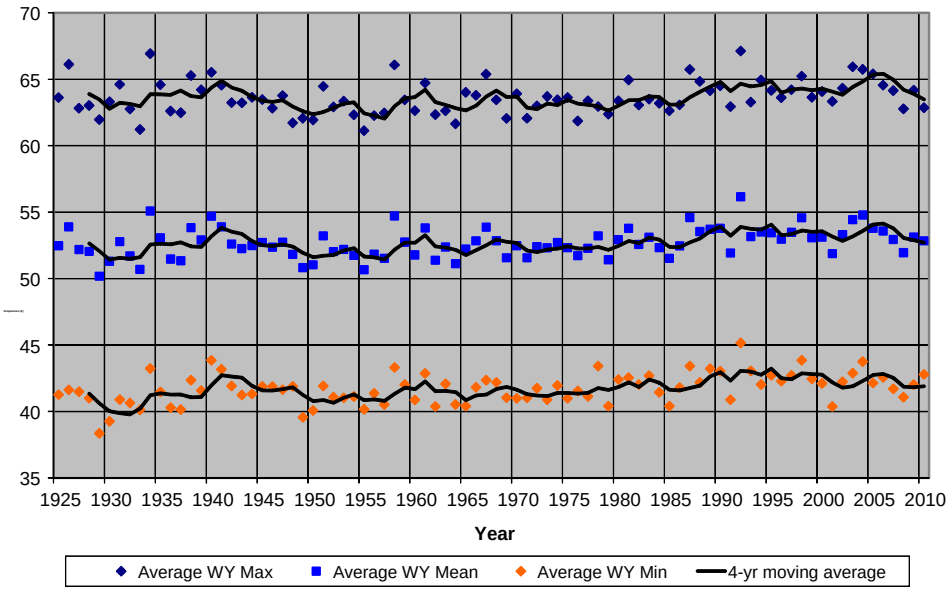

Figure 3-3. Water year temperature 1925-2010. USHCN Station: Forest Grove, Oregon (352997).

Table 3-2. Seasonal Temperature Trends, 1981-2010 (Monthly Records)

	Monthly Absolute Change		
	Temp. Max	**Temp. Avg**	**Temp. Min.**
Winter (Dec-Feb)	+0.54°F	+0.18°F	−0.21°F
Spring (march-May)	−0.23°F	−0.44°F	−0.64°F
Summer (Jun-Aug)	+1.36°F	+1.07°F	+0.79°F
Fall (Sept-Nov)	−0.36°F	−0.41°F	−0.48°F

* Forest Grove, Oregon United States Historical Climatology Network Observation Station

Looking to future projections, researchers have refined global circulation models so that they are useful at a regional scale, in our case, for the Pacific Northwest. One approach involves statistical downscaling of 20 global climate models, which projects that average annual temperature would increase by 2.0°F by the decade of the 2020s for the Pacific Northwest, 3.2°F by the decade of the 2040s, and 5.3°F by the decade of the 2080s, relative to the 1970-1999 average temperature (Mote and Salathé 2009, 2010). This is substantially greater than the 1.5°F increase in average annual temperature observed in the Pacific Northwest during the twentieth century. Seasonally, summer temperatures are projected to increase the most. One important note is that actual global emissions of GHGs in the past decade have exceeded even the highest emissions scenario (the A2 scenario), a scenario that was not modeled by Mote and Salathé in 2009 and 2010, or Salathé et al. in 2010 (discussed below). The authors used more moderate emissions scenarios. If these emission trends continue, temperature increases could turn out to be much greater than projected.

Another approach involves two regional climate simulations (Salathé et al. 2010). These findings support the warming increases described above, with small variations. West of the Cascades, both regional climate change models predict warming in all seasons (when compared to current average air temperatures) (Salathé et al. 2010). Increases in air temperature are forecasted to be the greatest in summer and spring (including increased frequency of heat waves, which are three or more consecutive days with a daily heat index of over 89.6°F or 32°C), while increased marine cloudiness in fall and winter may dampen temperature increases during those seasons (Salathé et al. 2010).

It should be noted that these projections are not intended to be predictions of actual conditions on any given date. Models represent the average response over climatological timescales (i.e., on a multi-decadal timescales) rather than precise behavior at exact dates. As discussed above, the Pacific Northwest's long-term climate includes a high degree of interannual and decadal variability, and this is projected to continue. However, long-term trends and projections indicate that overall temperatures are increasing and will continue to do so.

3.1.2.2 Precipitation: Historical Trends and Projections

Longer-term precipitation trends in the Pacific Northwest are more variable than temperature and vary with the period of record selected for analysis (Mote et al. 2005). The Pacific Northwest experiences this wide precipitation variability due to geography (e.g., the Olympic, Coast, and Cascade mountain ranges cause orographic, or upward, lift of air masses and precipitation) and seasonal and year-to-year variability (e.g., variation associated the El Niño Southern Oscillation and other longer-term oscillations) (Salathé et al. 2010). Looking at the period 1920 to 2000, precipitation has increased almost everywhere in the region, though not in a uniform fashion. Most of that increase occurred during the first part of the record (Mote et al. 2005).

The Forest Grove USHCN station (the closest station to the refuge) provides historical precipitation data, shown in Figure 3-4. There is no statistically significant trend, but note the year-to-year variability, such as flood risk during El Niño years in the late 1990s, which can provide management challenges for the refuge.

