Lower Tualatin Watershed Analysis

Washington County Soil and Water Conservation District

J.T. Hawksworth, Principal Author

Tualatin River Watershed

Partners For Clean Water

August 2001

Table of Contents

List of Tables

List of Figures

List of Maps

Abbreviations and Acronyms

ACS	Aquatic Conservation Strategy
AF	Agriculture-Forestry (zoning designation)
BMP	Best Management Practice
BOD	Biological oxygen demand
cfs	Cubic feet per second
CREP	Conservation Reserve Enhancement Program
CWS	Clean Water Services (formerly USA)
DBH	Diameter at breast height
DMA	Designated Management Agency
D.O.	Dissolved Oxygen
DOGAMI	Department of Geology and Mineral Industries (Oregon)
EFU	Exclusive Farm Use (zoning designation)
EPA	Environmental Protection Agency (federal)
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FC	Federal Candidate species for listing under the ESA.
FSA	Farm Service Agency
FT	Federal Threatened (under the ESA)
GIS	Geographic Information System
GTAC	Greenspaces Technical Advisory Committee
HEL	Highly Erodible Lands
LMA	Local Management Agency
LWD	Large Woody Debris
LWI	Local Wetland Inventory
NMFS	National Marine Fisheries Service
NRCS	Natural Resources Conservation Service
NWI	National Wetlands Inventory
OAR	Oregon Administrative Rules
ODA	Oregon Department of Agriculture
ODEQ	Oregon Department of Environmental Quality
ODF	Oregon Department of Forestry
ODFW	Oregon Department of Fish and Wildlife
ODOT	Oregon Department of Transportation
OGI	Oregon Graduate Institute

ONHP	Oregon Natural Heritage Program
OSU	Oregon State University
OWEB	Oregon Watershed Enhancement Board
OWRD	Oregon Water Resources Department
PAH	Polyaromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PSU	Portland State University
RLIS	Regional Land Information System
RM	River mile
ROS	Rain on Snow
SOD	Sediment Oxygen Demand
SU	Sensitive Undetermined species designation (State of Oregon)
SV	Sensitive Vulnerable species designation (State of Oregon)
SWCD	Soil and Water Conservation District (Washington County)
TAC	Technical Advisory Committee
THPRD	Tualatin Hills Parks and Recreation District
TMDL	Total Maximum Daily Load
TRWC	Tualatin River Watershed Council
TRWIS	Tualatin River Watershed Information System
TVID	Tualatin Valley Irrigation District
UGB	Urban Growth Boundary
USA	Unified Sewerage Agency (now Clean Water Services)
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WAB	Water Availability Basin
WQI	Water Quality Index
WY	Water Year

Introduction

The concept of watershed analysis is built on the premise that management and planning efforts are best addressed from the watershed perspective. Better decisions are made, and better actions taken, when watershed processes and other management activities within a watershed are taken into consideration. Issues related to erosion, hydrologic change, water quality, and species are not limited to a specific site. Changes to watershed processes at one site often have effects that extend downstream and elsewhere in the watershed. By addressing these issues at the watershed level, we take the interconnected nature of watershed processes into account. We are thereby enabled to synthesize approaches to planning and management that preserve ecosystem functions. Where these functions have been diminished from reference conditions, we are able to plan activities to restore these functions.

In keeping with the principle of ecosystem analysis at the watershed scale, the Washington County Soil and Water Conservation District (SWCD), in partnership with the Tualatin River Watershed Council (TRWC) has prepared the Lower Tualatin Watershed Analysis. As part of its mission, the SWCD works with farmers to conserve the soil resources of the valley, and to protect water quality within the watershed. The Tualatin River Watershed Council represents a number of stakeholder groups as they examine issues related to watershed health. These issues are diverse, and the commitment of the TRWC is to address these issues as expressed by the Tualatin River Basin Action Plan (TRWC 1999).

The framework of this watershed analysis is built according to the requirements of *Ecosystem analysis at the watershed scale: a federal guide for watershed analysis* (REO 1995). This watershed analysis methodology is built up of six complementary parts. The first chapter is a watershed **characterization**, defining the characteristics that distinguish the watershed. The background laid out in this chapter leads to a set of **core topics and key questions** that have to do with watershed processes and their specific interactions with management activities. In response to these questions, the third and fourth chapter are constructed. The third chapter describes the **current conditions** within the watershed, while the fourth chapter reconstructs watershed processes and conditions under **reference conditions** (usually prior to European settlement). Based on the information provided in these chapters, we are able to synthesize the changes in watershed process that have been caused by various management activities. The results of this **synthesis** are included in the fifth chapter. Based on this synthesis, **recommendations** for current management and restoration are formulated.

Within the general framework of the federal methodology, there were opportunities to incorporate many techniques of the 1999 Oregon Watershed Enhancement Board (OWEB) methodology. This approach has helped to ensure consistency with past watershed analyses in the Tualatin subbasin, while assisting with the watershed preservation and restoration efforts of the SWCD, TRWC and other interested parties.

This watershed analysis report relies heavily upon data collected by other agencies and private sources. It has relied extensively upon GIS analysis of publicly available data contained in the Tualatin River Watershed Information System (Ecotrust 1998). These data have facilitated the analysis from these reports. However, they are not intended to replace field-based data for site-specific decisions. Although the data were analyzed for obvious flaws, no intensive review was performed on any data used in this report. There may be flaws in the source data and/or analysis performed in this report. This report should be used for general guidelines to point the direction to more site-specific studies.

The production of this watershed analysis required many analytic steps that are not contained within the pages of the Lower Tualatin watershed analysis report. Supplementary information is available on the Washington County SWCD web site (www.swcd.net). This includes the results of individual OWEB modules, as well as other technical appendices. Requests for further information can also be submitted to this site. In the interest of maintaining an accurate and current information base, those who access this site are encouraged to submit additional information based on their knowledge of the watershed.

Acknowledgements

Successful completion of the Lower Tualatin watershed analysis report required the contribution of experts in many disciplines. The following primary team members contributed technical assistance and provided editorial review.

Kathy Clair, WCSWCD, Director
Susan Gries, TRWC, Watershed Council Coordinator
Kevin Leader, ODFW, Fisheries
Dean Moberg, NRCS, Soils and agriculture
Tom Nygren, TRWC, Forestry (small woodlands)
Ross VanLoo, Washington County, Infrastructure issues
Tom Vanderplaat, CWS, Urban issues
Greg White, TRWC, Fisheries

People outside the primary team also made substantial contributions to the watershed analysis. Many thanks to all of these people for their assistance with the preparation of this watershed analysis report.

Finally, we express our appreciation to the Oregon Watershed Enhancement Board, which provided funding to produce this watershed analysis.

John Hawksworth

August 6, 2001

Chapter 1: Characterization

1.1 Physical

1.1.1 Size and setting

The Lower Tualatin watershed drains 97 square miles (62,300 acres) in the southeastern part of the Tualatin River subbasin (Map 1-1). It includes the Tualatin River and its tributaries downstream of (but excluding) McFee Creek (RM 28.2).

The watershed is drained by the mainstem Tualatin River and two fourth-order tributaries, Fanno and Chicken creeks. Fanno Creek drains the Portland Hills (Tualatin Mountains) and the urbanized northern portion of the watershed, while Chicken Creek drains the Chehalem Mountains and Parrett Mountain in the southwestern portion of the watershed. Mainstem lengths and their drainage areas are given in Table 1-1. Stream mile indices, including tributaries, for these mainstem reaches are given in Appendix 1. The Tualatin River Watershed Information System (Ecotrust 1998) divides the watershed into 13 subwatersheds (6th field watersheds). These subwatersheds are displayed in Map 1-2.

Major stream	Area (mi^2)[1]	Mainstem length (mi) [2]	Confluence with Tualatin (RM)
Tualatin River (total at Willamette River)	712	80	--------
Tualatin River (Lower Tualatin watershed)	97	28	--------
Chicken Creek	17	7	15.5
Fanno Creek	32	14	9.3

Table 1-1. Major drainages of the Lower Tualatin watershed

1.1.1.1 Topography

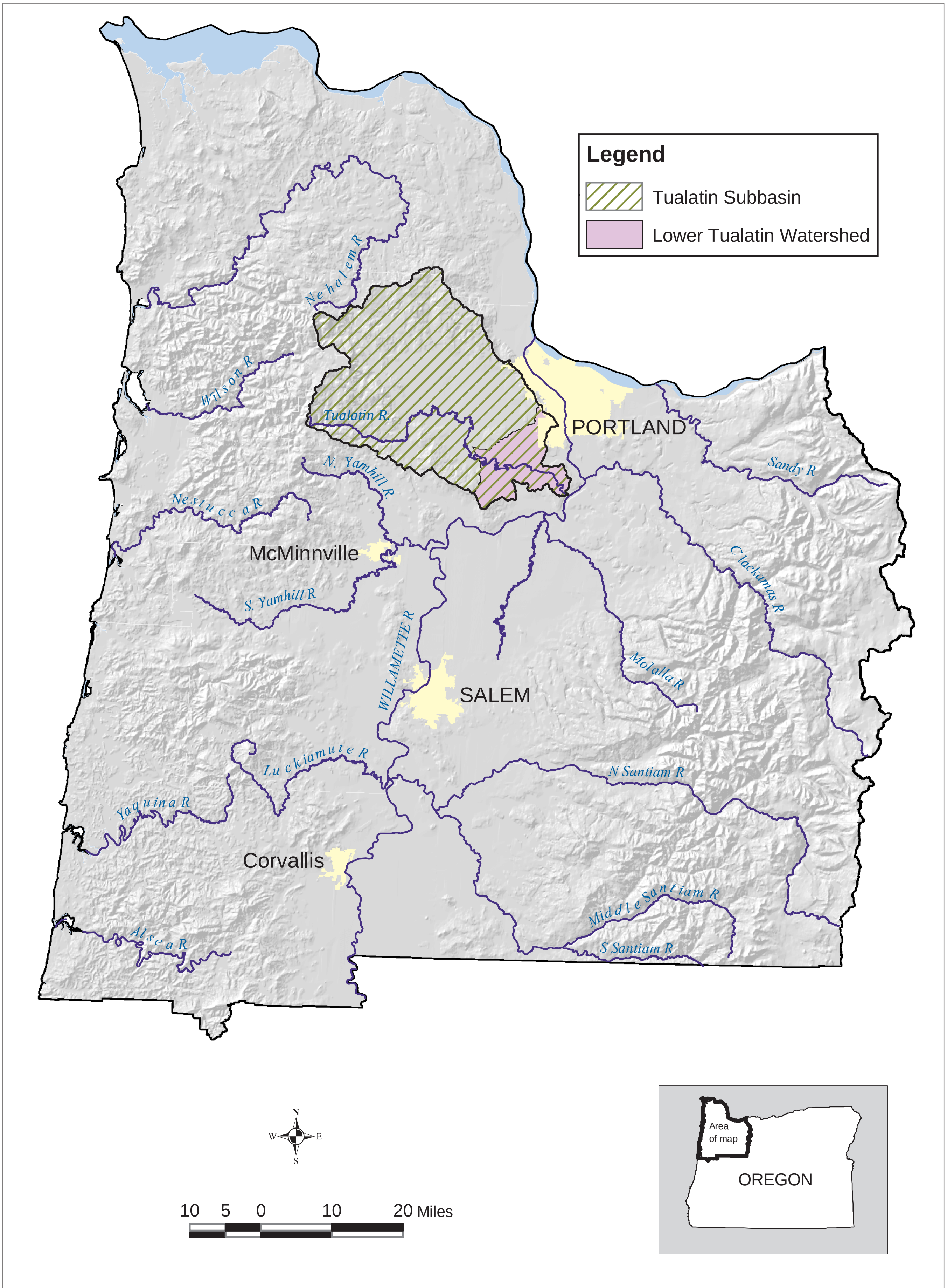
The watershed consists of ranges of hills separated by the Tualatin Plain (Map 1-3). These include the Portland Hills in the northern portion of the watershed, the Chehalem Mountains and Parrett Mountain, to the southwest, and Bull Mountain and Cooper Mountain, to the northwest. These hills seldom exceed 1,000 feet elevation, and the maximum watershed elevation of 1,247 feet is located at Parrett Mountain. These hills are characterized by extensively dissected terrain. Although stream gradients are locally steep, they seldom exceed 16% for any extended length.

Between these hills, the Tualatin Plain provides an extensive area of flat to rolling terrain. About 63% of watershed area is included in this alluvial plain, where elevation is generally less than 300 feet. Streams within the plain experience little change in elevation, as expressed by stream gradients that are generally much less than 1%. For example, the mean gradient of the Tualatin River in the watershed

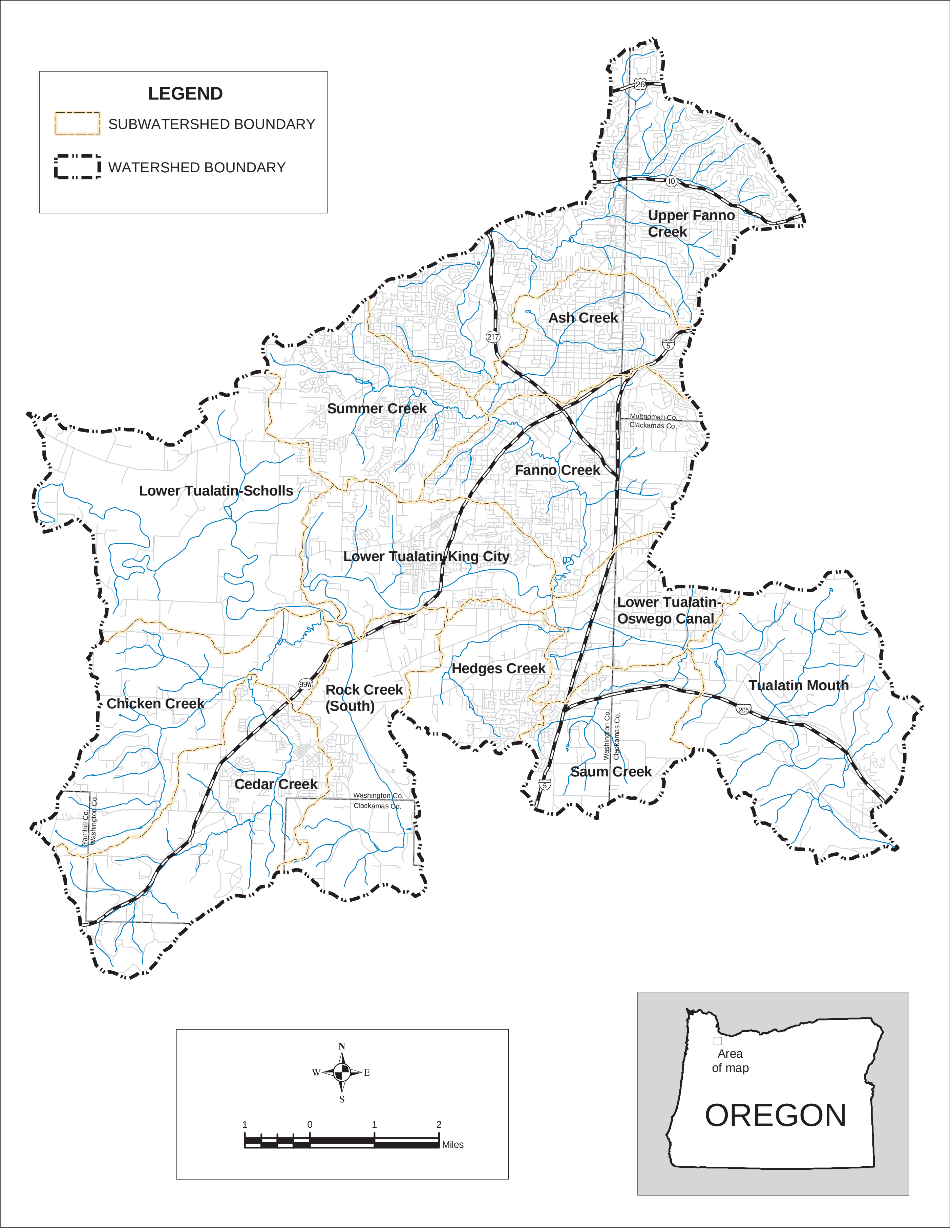
---

[1] Derived from GIS analysis of Tualatin River Watershed Information System (TRWIS) 6th field watershed layer.

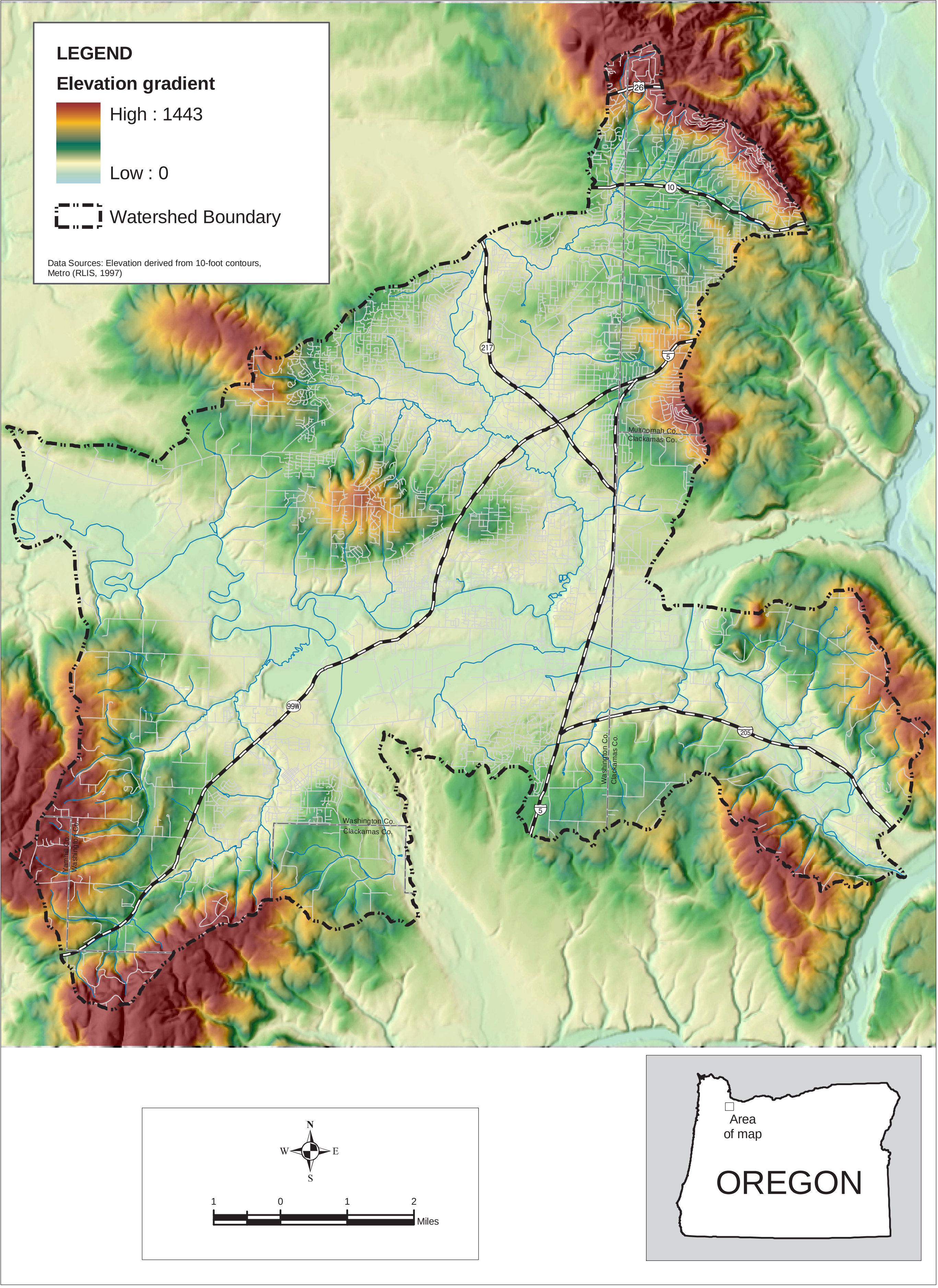
[2] Derived from GIS analysis of Ecotrust's digitized 1:24,000 stream layer.