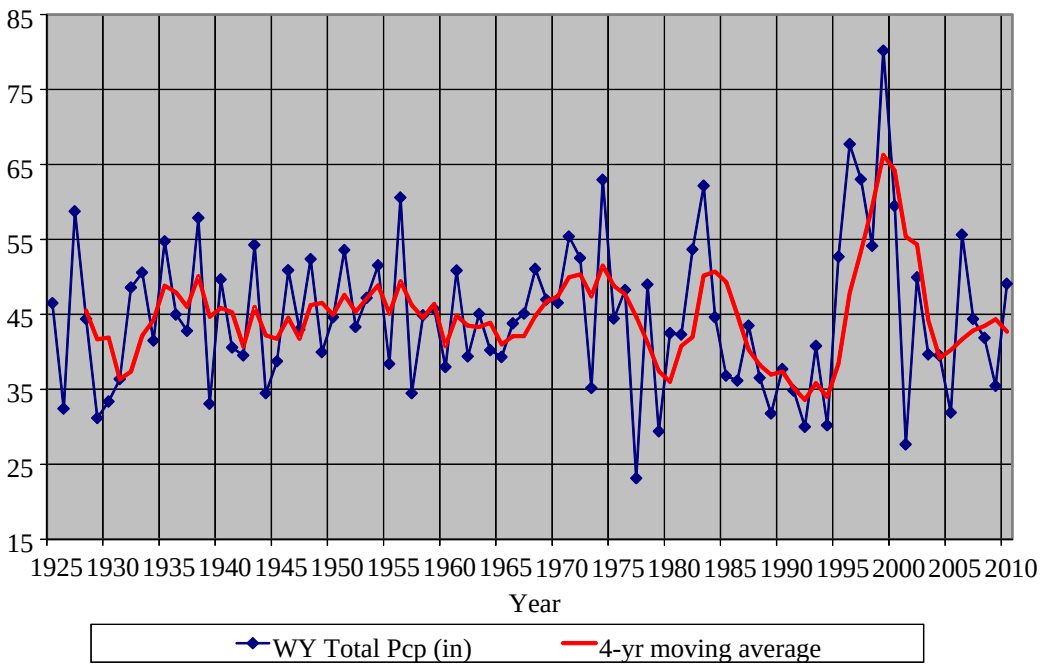

Figure 3-4. Water year total precipitation 1925-2010. USHCN Station: Forest Grove, Oregon.

The other significant trend found from the Forest Grove USHCN observation station is a 37 percent decline in summer precipitation in the last 30 years (Figure 3-5).

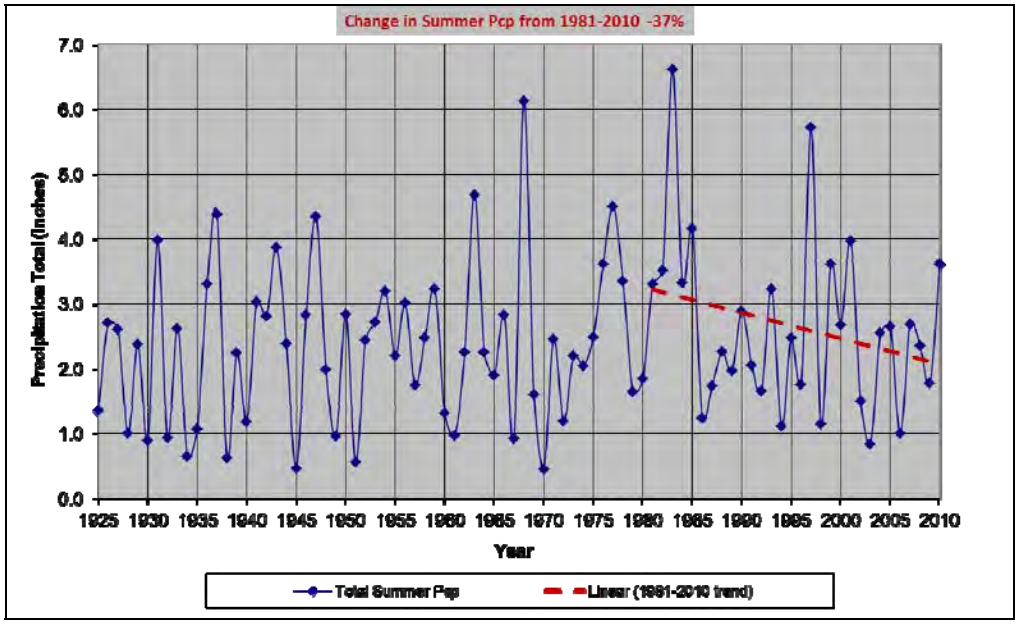

Figure 3-5. Summer (Jun-Aug) total precipitation, 1925-2010. USHCN Station: Forest Grove, Oregon (352997).

West of the Cascades, projections of future precipitation levels vary by model, with a majority of models projecting an annual increase in precipitation (Mote and Salathé 2010) and some models projecting a decrease relative to current observations (Leung et al. 2004). A strong seasonal pattern in altered precipitation relative to current levels is foreseen, as well as increases in the number of extreme precipitation events (daily precipitation exceeding the twentieth-century 95th percentile) (Salathé et al. 2010). Seasonal increases in precipitation are projected for fall, winter, and spring, and little change or a slight decline in precipitation for summer (Salathé et al. 2010). Regional climate change models project conflicting results for the spring season, with one model showing a substantial decline in precipitation while the second shows increases in precipitation (Salathé et al. 2010).

3.1.2.3 Stream Flow Changes

In addition to changes in the amount of precipitation, a major concern in the Pacific Northwest is change in the form of winter precipitation expected due to warmer temperatures. The CIG has modeled changes in current and future peak snowpack versus October through March precipitation for watersheds in the Columbia River Basin and the coastal watersheds of Oregon and Washington. Generally, there is a large shift in the form of winter precipitation from snow to rain, with lower elevation basins affected before upper elevation basins (Elsner et al. 2010). As these changes occur, there would likely be a tendency for higher winter flows and possible increased risk of flooding in transition watersheds (those not dominated by snow processes and those not rain-dominant), earlier snowmelt and runoff from peaks, and lower summer stream flows (Hamlet and Lettenmaier 2007). The Tualatin River watershed is a rain-dominant system, and these changes may not be significant to the refuge.

3.2 Hydrology

3.2.1 Regional Hydrology

The refuge lies within the Tualatin River watershed, which is a part of the Willamette River Basin (see Appendix P, Map 3). The Tualatin River is one of the most northern tributaries in the Willamette River watershed and is about 80 miles long (Tualatin River Watershed Council [TRWC] 1998). The river flows roughly eastward from the Coast Range mountains in Washington County, Oregon, to its confluence with the Willamette River in Clackamas County, Oregon, near the City of West Linn. The elevation at the headwaters of the Tualatin River is approximately 1,980 feet, and there are four large elevation drops in the river before it enters the Tualatin Valley plain at an elevation of 240 feet. Where the Tualatin River meets Wapato Lake, the elevation is about 170 feet, and where the Tualatin River meets the Willamette River, it is 58 feet in elevation. The Tualatin River drainage basin is approximately 43 miles long and 29 miles wide, covering an area of 712 square miles (TRWC 1998). Annually, more than 1.1 million acre-feet of water flow out of this watershed into the Willamette River. Nearly 85 percent of this flow is discharged during November through March.

The river can be characterized in four distinct reaches with varying degrees of flows and gradients (Table 3-3).