Map 1-1 -- Location of the Lower Tualatin Watershed



Map 1-2. Lower Tualatin Watershed and Subwatersheds



Map 1-3 -- Terrain elevation of the Lower Tualatin Watershed.

is 0.04%. However, the river's flow characteristics change at River Mile 3.4. Upstream of this point, river gradient averages 0.013%. This reach is characterized by low velocity flow and pool stratification (SRI 1990, ODEQ 2000). Downstream of River Mile 3.4, mean gradient averages 0.19% as the river enters an area of pools and riffles. Ultimately, the Tualatin River flows into the Willamette River at an approximate elevation of 60 feet.

1.1.1.2 Ecoregions

In order to facilitate management, the federal Environmental Protection Agency (EPA) has subdivided the landscape into units based on physical and biotic characteristics. These units, called ecoregions, are designated on a hierarchical scale, with higher level classifications denoting finer divisions of the landscape. At level IV of the EPA classification system, virtually the entire Lower Tualatin watershed falls within the Prairie Terraces ecoregion. Characteristics of this ecoregion are given in Table 1-2.

1.1.1.3 Geomorphology

Tectonic folding and subsequent alluvial deposition characterize the geological structure of the watershed. Terrestrial lava flows overlaid sedimentary formations east of the Coast Range. Subsequent folding of this area resulted in formation of anticlinal ridges such as the Portland Hills, Chehalem Mountains, Parrett Mountain, and Bull Mountain, as well as a synclinal trough, which became the Tualatin Plain. Subsequently, alluvial silts and clays settled in the plain. Additionally, sites of impeded drainage accumulated organic matter (Orr et al. 1992, Wilson 1997, Schlicker 1967).

At the far eastern portion of the watershed, volcanic vents formed subsequent to the formation of the Tualatin Plain. Eruptions from these vents resulted in localized lava flows. Geologists refer to the rock formation from these eruptions as the Boring lavas, as distinguished from the older Columbia River basalt.

Surface rock types vary between hills and valleys in the watershed (Map 1-4). Hills are typically characterized by Columbia River basalt interspersed with sedimentary formations. Aeolian silts often overlie the ridgetops.

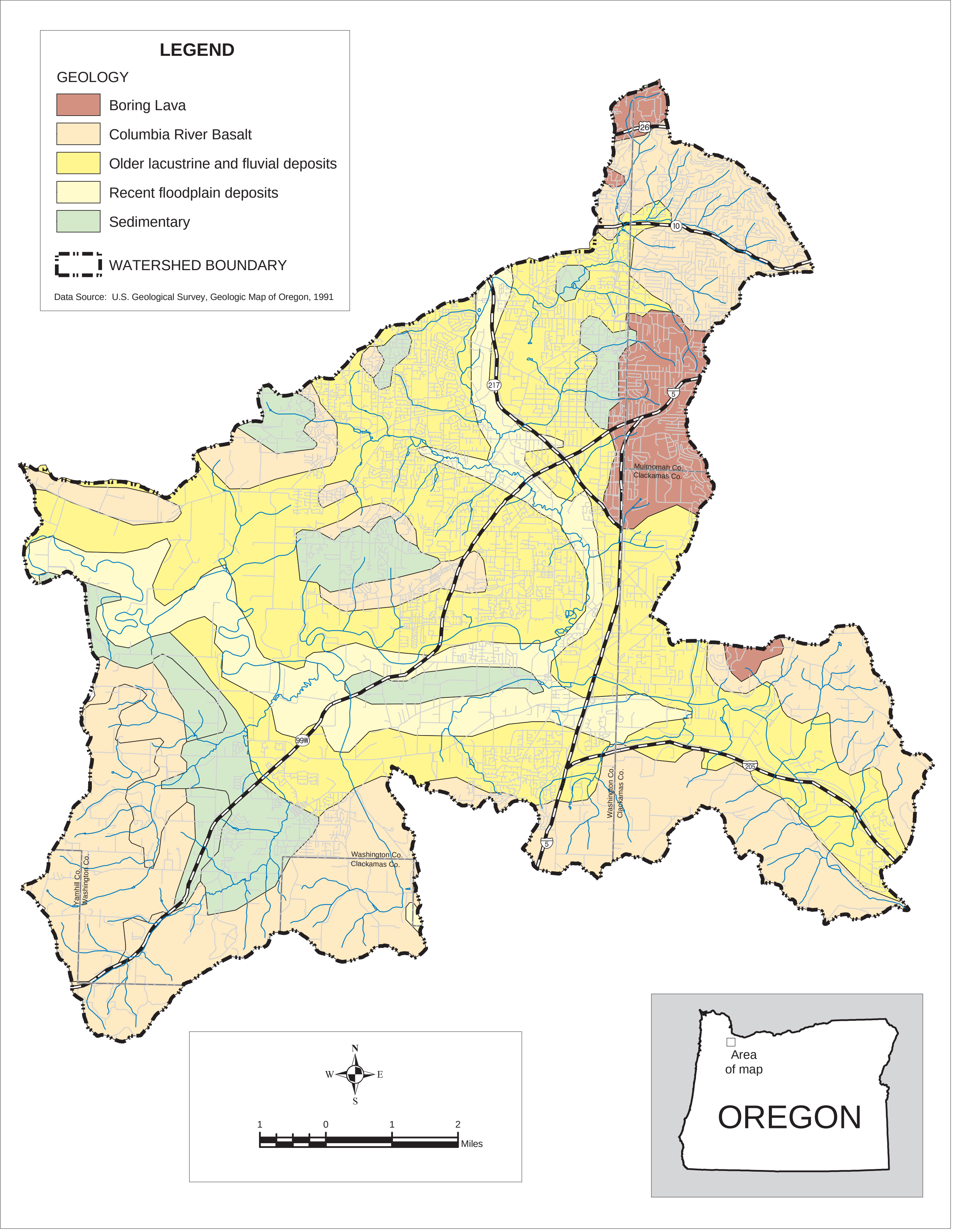
The Tualatin Plain is composed of recent alluvial floodplains surrounded by thick beds of older alluvium, which are largely the result of Pleistocene flooding. The Missoula floods resulted as massive lakes in the Rocky Mountain province burst through their glacial dams. Release of impounded lake waters resulted in a flood wave that immersed the Tualatin Valley to an elevation of roughly 250 feet. The initial flood waves carried gravel, sand, silt and clay, much of which was deposited in the Tualatin Valley. Much of this water remained in the valley for a substantial period of time, forming Lake Allison. Subsequently, this lake deposited lacustrine silt/clay throughout the Tualatin Valley. Many of these deposits have low permeability, resulting in poorly drained conditions in many parts of the subbasin (Orr et al. 1992, Hart 1965).

1.1.1.4 Erosion

Erosion processes are strongly influenced by the watershed's soils and geology. Due to the moist climate, most upland rocks have weathered to deep, fine-grained soils. Additionally, the hills within the watershed are typically covered by wind-blown silt (NRCS 1982). The soils generated through these

Table 1-2 Characterization of EPA Level IV ecoregions in the Lower Tualatin watershed. (Adapted from Pater et al. 1998, NRCS 1982.)

Level IV ecoregion	Elevation	Physiography	Lithology	Soil Orders	Common soil series	Potential natural vegetation	Land use	Climate
3c. Prairie Terraces	60-1250 feet	Nearly level to undulating fluvial terraces with sluggish, sinuous streams and rivers. Historically, seasonal wetlands and ponds were common. Many streams now channelized.	Quaternary and Tertiary lacustrine and fluvial sedimentary deposits.	Alfisols, Mollisols, Inceptisols	Aloha, Woodburn, Cornelius, Kinton, Chehalis	Prairies interspersed with oak and conifer forest. In riparian locations, Oregon ash, black poplar, willow.	Agriculture and urban. Also rural residential development and some forested riparian zones.	Mesic/Xeric
3d. Valley Foothills	680-1060 feet	Rolling to steep foothills with medium gradient, straight to sinuous streams.	Miocene andesitic basalt.	Alfisols, Inceptisols	Laurelwood, Cascade	On drier sites: Oregon white oak. On moist sites, western redcedar and Douglas-fir.	Rural residential development, pastureland, coniferous and deciduous forests, forestry, vineyards, Christmas tree farms, orchards.	Mesic/Xeric



Map 1-4 -- Geology of the Lower Tualatin Watershed.

processes are readily erodible. Under natural conditions, a heavy forest cover moderates erosion in these areas. Where human activities lead to clearing and soil disturbance, erosion rates can be quite high.