Table 3-3. Approximate Reaches of the Tualatin River As it Flows from the Coast Range Mountains (rivermile 80) to its Confluence with the Willamette River (rivermile 0)

Reach	Description	Rivermile	Elevation Gradient (feet/mile)	Description
1	Mountain	80-58	80.4	Forested, fast-moving mountain streams, rock channels
2	Meander	58-33	2.8	Transition from timberland to farmland, major floodplain storage, logjams
3	Reservoir	33-3.4	0.2	Flat, “reservoir like” flow with heavy sedimentation, recreational use
4	Riffle	3.4-0.0	10.1	Steep gradient, short series of shallow pools and riffles

The first reach of the river starts in the mountains and is characterized by forested, fast-moving mountain streams with rock channels. As the river flows through the basin, it slowly transitions from forested areas into more open habitat, and the flow changes from fast to slow flowing. The Tualatin River has five major and numerous minor tributary streams. Streams entering the river within the refuge include Wapato, Ayers, Hill, Harris, and Scoggins Creeks in the Wapato Lake Unit, and Chicken and Rock Creeks in the Sherwood Units. Average daily flow rate in the Tualatin River measured at the West Linn gauging station, approximately 1.7 miles from the confluence with the Willamette River, ranged from a low of 80 cubic feet per second (cfs) to a high of 4,150 cfs between 1928 and 2010 (Figure 3-6). These figures do not include water that is diverted upstream of this gauging station into Oswego Lake.

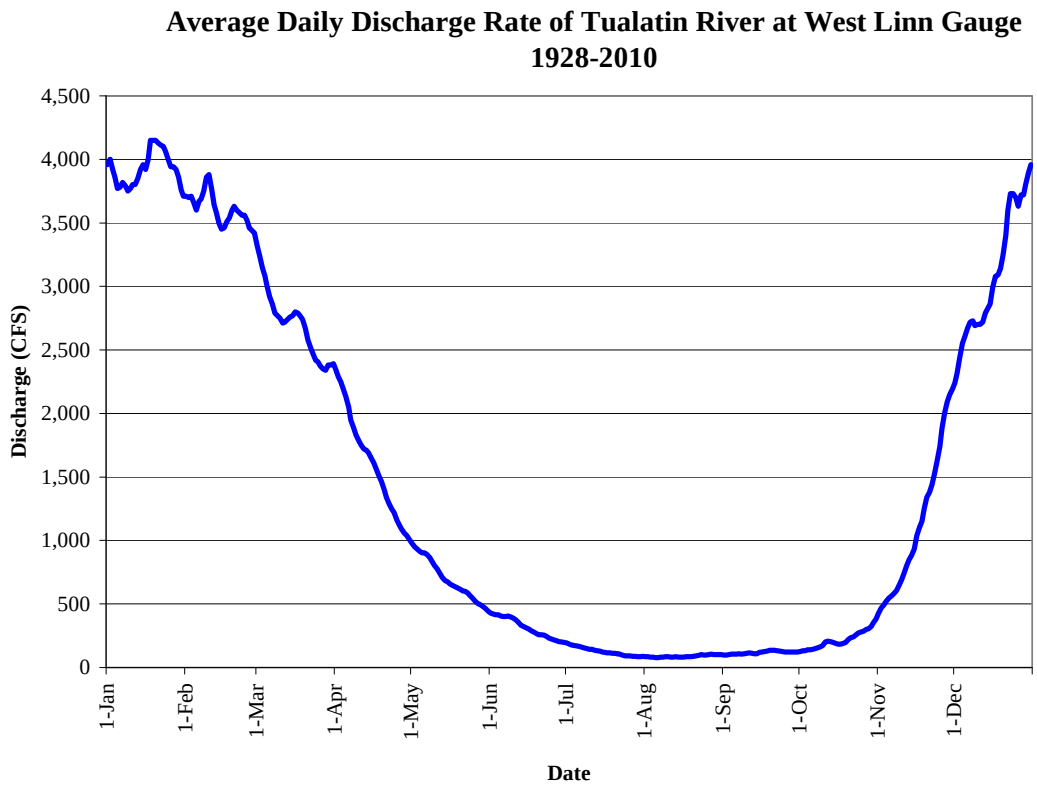

Figure 3-6. Average daily discharge rate (cfs) measured on the Tualatin River at the West Linn gauging station.

In general, stream flow in the Tualatin River Basin reflects patterns of precipitation with high winter and low summer flows (Figure 3-6. River elevation measured at the Farmington gauge is typically at summer flows (<110 feet) from late April to early May until late October when precipitation begins to fill the river basin. Flooding in tributary streams is typically more prevalent during short-term heavy rainfall after the surrounding watershed is saturated by early season rainfall. In particular, the Chicken Creek watershed, which includes Cedar Creek, flows from the City of Sherwood and experiences heavy flooding. The population of Sherwood has increased from about 3,000 in 1990 to over 18,000 in 2010, and this has led to an increase in urban development (U.S. Census Bureau 2011). This change has created increased impervious surfaces (e.g., roads, rooftops) and has led to an increase in runoff and higher peak flows in Chicken Creek that flow into the refuge.

Photo 3-2. Chicken Creek flooding. Peter Schmidt/USFWS.

There are two dams affecting water flows within the basin: Scoggins dam on Scoggins Creek, creating Henry Hagg Lake, and the Lake Oswego diversion dam, which shunts water to Oswego Lake. In addition, Barney Reservoir on the Trask River diverts water to the Tualatin River during summer to augment flows. Henry Hagg Lake has a capacity of 53,600 acre-feet of water and is managed by the Bureau of Reclamation (USDOI 2011). A large part of refuge lands, both in the Sherwood Units and the Wapato Lake Unit, lie within the jurisdictional boundary of the Tualatin Valley Irrigation District. This district was formed to deliver irrigation water associated with the Henry Hagg Lake project. As members of the district with attached water rights, the refuge is required to pay for irrigation on lands that fall within the district.

3.2.2 Refuge-specific Hydrology

Water Rights: The refuge has a complex system of irrigation ditches, springs, creeks, wetland cells, and water control structures for moving water within the refuge to fill the various wetland cells and for irrigation purposes in the cooperative farming program. The refuge has 51 water rights with priority dates ranging from 1890 to 2000. Sources of water include wells, ditches, unnamed creeks, springs, overland flow and runoff, Chicken Creek, Hill Creek, Rock Creek, Scoggins Creek, and the Tualatin River. The purposes of the water rights are primarily for irrigation and wildlife use, and to ensure that water is diverted for use on approximately 1,157 acres of wet prairie, scrub-shrub, and herbaceous wetlands at the Sherwood Units and the lake bed at the Wapato Lake Unit. In addition, the Service voluntarily selected 15 irrigation water rights for in-stream leases, which aids in restoration and protection of over 4 cfs of stream flow in Rock Creek and the Tualatin River.