In the hills, several geologic factors contribute to slope instability. In many areas, rock layers of different strength lie adjacent to each other, thus providing a plane naturally prone to failure. In other cases, the soil and rock material is inherently weak. Both mechanisms contribute to instability along the ridges, which are typically capped with a heavy, unstable overburden of silt-clay textured soils. Slumping and sliding in these areas is common, especially where construction creates overly steep slopes (Schlicker 1967).

In the Tualatin Plain, streambank erosion is an important process, as fluvial action erodes the soft alluvium of the banks. In these areas, sheet, rill, and gully erosion are also important, particularly where agricultural activities take place on steep slopes.

1.1.1.5 Climate and Precipitation

The Tualatin subbasin lies in a region of moderate climate. Summers are warm and generally dry, while winters are cool and wet. Temperatures are moderated by the moist climate. In the Tualatin Valley, the freeze-free growing season averages 180 days, and the temperature falls below freezing 65 days out of the year (NRCS 1982). Mountainous regions have shorter growing seasons and greater incidence of freezing temperatures than those experienced in the valley. Weather is often cloudy, but precipitation is generally concentrated in the winter months. This precipitation comes mainly in the form of rain, although minor amounts of snow fall during the winter. Roughly 67% of precipitation occurs between November and March (Figure 1-1)[3]. The highest amounts of precipitation occur in the mountains and decrease with decreasing elevation. Annual precipitation ranges from 55 inches at the headwaters of Chicken Creek (T3S, R2W, S3) to 39 inches at Beaverton (OCS 1998). Precipitation in the Coast Range is generally light with little intensity (OCS 1997). Although the mountain regions experience higher precipitation than the valleys, total amounts and intensity of precipitation are low relative to western portions of the Tualatin subbasin.

1.1.1.6 Hydrology

Streams within the Lower Tualatin watershed are subject to seasonal variations in discharge, with high peaks in winter and very low flows in summer. Prior to flow regulation, the period from November to March accounted for 84% of discharge in the Tualatin River at West Linn[4]. Rain on Snow (ROS) events are not a major part of the hydrologic regime in the watershed. Despite construction of Scoggins Dam and numerous small flood control structures on tributary streams, adjacent floodplains and wetlands continue to be important for attenuation of flood peaks. Additionally, ponding in the lowlands continues to be an important part of the watershed's hydrology. During wet years, standing water still occupies the Tualatin Plain for substantial parts of the winter.

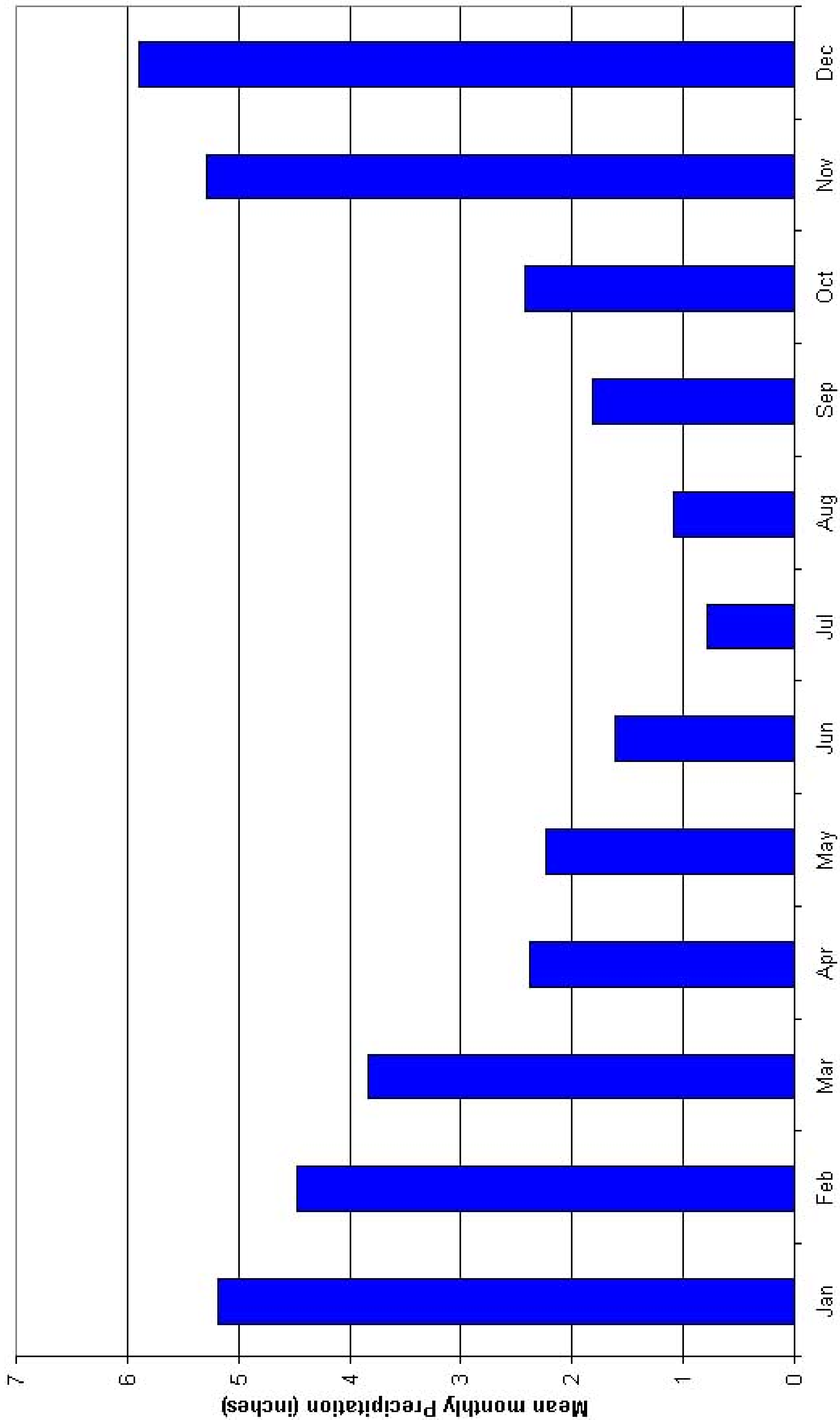
The United States Geologic Survey (USGS) has maintained a gage on the Tualatin River at West Linn (RM 1.8) since 1928. Currently, the Oregon Water Resources Department (OWRD) maintains stream gages on Fanno, Chicken, Summer and Hedges creeks, as well as the Oswego Diversion Canal.

---

[3] Based on precipitation records at Beaverton 2 SSW.

[4] Based on measured USGS flow at the Tualatin River gage at West Linn.

Figure 1-1. Beaverton: Rainfall distribution by month, 1972-1993
Source: OCS 2000



The natural flow characteristics of the Tualatin River have been modified by the Tualatin River and Trask River projects. Although these projects have a very small effect on the average annual discharge at West Linn, they alter the timing of the discharge by storing water in winter[5] and releasing water in the summer low flow season. This is particularly significant in the summer months.

Between May and October, water is diverted from the Tualatin River to Lake Oswego via the Oswego Canal (RM 6.7). Due to the low flows prevailing in this period, these diversions have potentially significant impacts. Although diversions have been greater in the past, they currently do not exceed 20 cfs (TRFMTC 2000).

Both unconfined and confined aquifers provide groundwater to the Lower Tualatin watershed. For the most part, the area lacks large aquifers, although some groundwater units are locally important for municipal and irrigation purposes. The most productive wells occur in the Columbia River Basalt (Orr et al. 1992, Hart 1965). Additionally, locally perched water tables occur on clay lenses in the watershed.

1.1.1.7 Stream Channel

Stream channels vary with topography within the watershed. Reaches in the foothills are moderately steep. Typical gradients within these reaches range from 2-12%. Gradients exceeding 16% occur over short reaches of headwater streams. These high gradient streams have a substantial capacity to carry sediments, with erosion and sediment transport being dominant fluvial processes. Under high flow conditions, the larger sediment fractions are deposited. These reaches tend to have a rocky substrate, ranging from gravel to bedrock. However, these coarse sediments are frequently embedded in finer material, such as silts and clays, which are delivered from surrounding banks and hillsides. As gradient decreases, the streams are less able to carry sediments, and finer sediments are deposited on the alluvial plain. Thus, most streams in the Tualatin Plain have substrates dominated by fine sand, silt, and clay.

1.1.1.8 Water Quality

Recently, increased attention has been focused on water quality in the Tualatin River watershed. Legislation, both at the state and federal level has mandated improvements in water quality. For example, the federal Clean Water Act requires implementation of Total Maximum Daily Load (TMDL) standards for parameters limiting water quality. In 1987, TMDL standards were implemented in the Tualatin subbasin for ammonia nitrogen and phosphorus. In 2000, the Oregon Department of Environmental Quality (ODEQ) proposed revisions to these TMDLs. Additionally, ODEQ proposed TMDLs for temperature, dissolved oxygen, and bacteria. These proposed TMDLs and revisions are currently undergoing review by EPA.