Table 3-4 summarizes the water rights of the refuge.

Table 3-4. Summary of Water Rights for the Refuge

Priority Date	Application No.	Certificate No.	Source Name	Flow Rate (cfs)	Place of Use/Storage (Acres/Acre-Feet)
Groundwater					
25-Jul-50	G-2325	33116	Well	0.026	2.9
30-Sep-68	G-4614	45012	Sump well	0.07	
27-Oct-88	G-11863	72443	Well	0.35	
19-Oct-06	G-16740		Three wells	0.13	
Instream Lease					
02-Mar-51	IL-809	20149	Rock Creek	0.34	
05-Dec-28	IL-867	8117	Rock Creek	0.38	
05-Dec-28	IL-867	8117	Rock Creek	0.38	
1-01-1890	IL-869	29185	Cummings ditch	0.1	
16-Jun-50	IL-868	22918	Tualatin River	0.35	
1-01-1890	IL-870	29186	Rock Creek and unnamed ditches	0.338	
1-01-1890	IL-871	29191	Rock Creek	0.044	
1-01-1890	IL-872	29192	Unnamed ditches	0.037	
1-01-1890	IL-873	29193	Rock Creek	0.1	
1-01-1890	IL-874	29195	Springs and ditch	0.044	
1-01-1890	IL-875	29202	Cummings Ditch and unnamed ditches	0.231	
1-01-1890	IL-876	29282	Rock Creek	0.063	
25-May-53	IL-890	81965	Tualatin River	0.97	
Reservoir					
23-Jun-97	R-83470		Chicken Creek		579 Acre-Feet
01-Jul-97	R-83496		Runoff		180 Acre-Feet
12-Aug-97	R-83529		Runoff and Chicken Creek		40 Acre-Feet
08-Aug-00	R-84503		Tualatin River, overland flow		100 Acre-Feet

Table 3-4. Summary of Water Rights for the Refuge

Priority Date	Application No.	Certificate No.	Source Name	Flow Rate (cfs)	Place of Use/Storage (Acres/Acre-Feet)
25-Jul-01	R-84813		Runoff		10 Acre-Feet
24-Apr-03	R-85570	84056	Overland flow/runoff		1.6 Acre-Feet
24-Apr-03	R-85571	84055	Overland flow/runoff		2.9 Acre-Feet
24-Apr-03	R-85572	84054	Overland flow/runoff		2 Acre-Feet
24-Apr-03	R-85573	84053	Overland flow/runoff		1.8 Acre-Feet
06-May-05	R-86279		Runoff		60 Acre-Feet
Surface Water					
29-Dec-28	S-12500	14092	Tualatin River	6.93	553.8 Acres
29-Dec-28	S-12500	14093	Tualatin River	2.03	162.3 Acres
29-Aug-30	S-13702	14096	Chicken Creek (Cedar Creek)	1.8	143.3 Acres
19-Nov-35	S-16153	24368	Chicken Creek	1.01	80.8 Acres
04-Sep-36	S-16568	45451	Hill Creek	0.06	4 Acres
04-Sep-36	S-16568	45451	Tualatin River	.44	36 Acres
01-Aug-39	S-18312	19761	Tualatin River	1.08	21 Acres
26-Feb-40	S-18591	15099	Tualatin River	0.21	2.1 Acres
14-Nov-49	S-24270	22317	Rock Creek	0.044	3.5 Acres
25-Jul-50	S-25034	23148	Drainage ditch and unnamed stream	0.16	7 Acres
25-Jul-50	S-25035	20132	Unnamed drainage	0.024	2.9 Acres
12-Mar-51	S-25704	40860	Tualatin River	0.38	30 Acres
02-Jun-65	S-40957	40726	Tualatin River	0.6	50 Acres
31-Mar-71	S-48082	43946	Tualatin River	0.96	77.1 Acres
28-Jun-82	S-63714	64950	Chicken Creek	1.08	86.2 Acres
25-May-53	T-10246	81965	Tualatin River	0.13	
02-Jan-00		29187	Rock Creek		

Source: USFWS 2012.

The main season of water use is usually between November until May at select locations. This varies with water conditions as determined by annual precipitation. Adequate water is important to provide habitat for migratory birds and for irrigation of habitat restoration sites. During the winter, most wetland cells (including the Wapato Lake Unit lake bed) are kept full to provide water for both resident and wintering species.

Photo 3-3. Tualatin River flooding at the Tualatin River Unit, December 2007.
Peter Schmidt/USFWS.

Sherwood Units: The floodplain of the Tualatin River is the dominant feature within the Sherwood Units (see Appendix P, Map 6). The Atfálat'i Unit is bordered by the Tualatin River, but water for wetlands in much of this unit comes from a diversion on Chicken Creek. The diversion allows gravity flow to fill five managed wetland cells in the unit. One additional wetland cell is filled by rain water and is managed as a permanent wetland with no outlet structure. Another wetland cell is also filled with rain water and overland runoff, but is managed as a seasonal wetland with a water control structure at the outlet.

On the Tualatin River Unit there are five wetland impoundments that normally fill with rain and overland runoff, but the largest wetland also has a pump with a fish screen in the Tualatin River that may be used to conduct early season flood-up or to augment rainfall during periods of drought. On the Riverboat Unit there are four impoundments, with a seasonal wetland filled using a water control structure to back up overland flow from springs and rainfall and, frequently, floods from high water in the Tualatin River. In addition, the seasonal wetland has a series of three low-capacity wells that are sometimes used to augment overland flow in early fall. There is also a scrub-shrub wetland, which is a closed water body and is filled by rainfall alone. During extreme flooding of the Tualatin River, the scrub-shrub wetland becomes a flow channel for river water. This unit has extensive floodplain connections to the river and is often saturated through the winter.