In order to meet the requirements of the Clean Water Act, legislation has been passed affecting all types of land use. Within the agricultural sector, for example, the Tualatin River Subbasin Agricultural Water Quality Management Area Plan (Senate Bill 1010) prohibits certain conditions leading to diminished water quality (OAR 603-095). Implementation of environmental legislation has required monitoring of water quality. Monitoring by the ODEQ, Clean Water Services (CWS), and several other public agencies and private organizations has been conducted at many locations within the watershed.

---

[5] The Tualatin project stores water at Henry Hagg Lake. The Trask project diverts water from the Trask River drainage to the Tualatin River subbasin.

In response to the requirements of the Federal Clean Water Act, the state of Oregon produced the 303(d) list, which identifies streams with water quality limitations potentially impacting beneficial uses[6](ODEQ 1998). Nine streams in the Lower Tualatin watershed are on the 1998 ODEQ 303(d) list. For details on these streams, see Section 3.1.4.4.

1.1.1.9 Soils

The soils of the Lower Tualatin watershed are largely influenced by their parent material. In the mountains and foothills, most soils are silty loams from aeolian (wind-deposited) material. In the Portland Hills, the dominant soils belong to the Cascade-Cornelius association, which indicates soils formed in silty loess and mixed alluvium. Soils in the Chehalem Mountains typically belong to the Laurelwood association, which includes soils built on aeolian silts overlying Columbia River basalt (NRCS 1982).

Soils in the Tualatin Plain typically consist of fine alluvium in the silt and clay classes. On terraces and uplands, these soils typically belong to the Woodburn-Quatama-Willamette association, which forms on silty alluvium and clay material. The bottomland soils along the Tualatin River fall into two main associations: Upstream of Chicken Creek, most soils along the Tualatin River belong to the relatively well-drained McBee-Chehalis association. Downstream of Chicken Creek, this type gives way to the poorly drained Wapato-Verboort-Cove association.

Some soils in the Tualatin Plain are rich in phosphorus. In some cases, high phosphorus levels may indicate accumulation over many years from agricultural use. However, groundwater phosphorus levels in this region are naturally quite high, thus contributing to high soil phosphorus levels (TAC 1997).

1.2 Biological

1.2.1 Vegetation characteristics

The vegetation throughout the watershed is highly fragmented, resulting in a mélange of forested, agricultural, and urban landscapes. The largest contiguous tracts of forest vegetation are found in foothill and riparian settings, most notably on Parrett Mountain. Upland stands typically consist of mixed coniferous and deciduous species. Douglas-fir (*Pseudotsuga menziesii*) is typically the dominant conifer in these forests. Associated conifers include western redcedar (*Thuja plicata*). Hardwood stands dominated by red alder (*Alnus rubra*) are common in riparian areas. Red alder is also common on disturbed sites. Bigleaf maple (*Acer macrophyllum*) is typically abundant on canyon walls, and often occurs as a stand component in upland Douglas-fir forests and drier portions of riparian forests. Oregon white oak (*Quercus garryana*) is common in drier locations. The Tualatin Plain is primarily used for agriculture or are urbanized. Agricultural vegetation varies depending on drainage. Better-drained sites can sustain orchards, while the periodically inundated bottomlands are typically in row crops or pasture. Occasional patches of Douglas-fir, ponderosa pine (*Pinus ponderosa*) and Oregon white oak, along with grasslands, are interspersed with the agricultural areas. A diverse mix of native and exotic species characterizes vegetation within urbanized portions of the watershed.

---

[6] Most of these determinations, along with the cited figures, were based on data gathered prior to 1996.

Riparian zones in the lower reaches of the Lower Tualatin system are often dominated by Oregon ash (*Fraxinus latifolia*), black poplar (*Populus balsamifera ssp. trichocarpa*), willows (*Salix* spp.) and bigleaf maple. Where riparian tree species do not provide an overstory, the streambanks are often dominated by shrubs such as the native red-osier dogwood (*Cornus sericea*) and the introduced invasive Himalayan blackberry (*Rubus discolor*). Within urbanized portions of the watershed, other exotic species increasingly become part of the riparian landscape.

The expansion of exotic plant species within the Willamette Valley has largely come at the expense of native prairie plant communities. This has caused several plant species to be listed on federal and state lists of endangered and sensitive species. Those species considered to potentially exist in the Lower Tualatin watershed include the following:

Bradshaw's lomatium	*Lomatium bradshawii*
Golden paintbrush	*Castilleja levisecta*
Kincaid's Lupine	*Lupinus sulphureus* ssp. *kincaidii*
Nelson's checkermallow	*Sidalcea nelsoniana*
Water howellia	*Howellia aquatilis*
Willamette daisy	*Erigeron decumbens* v. *decumbens*
Curtus aster	*Aster curtus*
Howell's montia	*Montia howellii*
Peacock Larkspur	*Delphinium pavonaceum*
White rock larkspur	*Delphinium leucophaeum*

Weed species present problems in many parts of the watershed, particularly in disturbed areas. Prominent invasives include Himalayan blackberry, which is nearly universal along waysides and disturbed portions of streambanks. Reed canarygrass (*Phalaris arundinacea*) is also abundant in moist, disturbed areas in the watershed. Other wed species include Scotch broom (*Cytisus scoparius*), purple loosestrife (*Lythrum salicaria*) and thistles (*Cirsium sp*).

1.2.2 Species and Habitat

1.2.2.1 Wildlife species

1.2.2.1.1 Aquatic species

Several native salmonid species inhabit the watershed, including steelhead trout (*Oncorhynchus mykiss*) and cutthroat trout (*O. clarki clarki*). Although coho salmon (*O. kisutch*) is not native, they have been introduced and now spawn naturally within the watershed.

Salmonid habitat in the Lower Tualatin watershed is more limited than is the case for upstream watersheds. Winter steelhead trout are considered by ODFW to spawn and rear in Fanno and Chicken creeks (ODFW 1999). Additionally, these fish use the Tualatin River for migration. Resident cutthroat trout also utilize these streams, and additionally are distributed in Rock and Cedar creeks in the southern part of the watershed.

Abundance of salmonid species is a matter of concern. Steelhead trout within the Upper Willamette River Evolutionarily Significant Unit (ESU), which includes the Tualatin Basin, have been listed as threatened under the federal Endangered Species Act (ESA). In 1999, the National Marine Fisheries Service (NMFS) determined that coastal cutthroat trout within the Upper Willamette River ESU were not warranted for listing under the ESA. The United States Fish and Wildlife Service (USFWS), which now has authority for cutthroat trout, is currently reviewing their status. These species are also on the ODFW sensitive species lists.

Many native non-salmonid species are present in streams within the watershed, including sculpin, lamprey, dace, coarsescale sucker, threespine stickleback, northern pikeminnow, and redside shiner (SRI 1990, CWS 2000). Additionally, the mainstem Tualatin River and several tributaries provide habitat for non-native warm water species, including mosquitofish, largemouth bass, bluegill, and bullhead.

1.2.2.1.2 Economically important and ecologically sensitive terrestrial species

Forests, fields, and riparian areas within the watershed potentially provide habitat for diverse animal species. Some of these species attract extra attention due to biological, recreational, or economic factors. These include game species, such as blacktail deer, which are important for recreational hunting. Additionally, the wetlands within the watershed provide abundant habitat for waterfowl, such as Canada geese.

Special status species include federally listed species and those species listed by the Oregon Natural Heritage Program (ONHP). The ONHP lists species that are of concern because of diminished population or habitat. Those ONHP-listed wildlife species potentially found in the Lower Tualatin watershed are displayed in Table 1-3.

1.2.2.2 Habitat

1.2.2.2.1 Aquatic Habitat

The suitability of aquatic habitat for sensitive cold water species is quite limited. High temperatures limit the ability of most stream reaches to provide suitable summer rearing habitat for salmonids. Habitat diversity is also limited in many reaches.

Riparian degradation has contributed to a declining quality of aquatic habitats in the valleys. Loss of large trees has resulted in a reduced supply of large woody debris to streams, thus causing a loss in habitat diversity. Consequently, the stream's ability to form pools has been diminished, resulting in a reduction of the number and size of pools. Additionally, reductions in riparian canopy have led to increased summer water temperatures. The weedy shrub species, such as Himalayan blackberry, that have replaced the native riparian forest canopy in many sites are unable to provide adequate stream shading.

In many foothill and headwater reaches, salmonid habitat is also impaired. This is particularly true of urban streams. Although some of these streams have cobble-gravel substrates, these gravels are often embedded in fine sand and silt, decreasing or eliminating successful salmonid spawning. The riparian

Table 1-3. List of Oregon Natural Heritage Program listed species that may be found within the Lower Tualatin watershed.

		Federal	ODFW	ONHP
Fungi				
Scientific Name	Common name	status	status	schedule
Amanita novinupta	fungus	…	…	3
Vascular plants				
Scientific Name	Common name	status	status	schedule
*Cimicifuga elata**	tall bugbane	SC	C	1
*Delphinium leucophaeum**	white rock larkspur	SC	LE	1
Erigeron decumbens var. decumbens	Willamette daisy	PE	LE	1
Horkelia congesta ssp. congesta	shaggy horkelia	SC	C	1
Lupinus sulphureus ssp. kincaidii	Kincaid's lupine	PT	LT	1
Montia diffusa	branching montia	…	…	4
Sidalcea campestris	meadow sidalcea	…	C	4
Sidalcea nelsoniana	Nelson's sidalcea	LT	LT	1
Insects		Federal	ODFW	ONHP
Scientific Name	Common name	status	status	schedule
Acupalpus punctulatus	marsh ground beetle	…	…	3
Fish		Federal	ODFW	ONHP
Scientific Name	Common name	status	status	schedule
Lampetra tridentata	Pacific lamprey	SC	SV	3
Oncorhynchus clarki clarki	coastal cutthroat trout		SV	3
Oncorhynchus kisutch	coho salmon	C	SC	1
*Oncorhynchus mykiss**	steelhead trout	FT	SV?	1
Amphibians		Federal	ODFW	ONHP
Scientific Name	Common name	status	status	schedule
Bufo boreas	western toad	…	SV	3
*Rana aurora aurora**	northern red-legged frog	SC	SV	3
Rana pretiosa	Oregon spotted frog	C	SC	1
Reptiles		Federal	ODFW	ONHP
Scientific Name	Common name	status	status	schedule
Chrysemys picta	painted turtle	…	SC	2
*Clemmys marmorata marmorata**	Northwest pond turtle	SC	SC	2
Contia tenuis	sharptail snake	…	SV	4
Birds		Federal	ODFW	ONHP
Scientific Name	Common name	status	status	schedule
Branta canadensis leucopareia	Aleutian Canada goose (wintering)	LT	LE	1
Branta canadensis occidentalis	dusky Canada goose (wintering)	…	…	4
Chordeiles minor	common nighthawk (SC in WV)	…	SC	4
Contopus cooperi	olive-sided flycatcher	SC	SV	3
Empidonax traillii brewsteri	little willow flycatcher	SC	SV	3
Eremophila alpestris strigata	streaked horned lark	…	SC	3
*Haliaeetus leucocephalus**	bald eagle	LT	LT	1
Icteria virens	yellow-breasted chat (SC in WV)	…	SC	4
Melanerpes foricivorous	acorn woodpecker	…	…	3
Pooecetes gramineus affinis	Oregon vesper sparrow	…	SC	3
Progne subis	purple martin	…	SC	3
Sialia mexicana	western bluebird	…	SV	4
Sturnella neglecta	western meadowlark	…	SC	4
Mammals		Federal	ODFW	ONHP
Scientific Name	Common name	status	status	schedule
Arborimus albipes	white-footed vole	SC	SV	3
*Corynorhinus townsendii townsendii**	Pacific western big-eared bat	SC	SC	2
Lasionycteris noctivagans	silver-haired bat	…	SU	3
Myotis evotis	long-eared bat	SC	SU	4
Myotis thysanodes	fringed bat	SC	SV	3
Myotis volans	long-legged bat	SC	SU	3
Sciurus griseus	western gray squirrel	…	SU	3

*Confirmed by ONHP to be (or to have been) present within the Lower Tualatin Watershed.

canopy is impaired in many of these reaches, and high summer water temperatures are a major concern here, as well as in valley reaches.

1.2.2.2.2 Wildlife Habitat (terrestrial)

Wildlife habitat has changed along with changes in the vegetation of the basin. Urbanization in the eastern portion of the watershed and agriculture to the west have reduced the total amount of natural vegetation. The remaining natural vegetation in the Lower Tualatin watershed is predominantly in early and mid-successional seral stages, and structurally quite fragmented. The patchiness of the current landscape is favorable to production of species that prefer "edge" habitat and those that are tolerant of human activity.

The amount and quality of riparian habitat has declined in many parts of the watershed. The ability of riparian stands to provide large woody debris has been reduced, resulting in a reduction of the amount of down wood and snags within the riparian zones. Many of the large trees that formerly surrounded streams have been cleared, resulting in reduced canopy and increased summer temperatures. This has negatively altered the habitat types available to species, especially those that benefit from cool, humid sites, such as amphibians.

1.2.2.2.3 Special Habitats

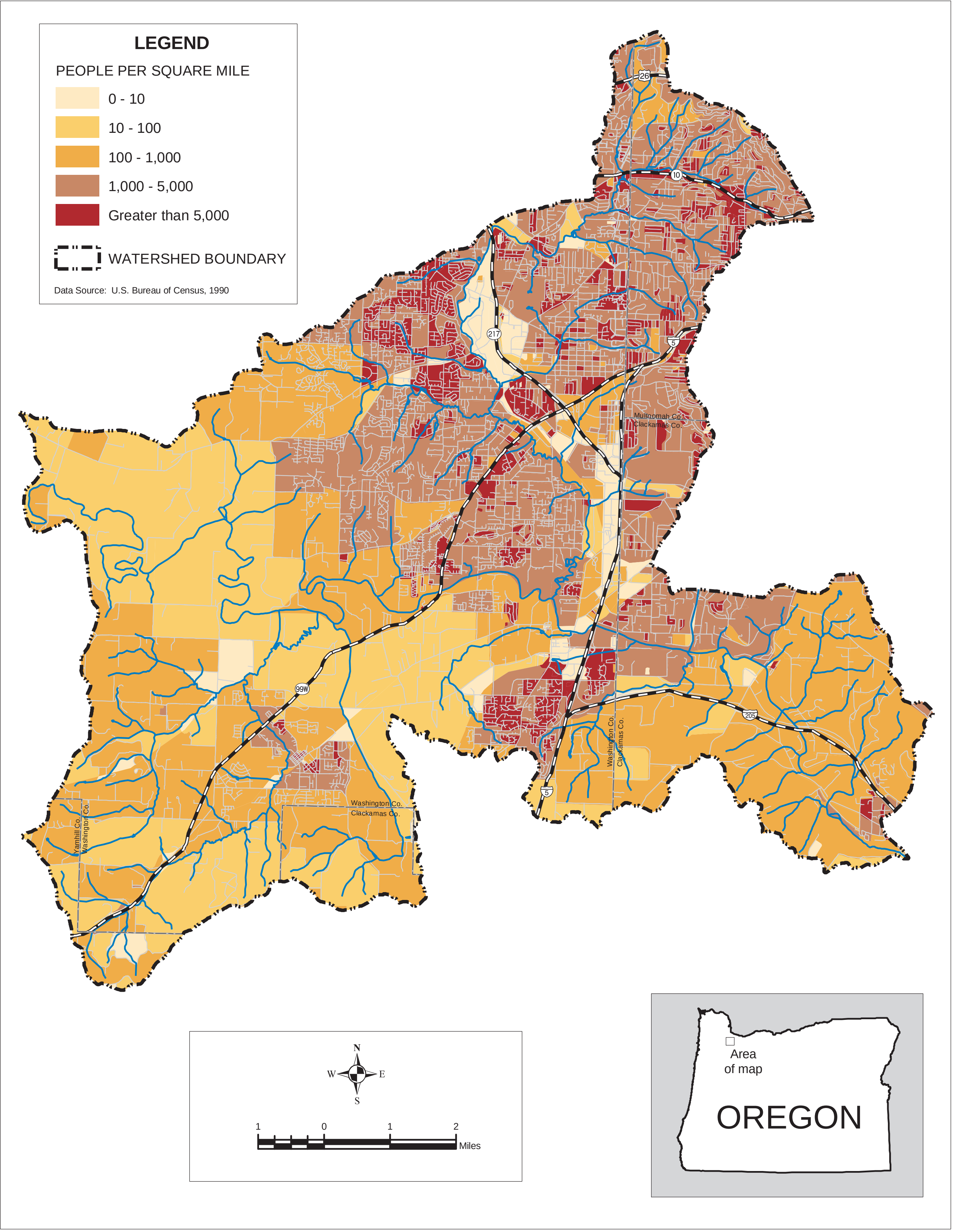
Certain habitat types in the watershed have special significance through their rarity in Oregon and their importance to sensitive species. One such habitat type is forest with late-successional characteristics. This habitat type is especially rare in the Lower Tualatin watershed.

Wetlands represent a far more abundant habitat type in the watershed. In the hills, wetland types include small ponds built by beavers or through landslide processes. Additionally, numerous impoundments exist that potentially provide wetland values. Large wetland areas are present in the Tualatin Plain. Often, these wetlands are in poorly drained bottomlands adjacent to the Tualatin River. A large tract of these bottomland wetlands is maintained as the Tualatin River National Wildlife Refuge. Wetlands are also common in tributary floodplains. Although these wetland areas have been heavily impacted by human use, they have the potential to provide important habitat for a number of aquatic, amphibian, and avian species.

1.3 Social

1.3.1 Population

Population within the Lower Tualatin watershed is concentrated in the urbanized northeastern portion of the watershed (Map 1-5). Incorporated cities wholly or partially within the watershed (with estimated 2000 population) include Portland (513,325), Beaverton (70,230), Tigard (38,835), Lake Oswego (35,305), Tualatin (25,535). West Linn (23,380), Sherwood (10,815), King City (2,125), and Rivergrove (310). The growth of the Portland metropolitan area and increasing employment in high technology has contributed to rapid population growth within the watershed. To accommodate this growth in an orderly fashion, an urban growth boundary (UGB) has been designated. If the present urban growth boundary remains constant, most future development will take place as infill in currently urbanized areas.



Map 1-5 -- Population Density (1990) of the Lower Tualatin Watershed.