The Onion Flats Unit is a low-lying basin bisected by Rock Creek. The creek is channelized and straightened through this unit and is deeply incised. This area floods frequently as the Tualatin River water backs up Rock Creek, and also during periods of heavy rain. The Rock Creek Unit features its

namesake creek and is also largely channelized. This is a relatively small creek through this unit and rarely causes any major flooding. During winter as the Tualatin River begins to reach bankfull stage (elevation 128 above mean sea level), many backwater areas in riparian forest and wetland habitats begin to flood. Vegetation communities in these areas are adapted to frequent winter flooding, and fish and wildlife species use these areas for foraging and sanctuary. Inundation in these areas is typically intermittent and of short duration

Wapato Lake Unit: The Tualatin River bisects the Wapato Lake Unit acquisition boundary. Inputs to Wapato Lake proper were historically from Wapato, Ayers, and Hill Creeks, and from the river backing up into the lake (see Appendix P, Map 7). The historical Wapato Lake lake bed was severely altered during the 1920s with the formation of the Wapato Improvement District (WID), a state-sponsored irrigation and drainage district. This district supported onion farming that took place on the lake bed itself. The WID installed 5.5 miles of levees around the lake, a lift pump station, and interior ditches to facilitate drainage of the lake for historical farming. Wapato, Ayers, and Hill Creeks were diverted around the outside of the levees to connect with the Tualatin River later. During fall and winter, the lake was allowed to fill with rain water, and it was pumped out in early spring for farming. Currently the refuge has a cooperative farming program that uses much of the same infrastructure. In the northern part of the acquisition boundary, Scoggins and Harris Creeks are tributaries to the Tualatin River.

3.3 Topography and Bathymetry

The refuge area lies in the northwestern corner of the Willamette Valley, southwest of Portland, Oregon (see Appendix P, Map 1). Elevations on the refuge range from about 105 feet to 300 feet. The Tualatin River floodplain is relatively flat, with gradually sloping sides leading to upland forest types, agricultural lands, and developed areas. Major mountain features include the Coast Range to the west of the Wapato Lake Unit and Chehalem Ridge rising to 1,629 feet (Oregon Parks and Recreation Department 2011) between the Wapato Lake and Sherwood Units. The Tualatin River channel is deeply incised with steep banks throughout most of its length. Henry Hagg Lake is a 1,110-acre reservoir (ODFW 2011a) approximately 3 miles west of the Wapato Lake Unit.

Many refuge land parcels have had detailed topographic surveys completed prior to initiation of restoration projects. In the Sherwood Units, surveys were conducted on the Atfálat'i, Tualatin River, and Riverboat Units. The refuge is currently working with U.S. Geological Survey (USGS) and other partners to conduct a hydrogeomorphic survey at the Wapato Lake Unit that will provide a digital elevation model for the lake bed and surrounding area, as well as a water budget for future restoration planning.

3.4 Geology and Geomorphology

3.4.1 Origins and Development

During the Oligocene epoch roughly 35 million years ago (MYA), a line of sea floor subduction, which had run in a northeast direction from west of the Klamath Mountains to the Blue Mountains, moved to its current position several hundred miles to the west on its northern end. This change left a slab of what had been subducting sea floor attached to the continental margin and also moved the line of volcanic activity associated with remelting oceanic crust. Part of this slab, covered by shallow

seas, ultimately became the floor of the Willamette River basin. Although volcanic eruptions had started building the southern Cascade Mountains millions of years earlier in the Eocene epoch, the northern Cascades lie on top of the slab and arose as volcanoes. Volcanic rocks in the western Cascades date from two principal periods of volcanic activity, one occurring 20 to 30 MYA and the other in the Miocene, 10 to 15 MYA; both periods included the entire length of the Cascades (Branscomb 2002). The Tualatin River Basin is underlain by 9,000-12,500 feet of sedimentary and volcanic rock (Popowski 1996; Wilson 1998). On top of this layer lie up to 900 feet of Columbia River basalt and another 1,200 feet of sediments from the late Miocene to Pleistocene.

The Coast Range arose as continental sediments carried eastward by the subducting oceanic plate were forced under the western edge of the slab, pushing it upward. The rise proceeded from south to north, the northern Coast Range not appearing until roughly 15 MYA. During this process, the area of the future Willamette Valley also rose, becoming dry land and draining its embayment by about 20 MYA. Although the direction of sea floor spread is southeastward toward the Oregon coast, the entire Pacific plate, including the spreading and subduction zones, is moving northward. The net effect for the Oregon Coast Range appears to be a slow movement north, evidence for which may be seen in the roughly 50-mile northward offset of the Columbia River at Portland and the sharply curved Olympic Mountains in western Washington State, where movement of the Coast Range encountered the more deeply rooted Vancouver Island. This northward tearing of the Coast Range may also have contributed to the formation of the Willamette Valley, the floor of which is now composed of multiple fault blocks. In contrast to its south end, the valley is spreading more in the north, possibly due to the thinner crust and reduced linkage with the subducting sea floor present there (Branscomb 2002).

3.4.2 Recent Geologic Events

Defining the northern limit of the Willamette River Basin, the Columbia River has reestablished its course through multiple dammings by slides, basalt flows, and ice. Reaching their maximum 13 MYA, basalt floods from the enormous Grande Ronde volcano in northeast Oregon flowed down the Columbia channel all the way to the river’s mouth and into the Willamette Valley. In the Pliocene (3 to 11 MYA), western Oregon was a desert, and gravels produced during that time eroded into and covered the spreading valley floor.

Work performed by J. Harlan Bretz in the 1920s revealed that between 15,500 and 13,000 years ago, ice periodically dammed the Clark Fork in Idaho east of Spokane, Washington, forming a lake in the present-day Missoula Valley of Montana covering some 3,100 square miles and containing 500 cubic miles of water. In a typical release occurring over less than two weeks, a quantity of water equal to half the present volume of Lake Michigan, more than the modern annual volume of all the world’s rivers, poured down the Columbia channel. These floods were known as the Missoula Floods. Backwater from these floods carried ice-rafted “erratic” rocks from Montana repeatedly into the Willamette Valley, filling it to about 400 feet above current sea level. Evidence in the geologic record suggests that these floods entered the Tualatin River Valley at least 22 times during this time period (Wilson 1998). This vigorous overflow southward across the divide between the Willamette River and Tualatin River Basins scoured multiple channels in the basaltic bedrock, dug small rock-bound basins, and left rock knobs barren of soil, forming a topography in the Rock Creek area just east of the City of Sherwood that is a miniature replica of the well-known scablands in eastern Washington. The sediments left by these floods form much of the present valley floor (Branscomb 2002). In the Tualatin River Basin, these overlying sediments have been classified as the Hillsboro

Formation (Wilson 1998) and consist of about 900 feet of fluvial and lacustrine sediment overlying 95 feet of lateritic soil and weathered basalt of the Columbia River Basalt Group. This area is still geologically active as evidenced by the 1980 eruption of Mount Saint Helens 65 miles to the northeast.

3.5 Soils

Within the refuge boundaries there are 64 soil types described (U.S. Department of Agriculture [USDA] 1982). These can roughly be broken down into the following six categories: 1) clay, 2) loam, 3) silt loam, 4) silty clay loam, 5) stony silt loam, and 6) Xerochrepts. A majority of refuge lands in the floodplain contain clays, silty clay loams, and silty loams. Most of these lands were in agricultural production prior to purchase by the Service. On areas outside the floodplain, most of the soils are loams and silty loams that are well drained and primarily support mixed upland forest types.

There are two areas of particular historical interest—Onion Flats and Wapato Lake. These areas contain Labish Mucky Clay, a rare organic peat soil type that historically supported scrub-shrub and other wetland types. It is heavy, poorly drained soil, usually associated with old concave lake beds. These areas were drained for farming in the early twentieth century and continue to be cooperatively farmed by the refuge at present. The major crop in these areas was onion, but with a shift in economics, these areas now support small grains such as oats, corn, wheat, barley, and grass and clover crops.

Another area of interest is the Tonquin scablands along the Rock Creek drainage. This area contains soils of stony loam to Xerochrepts deposited by the ancient Missoula Floods, and is an area of rocky basalt outcrops and deep gravel. This soil varies greatly from highly porous, well-drained soil to highly impermeable rock creating perched wetlands. Much of the area surrounding refuge lands in the Rock Creek area is extensively mined for rock and gravel. Any organic soil existing within this area is relatively shallow, but still supports abundant native plant growth.

3.6 Fire

3.6.1 Historic Activity

For thousands of years prior to European settlement, fire played an important role in maintaining various habitat types within the Willamette Valley and in Oregon as a whole. Whether ignited by lightning or set by Native Americans, fire helped to maintain native habitat types by preventing woody species from encroaching into prairie habitat types, preventing build-up of volatile fuels in forested areas, creating a mosaic of habitat types and successional stages, and recycling nutrients (ODFW 2006). Since at least the 1850s, fire suppression actions began to change the landscape of the Willamette Valley, and have resulted in a host of unintended consequences for ecological health, wildlife populations, and people.

In more open habitat types such as prairies and oak savanna, fires were essential for removing encroaching woody species (especially conifers), reducing thatch left by annual and perennial grasses and forbs, and providing habitat for wildlife, such as elk, acorn woodpeckers, and white-breasted nutchatch, dependent on open habitat types. Native Americans often burned open habitat types to promote food plants such as camas and tarweed, provide for more open travel corridors, and provide

forage for elk, deer, and other game species that they hunted (ODFW 2005). Due to fire suppression, less than 1 percent of these habitats remain in the valley, as woody species, such as Douglas-fir, have moved in and changed the landscape.

Photo 3-4. Kalapuya people ignited fires to manage habitats for their needs.
USFWS.

In forested areas, fires played an important role in maintaining a diversity of habitat structure. Drier forests historically experienced frequent fires (usually at less than 25-year intervals) that mainly burned understory plants, but left larger trees undamaged. In wetter forests such as those in the Coast Range, fires were less frequent (on the order of once every 100 years), but often burned the entire stand, setting the stage for early successional plant growth.

3.6.2 Recent Activity

In forested areas, fire suppression has increased the likelihood of wildfires that are unusually large and severe (ODFW 2005). In the late nineteenth and early twentieth centuries, logging operations combined with fire suppression throughout the Pacific Northwest created conditions for catastrophic fires. Vegetation composition within forests has also changed as a result of fire suppression. Historically, conifer-dominated forests had little undergrowth because of the shade imposed by the closed canopy and frequent fires that cleared brush and downed woody debris. However, with the onset of widespread fire-suppression activities, debris was allowed to accumulate, and brush and eventually understory trees began to grow and provide “ladder” fuels that led to canopy fires when a fire did occur.

In prairie and savanna habitat types, fire suppression often led to a complete change in vegetation structure as woody species such as shrubs and conifers invaded and shaded out other species. In addition to fire suppression, these open habitat types were often the first to be converted to agriculture or developed as home and town sites, thus exacerbating their decline.

Photo 3-5. Prescribed fire can be used to manage native habitats. Scott Swanson/ USFWS.

3.6.3 Current Conditions

The refuge currently has a fire management plan (USFWS 2002b) in place that covers wildland fire events and pile burning, but does not address prescribed fire. This plan states that all wildland fires, whether human-caused or lightning-induced, will be suppressed. Brush and debris piles that result from management activities will be burned by fully trained and equipped Service fire crews in accordance with national and regional policies. The refuge is updating the fire management plan, which will propose prescribed fire; this information can be found in Appendix O of the Comprehensive Conservation Plan/Environmental Assessment (CCP/EA).

Many of the habitat types on the refuge are fire-dependent vegetation communities. In the absence of prescribed fire, these habitat types are maintained with surrogates for fire such as mowing and discing. The introduction of nonnative and invasive plant species such as reed canarygrass, velvetgrass, cocklebur, and Bermuda grass during the past century have complicated maintenance of these native habitat types. Use of prescribed fire to maintain native habitat types may or may not address some of these issues.

3.7 Environmental Contaminants

In 1992, prior to formal establishment of the refuge, the Service conducted a pre-acquisition contaminant survey (USFWS 1992b) to assess possible contaminants affecting proposed refuge lands. The survey found that there were " …a variety of contaminant sources on and adjacent to the refuge including container nurseries, a tannery, a potato processing plant, an abandoned town dump, nonpoint source pollution from highways and industrial areas, agricultural runoff, dairy farms, auto wrecking yards, electrical power lines, and possible hazardous wastes from farming and industrial operations."

In the Rock Creek drainage within the refuge acquisition boundary, but on lands not owned by the refuge, is the 33-acre site of a former tannery and battery company. The Frontier Leather Company

(Frontier) began operating a tannery at the site in 1947. Two 3-acre sedimentation lagoons were constructed, and placed in service in 1965. Frontier discharged wastewater to the sedimentation lagoons intermittently between 1965 and 1982. Between 1971 and 1974, chromium-treated hides were both stockpiled and buried at the facility. Frontier landfilled an estimated 21,000 cubic yards of chromium-containing wastes including chromium-treated hides and chromium-containing vacuum filter sludge. Some of the hides were later covered with approximately 2 feet of soil, but a large percentage of the landfill was not adequately consolidated and capped to control possible direct contact or surface water runoff. Landfilling of hides was discontinued in 1973 after analytical results from hide samples collected by the Department of Environmental Quality (DEQ) suggested that the hides could adversely impact soil, groundwater, or surface water quality (DEQ 2011c). Additionally, contaminants found in surface soil samples included antimony, trivalent chromium, lead, and mercury (DEQ 2011b). In addition to contaminants from the tannery, there are also contaminants from lead acid batteries at the tannery site, including lead, sulfuric acid, and battery casings (DEQ 2011b).