Although urban development is restricted outside of the UGB, extensive rural residential development has taken place. Most of this development has been located east of I-5, although rural residential land uses are also common in the Chehalem Mountains. Although rural residential activities occur at population densities lower than those in urban areas, there are a number of pressures that this type of growth places upon resources.

1.3.2 Ownership

Land in the Lower Tualatin watershed is almost entirely privately owned. More than ninety percent of the watershed is in private ownership. Most public lands lie within the Urban Growth Boundary (UGB). This includes approximately 3,200 acres of parklands and schools (Map 1-6). Management of these lands is distributed across many municipalities, agencies, and school districts.

Approximately 1,300 acres of public land lie outside the UGB. Of this total, the United States Fish and Wildlife Service (USFWS) manages approximately 650 acres of bottomland as the Tualatin River National Wildlife Refuge. These lands are distributed in several parcels adjacent to the Tualatin River, Chicken Creek, and Rock Creek.

1.3.3 Land Use Allocations

1.3.3.1 Zoning

Much of the Lower Tualatin watershed is in an urban region of Washington County. In order to restrict urban sprawl and to preserve historical land uses, the Washington County Comprehensive Plan was created. This plan divides the watershed into zones of forestry, agricultural, and urban uses. Under the plan, urban use will be restricted to the UGB, which is largely in the eastern portion of the watershed. Agriculture will continue to dominate the western portion of the watershed, while the portion of the watershed east of I-5 will largely remain rural residential. The Chehalem Mountains and Parrett Mountain will be divided between agriculture and rural residential uses.

Current zoning regulations provide for 16.2% of the watershed to remain in agricultural use, 9.2% in mixed forestry-agricultural use, and 0.42% in forestry, with 52.4% allocated for urban use and 21.6% in rural residential uses. The vast majority of forest and agricultural lands are zoned for parcels exceeding 20 acres, while rural residential lands are generally zoned for 5-10 acre parcels.

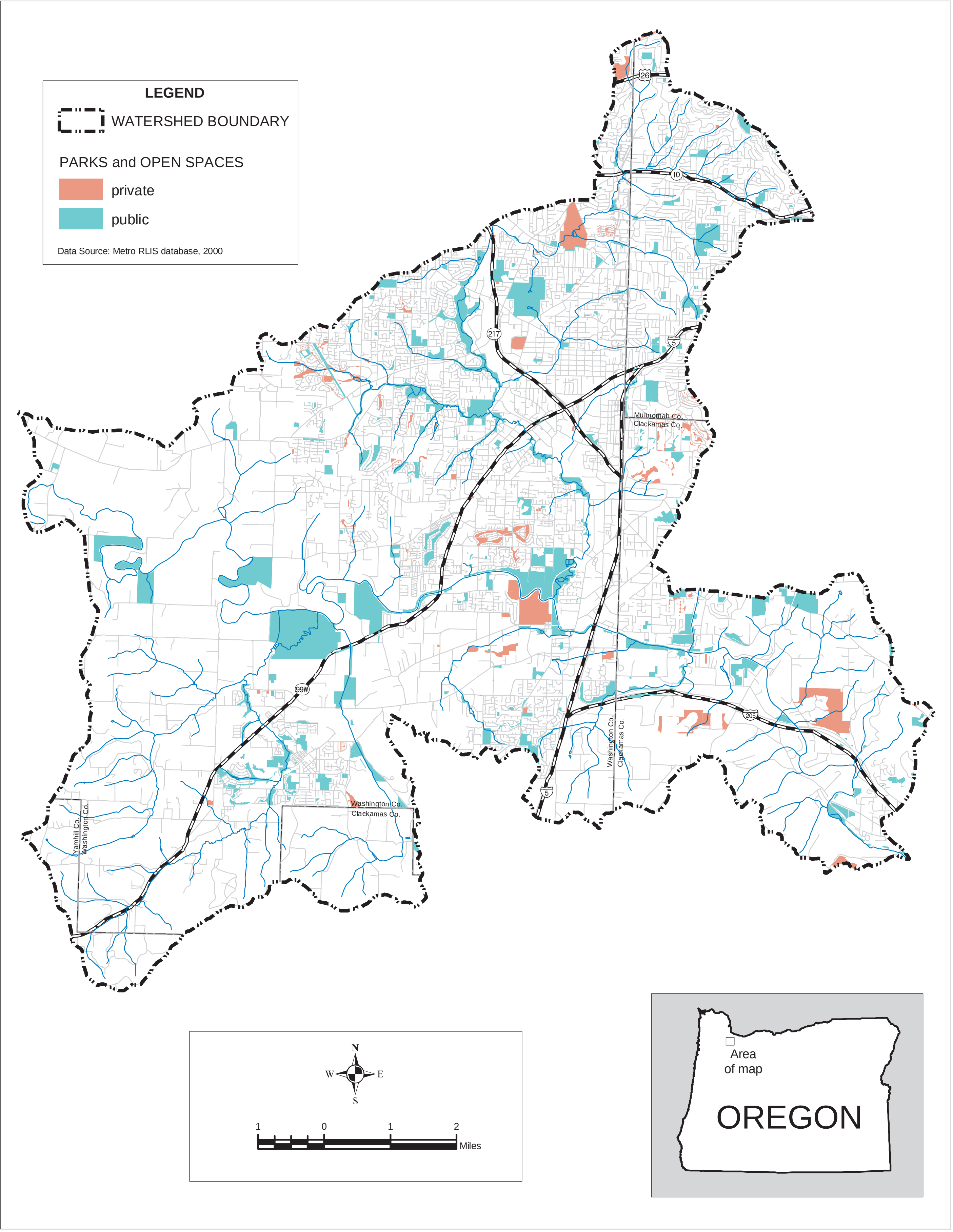
1.3.4 Human Uses

1.3.4.1 Forestry

Forestry is a minor land use within the watershed. The preponderance of forestry activities are conducted by non-industrial small woodland owners. Industrial forestland only accounts for 100 acres within the Lower Tualatin watershed.

1.3.4.2 Agriculture

Agriculture has traditionally been the predominant land use in the watershed and continues to be economically important outside the UGB, particularly in the western portion of the watershed. In



Map 1-6. Parks and Open Spaces in the Lower Tualatin Watershed.

addition to field crops and livestock, nursery crops and Christmas trees are important agricultural commodities produced within the watershed. Agricultural activities that can impact stream water quality include tillage, manure storage, fertilization, application of herbicides and pesticides, and encroachment upon the riparian zone. The USDA Natural Resources Conservation Service (NRCS) and Washington County Soil and Water Conservation District (SWCD) work with agricultural land owners to minimize effects of their operations upon streams.

1.3.4.3 Urban and rural residential

Urban lands are concentrated in the eastern two-thirds of the watershed. Additional rural residential development is taking place in the east of I-5 and in the Chehalem Mountains. As these subwatersheds develop, pressures on water and land resources increase. This gives rise to potential conflicts with aquatic life, agriculture, and other beneficial uses for these resources. Rural residential growth often brings problems in the form of enhanced erosion and inadequate septic systems. Older rural residential development often is built in floodprone areas near streams.

1.3.4.4 Recreation

The rural and urban portions of the watershed support diverse recreational opportunities. The abundant rural scenery of the southwestern portion of the watershed allows opportunities for bicycling, jogging, and touring along public thoroughfares. Opportunities for these activities elsewhere in rural portions of the watershed are limited by private property considerations. Although the Tualatin Hills National Wildlife Refuge is publicly owned, it is generally not open for public use.

A number of recreational opportunities are present within the UGB. The Tualatin Hills Park and Recreation District, Clean Water Services (CWS)[7], Metro, and individual municipalities have acquired open space and parks. This affords opportunities for hiking, birding, and education, as well as providing habitat for wildlife. At developed park sites, opportunities also exist for organized sporting activities.

---

[7] Formerly the Unified Sewerage Agency of Washington County (USA)

Chapter 2: Core Topics And Key Questions

This watershed analysis is designed to provide assistance in addressing diverse issues in the Lower Tualatin watershed. A basic understanding of pertinent physical, biological, and social processes is essential to analysis of more specific questions related to watershed issues. For this purpose, it is useful to use a format of Core Topics and Key Questions. Core Topics are general discussions of processes operating within the watershed. Key questions are specifically designed to address these identified issues of concern. As a quick reference, page numbers are provided to direct the reader to report pages that address each key question.

2.1 Aquatic

2.1.1 Erosion issues

Accelerated erosion may exist in some portions of the watershed. Related problems include decreased farm and forest productivity, accelerated sedimentation of streams, loss of habitat, loss of reservoir storage capacity, and decreased water quality. Under certain conditions, sediment delivery to streams constitutes a "prohibited condition" under SB 1010 and the Oregon Forest Practices Act.

Core topic

What erosion processes are dominant within the Lower Tualatin watershed? Where have they occurred or are they likely to occur? What is the effect of those erosion processes on beneficial uses in the watershed? *See pages: 5, 29*

Key questions

- How have human activities affected erosion processes within the watershed? *See page: 99*
- What is the distribution of prohibited conditions as defined under the Tualatin River Subbasin Agricultural Water Quality Management Area Plan? What types of prohibited conditions occur in the watershed? What can be done to improve these conditions? *See pages: 33, 109*

2.1.2 Hydrology and water quantity issues

Management activities have modified the natural flow regime in the watershed. Impacts include an altered flooding regime during high water periods, and changes in the amount of water available for human and fish use during low water periods.