DEQ uncovered records from the former tannery indicating that tannery wastes were land-applied to pasture land at Ken Foster Farm (KFF) during the 1960s. The former KFF 40-acre farm site is on Murdock Road, in Sherwood, outside the refuge acquisition boundary, but adjacent to and upslope of the Rock Creek Unit. Investigations of the KFF confirmed the presence of high concentrations of chromium in surface soils consistent with land application of the tannery wastes. These contaminants could have migrated into the Rock Creek drainage, which flows through the refuge. In 2007, the U.S. Environmental Protection Agency (EPA) published findings from their assessment of the former KFF site confirming that several heavy metals, primarily chromium, lead, and mercury were present at elevated concentrations in site soils. Sampling performed to date indicates lead and chromium in site soils are attributable to historical land application of tannery wastes at the site (DEQ 2011a). Additional work at the KFF site is warranted, including completion of a comprehensive remedial investigation and risk assessment, feasibility study, and implementation of remedial action as necessary (DEQ 2011b).

3.8 Air Quality

The EPA has lead responsibility for the quality of air in the United States; through the 1990 Clean Air Act, the agency sets limits on the amount of pollutants that can be discharged into the air. More than 170 million tons of pollution are emitted annually into the air within the United States, through either stationary sources (such as industrial or power plants) or mobile source (such as automobiles, airplanes, trucks, buses, and trains). There are also natural sources of air pollution such as fires, dust storms, volcanic activity, and other processes. The EPA has identified six principal pollutants that are the focus of its national regulatory program: carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide.

The Oregon DEQ is responsible for protecting Oregon’s air quality. DEQ monitors air pollution to ensure that communities meet national ambient air quality health standards (DEQ 2011c). There are three main pollutants that are of greatest concern in Oregon. These are:

- Ground-level ozone, commonly known as smog;
- Fine particulate matter (mostly from wood smoke, other combustion sources, cars, and dust) known as PM2.5 (2.5 micrometers and smaller in diameter); and
- Hazardous air pollutants (also called air toxics).

According to a 2010 DEQ report (DEQ 2011c), the PM2.5 level was below the Federal health level throughout Oregon. Ground-level ozone (smog) exceeded the Federal standards twice in Portland and once in Salem. They did not violate the standard, which requires four exceedance days. Forest fire smoke was light in 2010 and did not exceed the Federal health standard anywhere DEQ monitored. Air toxins, such as benzene and acetaldehyde, remain near or above the health benchmarks. The health benchmarks are concentration levels at which, if exposed over a lifetime, an individual's risk of getting cancer is increased by one in one million. Carbon monoxide and PM10 (particulate matter 10 micrometers in diameter and smaller) remained far below the Federal health standard. The pollutants have been trending down in the past 10 to 15 years.

According to Creative Methods (2011), Washington and Yamhill Counties received poor grades for air quality based on tons of emissions per square mile of the following pollutants (Table 3-5): carbon monoxide, lead and lead compounds, nitrogen oxides, volatile organic compounds, PM10, PM2.5, ammonia, sulfur dioxide, total hazardous air pollutants, and two particular hazardous air pollutants, diesel emissions and acrolein emissions.

Table 3-5. Letter Grades* of Selected Air Quality Measures Based on Tons Emission per Square Mile

County	CO	Pb	NOx	VOC	PM10	PM2.5	NH_3	SO_2	HAP	Diesel	Acrolein
Washington	F	C	D	D	D	F	C	D	D	F	D
Yamhill	D	D	C	D	D	D	C	C	C	C	D

*The grade "A" represents the best/cleanest emission densities in the United States, and "F" the worst/dirtiest in the United States.

CO: Carbon dioxide
Pb: Lead
NOx: Nitrogen oxides
VOC: Volatile organic compounds
PM10: Particulate matter less than or equal to 10 micrometers
PM2.5: Particulate matter less than or equal to 2.5 micrometers
NH_3: Ammonia
SO_2: Sulfur dioxide
HAP: Hazardous air pollutants

However, in actual tests of ambient air quality, only Yamhill County exceeded any air quality parameters. Based on these tests, EPA levels for quarterly levels of lead were exceeded (Creative Methods 2011).

As discussed in Section 3.6 above, prescribed fire can be a useful management tool, but smoke management is a concern and is governed in part by Oregon Administrative Rules (OARs) (OAR 2011).

3.9 Water Quality

3.9.1 Overview—Tualatin River and Basin

The Tualatin River watershed lies almost completely within Washington County but also crosses Multnomah, Clackamas, Yamhill, Tillamook, and Columbia Counties. This watershed, or subbasin, is part of the larger Willamette River Basin. The Tualatin River drains more than 700 square miles of land on the west side of Portland's metropolitan area; its headwaters are in the Coast Range and it flows in an easterly direction to the confluence with the Willamette River. The Tualatin River Basin supports a growing population of more than 450,000 people and a wide range of urban, agricultural, and forest-derived activities (DEQ 2011d). The discharge of the river reflects seasonal rainfall, and most precipitation occurs between November and March. Seasonal stream flow is typically highest from December through April and lowest from July through October (USGS 2008). The low flow period occurs during the summer from May through October. Streams entering the river within the refuge include Wapato, Ayers, Hill, Harris, and Scoggins Creeks in the Wapato Lake Unit, and Chicken and Rock Creeks in the Sherwood Units.

The Oregon DEQ is the agency responsible for ensuring that the streams and rivers of Oregon are within standards set forth by the Federal Clean Water Act of 1972. In the past, as human activity increased in the subbasin, the Tualatin River experienced many water quality problems including algal blooms. Many streams in the Tualatin River subbasin do not meet Oregon water quality standards as these streams have high water temperatures and low dissolved oxygen levels that can harm fish and other aquatic life. Some water bodies have bacteria counts that are higher than Oregon's water quality standards recommend (DEQ 2011d). In response to these streams not meeting water quality standards, DEQ listed the Tualatin River as a "water-quality limited" stream. The term "water-quality limited" is used in the Clean Water Act to define streams that do not meet established water quality standards even after the implementation of standard controls. In 1984 and 1986, Tualatin River was listed due to low dissolved oxygen concentrations and nuisance levels of algae. Once a river has been designated as water-quality limited, the Clean Water Act requires that the DEQ develop thresholds for the amount of pollutants to be released in the river (USGS 2008).

Since the 1970s, DEQ has worked with other agencies and organizations to ensure actions are taken to improve water quality in the Tualatin River. These actions include closure of several water treatment plants that historically discharged high concentrations of ammonia and phosphorous, upgrades at remaining treatment facilities, implementation of management plans by agencies that address potential sources of pollutants, tree plantings along streams to facilitate cooler water temperatures, and the release of water from Henry Hagg Lake by Clean Water Services (CWS) during the critical summer months when water flow is low. All of these actions have contributed to improvement in the water quality of the Tualatin River.

CWS has worked further with DEQ to improve water quality in the Tualatin River. Water is released by CWS from Scoggins and Barney Reservoirs to improve the river's water quality. In 2004, CWS received a watershed-based permit from DEQ that provided a mechanism to offset a portion of the thermal loads from their wastewater treatment facilities with releases of stored water from the reservoirs. Reservoir releases during July and August are used to mitigate part of the thermal impacts from wastewater treatment facilities. CWS offsets the remainder of its thermal impact by planting riparian areas along tributaries, either directly within its service area or through a partnership with the Tualatin Soil and Water Conservation District on rural lands. During the rest of the summer, the

water is released to offset the effect of sediment oxygen demand on the dissolved oxygen levels in the river. Dissolved oxygen levels in the river downstream of the wastewater treatment facilities determine the ammonia limits for wastewater treatment facilities. The higher the dissolved oxygen levels, the more operational flexibility the wastewater treatment facilities have (CWS 2011).

Low dissolved oxygen levels can be a water quality issue in the lower Tualatin River. During the early parts of the summer, photosynthetic production of oxygen by algae effectively offsets the oxygen consumed by the decaying substances in the sediment of the river (sediment oxygen demand). In the fall, however, oxygen production by algae is reduced as the days become shorter and it no longer offsets the oxygen consumption by sediment oxygen demand. This can lead to low dissolved oxygen levels. Increasing stream flow reduces oxygen consumption by sediment oxygen demand because it shortens the contact time between the river water and the river sediments (CWS 2011).

In addition to the above actions, DEQ developed total maximum daily loads (TMDLs) as required by the Clean Water Act. The TMDLs are developed to meet established water quality standards. They define the amount of heat, bacteria, phosphorous, and ammonia that can be added while still being protective of the river (DEQ 2011d). DEQ first released TMDL loads (or amounts) in the 1980s for various sources in the Tualatin River Basin. There has been a revision of these TMDLs, and they are currently undergoing public review at the time of this writing. The establishment of TMDLs in the Tualatin River Basin prompted many management agencies to take actions to meet the load allocations set forth by the TMDLs.

3.9.2 Refuge-specific Water Quality

There are some data available on several creeks that enter the Tualatin River through the refuge. Chicken Creek, which supplies most of the water to the managed wetlands on the Atfálat'i Unit, enters the refuge through a diversion point from which water is then diverted to several different ponds using an irrigation canal. Over the years, as more urban development occurs upstream, the refuge has observed higher stream flows at the diversion. Higher flows have caused extra management responsibility and burden on the refuge to divert the water to the river to avoid flooding or damage to refuge infrastructure. In response to the increases in high flows, the refuge has installed some new infrastructure, including an emergency spillway to facilitate water reaching the river. In addition to high water flows, another concern of the refuge is the water quality of Chicken Creek, due to the runoff from urban development that occurs in the watershed. However, CWS has been monitoring the water quality for upper and lower Chicken Creek and as of date, all standards of temperature, dissolved oxygen, pH, and toxics are below applicable water quality criteria.

3.10 Visual Quality

The scenic beauty of the refuge plays in sharp contrast to the surrounding urban development of homes and roads. All features of visitor and administrative facilities have been designed and constructed to complement the natural refuge environment. Buildings are placed to welcome visitors at the entry point of the refuge, but not detract from wildlife observation. Where possible, structures are set into the landscape and/or provide views through or around the structure itself. Overlooks, kiosks, benches, signs, and railings are all low profile and colored to match the environment. This careful planning allows the visitor to experience the refuge without distractions.

3.11 Surrounding Land Use

The region surrounding the refuge is primarily a mix of urban and agricultural lands (see Appendix P, Map 2). The City of Sherwood in Oregon (population 17,930) abuts the southern and western boundaries of the Sherwood Units (U.S. Census Bureau 2011), the City of Tualatin (population 26,745) is to the east, and King City (population 2,965) is northeast of the refuge. The City of Gaston, Oregon (population 792), is adjacent to the west boundary of Wapato Lake Unit, and Forest Grove (population 21,448) is north of the refuge boundary by approximately 2 miles. Oregon's largest metropolitan center with Portland at its core is approximately 12 miles from the Sherwood Units and 23 miles from the Wapato Lake Unit. The population of Portland is 566,143; the population including its surrounding metropolitan area is approximately 2,260,000 (Portland Business Journal 2011). The population of Sherwood has increased by more than five times from 3,093 in 1990 (U.S. Census Bureau 2011) to the current level, and other cities in the surrounding area are also experiencing rapid population growth. In fact, some areas within the refuge acquisition boundary have already been developed with housing and businesses.

The western part of the Sherwood Units and Wapato Lake Unit are characterized by a more rural nature, with active agriculture as well as scattered patches of potential wildlife habitat. Dominant agricultural practices include growing of nursery and greenhouse stock; field crops such as winter wheat, corn, grass hay, and clover and grass seed; orchards of fruit and nuts; berry crops; and row crops such as potatoes and onions. In 2009, Washington County produced $4,106,865 in agricultural products (Oregon State University 2011). Yamhill County is a more rural county with high production of both agricultural commodities and timber products. Yamhill County is the nation's leader in production of hazelnuts and the fifth-largest producer of grass seed; it has the third-largest acreage of rhubarb, and is number five nationally for llama production (Oregon Department of Agriculture 2012). Active timber harvest occurs both east and west of the Wapato Lake Unit in the Chehalem Ridge area and in the Coast Range, respectively.

Within the Tualatin River Basin there are a number of public and private lands managed as wildlife. The regional Metro government has an active greenspaces program and has acquired and restored several land parcels. CWS maintains several land parcels that benefit wildlife, and other county and public entities maintain suitable wildlife habitat within the basin. In addition, private landowners maintain waterfowl hunting clubs throughout the area that benefit fish and wildlife. Other private landowners maintain habitat in a natural condition that also benefits fish and wildlife.

The lower reaches of the Tualatin River are navigable with small boats, and many recreationists take advantage of the river using canoes and kayaks. Fishing opportunities are limited; however, a few people use motor boats to fish for warm-water species during summer, and at least one person fishes for crayfish commercially on the river.