Human and instream needs place a heavy demand on water resources. In some areas, water quantity may be insufficient to meet these needs.

Core topic

What are the dominant hydrologic characteristics (e.g. total discharge, peak and minimum flows) and other notable hydrologic features and processes in the watershed? *See page: 33*

Key questions

- How have human activities altered the natural hydrologic regime? What are potential effects of the altered flow regime? *See page: 102*
- Are water rights allocations sufficient to provide both for human and fisheries needs? If not, where are the deficits greatest? Where are the best sites for purchases of water rights for instream purposes? *See pages: 34, 104*

2.1.3 Stream channel issues

Stream morphology affects the way in which streams transport water and sediments, as well as the stream's ability to provide suitable habitat for aquatic life. Where the channel has been altered through human activity, the ability of the stream to perform these functions will be changed. Furthermore, restoration activities must be appropriate to the natural characteristics of the stream channel.

Core topic

What are the basic stream morphological characteristics and the general sediment transport and deposition processes in the watershed? *See page: 46*

Key questions

- How have human activities altered stream morphology? In instances where effects have been negative, what sort of restoration activities are appropriate? *See pages: 50, 104, 125*

2.1.4 Water quality issues

Streams within the Lower Tualatin watershed have experienced diminished water quality relative to reference conditions. Nine of these streams have been designated on the ODEQ 303(d) list as having characteristics limiting their ability to support aquatic life and provide recreation. Parameters of concern include low dissolved oxygen levels, high water temperatures, elevated phosphorus levels, and high bacteria counts.

Core topic

What are the beneficial uses of water in the watershed, where are these uses located, and which of these are sensitive to activities occurring in the watershed? *See pages: 50, 105*

Key questions

- What beneficial uses of water occur in this watershed? *See page: 50*
- How is water quality being impacted by human activities and what can be done to reduce these impacts? *See pages: 105, 126*
- What are probable sources of phosphorus in streams? Where do phosphorus levels exceed TMDL standards? What can be done to reduce aquatic phosphorus levels? *See pages: 58, 106, 127*
- What are the factors causing 303(d) listed streams to exceed water quality criteria? What can be done to improve water quality on these streams? *See pages: 109, 126*
- At which locations are stream temperatures above desirable levels for salmonid production? What measures can be taken to reduce water temperatures? *See pages: 58, 127*
- What is the effect of current water quality upon non-salmonid species? *See page: 110*
- Where are recreational activities limited by current water quality? What can be done to restore the ability of streams to support recreation? *See page: 109*

2.1.5 Aquatic species and habitat issues

Salmonid species are an important component of streams within this watershed. These species are sensitive to changes in aquatic habitat. Upper Willamette steelhead trout are listed as threatened under the Endangered Species Act. Additionally, coastal cutthroat trout are an Oregon state sensitive species and are currently being reviewed by USFWS for potential listing under the federal Endangered Species Act.

Many species such as frogs, turtles, salamanders and newts are dependent on wetland/marsh and pond areas. It is recognized in the scientific community that frogs are declining worldwide at an unprecedented rate.

Core topic.

What is the relative abundance and distribution of sensitive aquatic and amphibian species in the watershed? *See pages: 60, 67*

What is the distribution and character of their habitats? *See pages: 65, 67*

Key questions related to fisheries.

- What factors are impacting habitat quality, quantity, and diversity for fish species of interest? What management actions can be taken to improve habitat conditions for these species? *See pages: 65, 67*
- Where are barriers to fish passage located? Of the barriers created through human activity, which would be feasible to alter or remove? *See pages: 66*

Key questions related to amphibian species and wetland habitats.

- Where are marsh/wetland areas and ponds in the watershed? *See pages: 97, 110*
- How have human activities impacted these wetland areas? *See pages: 97, 110*
- What activities could enhance or restore the historic characteristics of these wetland habitats? *See page: 130*
- What is the relative abundance and distribution of wetland-dependent species in the watershed? *See page: 112*
- What are the population trends for frogs and other species dependent upon moist and aquatic habitats? Are there any such species have been extirpated, or face imminent extirpation, within the watershed? What is the prognosis for these species? *See pages: 67, 112*

2.2 Terrestrial

2.2.1 Vegetation issues

The structure and composition of vegetation has been extensively altered from reference conditions. This has altered the type and availability of beneficial uses provided by vegetation. Additionally, these changes are likely to have favored certain animal species at the expense of others.

Noxious weeds and other non-native species have colonized many areas within the watershed. These species tend to outcompete native plants, resulting in decreased diversity. Many of these exotic species provide inferior habitat for native wildlife. Additionally, some of these species are poisonous to livestock, and otherwise interfere with agricultural, urban, and forest management.

Riparian vegetation has been extensively altered, changing the functions that these areas are able to provide for aquatic and riparian plant and animal species.

Some native plant species are in danger of eradication, are endemic, or are otherwise of special concern. These species include those listed or proposed for listing under the Endangered Species Act (ESA).

Core topics

- What is the array and landscape pattern of plant communities in the watershed? How does this compare to reference historical patterns? *See pages: 68, 88*
- What processes caused this pattern? See pages: 92, 112

Key questions

- What measures can be taken to retain habitat for terrestrial plant species, and to maintain and enhance forest health? *See page: 131*
- What control measures could be reasonably implemented to reduce the introduction and spread of exotic/noxious plants? What opportunities are available for partnerships in controlling the spread and introduction of exotic plants within the watershed? *See pages: 70, 113, 131*

2.2.2 Wildlife species and habitat issues

Some terrestrial animal species bear special concern because of diminished numbers or endemic status. Care must be taken to avoid further reduction in numbers of these species. These include species listed or proposed for listing under the Endangered Species Act (ESA).

Some species are popular as game. It is important to maintain these species at a sustainable level.

Core topic

What is the relative abundance and distribution of terrestrial species of concern that are important in the watershed? What is the distribution and character of their habitats? *See page: 72*

Key questions

- Which species are listed or proposed for listing under the Endangered Species Act? What are their relative abundance and distribution? *See pages: 72, 113*
- What are the condition, distribution and trend of habitats required by those species of concern that may occur in the watershed? *See page: 72*
- What are the current distribution and density of snags and down wood on lands within the watershed? *See page: 76*
- What are the natural and human causes of change between historical and current species distribution and habitat quality for species of concern in the watershed? *See pages: 92, 112*
- What are the influences and relationships of species and their habitats with other ecosystem processes in the watersheds? *See pages: (dispersed throughout document)*
- What factors contribute to the decline in population levels for those species that are of concern? Given the current ownership pattern, what opportunities exist to manage for these species? How does the ownership pattern affect the potential to preserve and restore quality habitat within the watersheds? *See pages: 113, 76*

2.3 Social

2.3.1 Issues related to human uses

Important economic and recreational activities take place in the watershed. These activities make demands upon watershed resources and provide potential conflicts with other watershed interests.

Dumping takes place on unoccupied lands.

Core topic

What are the major human uses and where do they occur in the watershed? What demands are changing land uses placing upon the watershed? *See pages: 17, 77, 114*

Key questions

- What are current recreational opportunities in the watershed? What demands do they place on resources? Can these demands be reduced? Are there opportunities to encourage low-demand activities? *See pages: 80, 133*

2.3.2 Road-related issues

Roads can contribute to hydrologic change, erosion, and mass wasting. Road-related ditches tend to concentrate flow, facilitating ditch erosion and transport of eroded sediments from the road. In certain cases, roads may contribute to excessive sediment delivery to streams, affecting fish habitat.

Stream crossings usually necessitate placement of culverts or bridges. Poorly placed culverts can alter channel morphology, increase stream density, and impede fish passage. Undersized culverts can wash out during flooding events. Poorly constructed bridges can negatively alter stream hydrology and cause sediment and erosion.

Hazards are not limited to currently maintained roads, but also extend to “legacy roads”. These compacted surfaces, railroad grades, and associated culverts, can impede fish passage and disrupt hydrologic and sediment regimes.

Key questions

- Where are high risk areas for slope failures due to roads? What resources are potentially at risk as a result of road failures within these areas? *See pages: 82, 116, 133*

- How many stream crossings, bridges, and culverts are in the watershed? Which of these structures impede fish passage? *See page: 81*
- What is the size and condition of existing culverts? Are they likely to withstand a 100 year flood event? *See page: 82*
- Where are rock pits and other sediment sources located? What measures should be taken to mitigate for impacts of these sites? *See page: 116*

Chapter 3: Current Conditions

3.1 Aquatic

3.1.1 Erosion processes

3.1.1.1 Overview of erosion and sedimentation processes

Although virtually the entire Lower Tualatin watershed falls within the Prairie Terraces ecoregion, dominant erosional processes vary with topography. The Chehalem Mountains, Portland Hills, Bull Mountain and Parrett Mountain fall into an erosion regime dominated by relatively steep slopes. Collectively, this area will be referred to as the foothills. The Tualatin Plain is mostly a depositional area.

In the foothills, both slumping and shallow landsliding are potentially important. These regions are typically comprised of interbedded sedimentary layers overlain by Columbia River Basalt. Thick layers of silty soils cap this basalt layer. These factors, along with steep slopes, contribute to slope instability. Landslides are especially common along the contacts between different rock types.

The fine-grained particles produced from erosion in the incised middle to upper-middle portions of the foothills are often delivered to streams. This is an especially important process in first and second-order reaches, where steep canyon walls often expedite the delivery of eroded material to the streams.

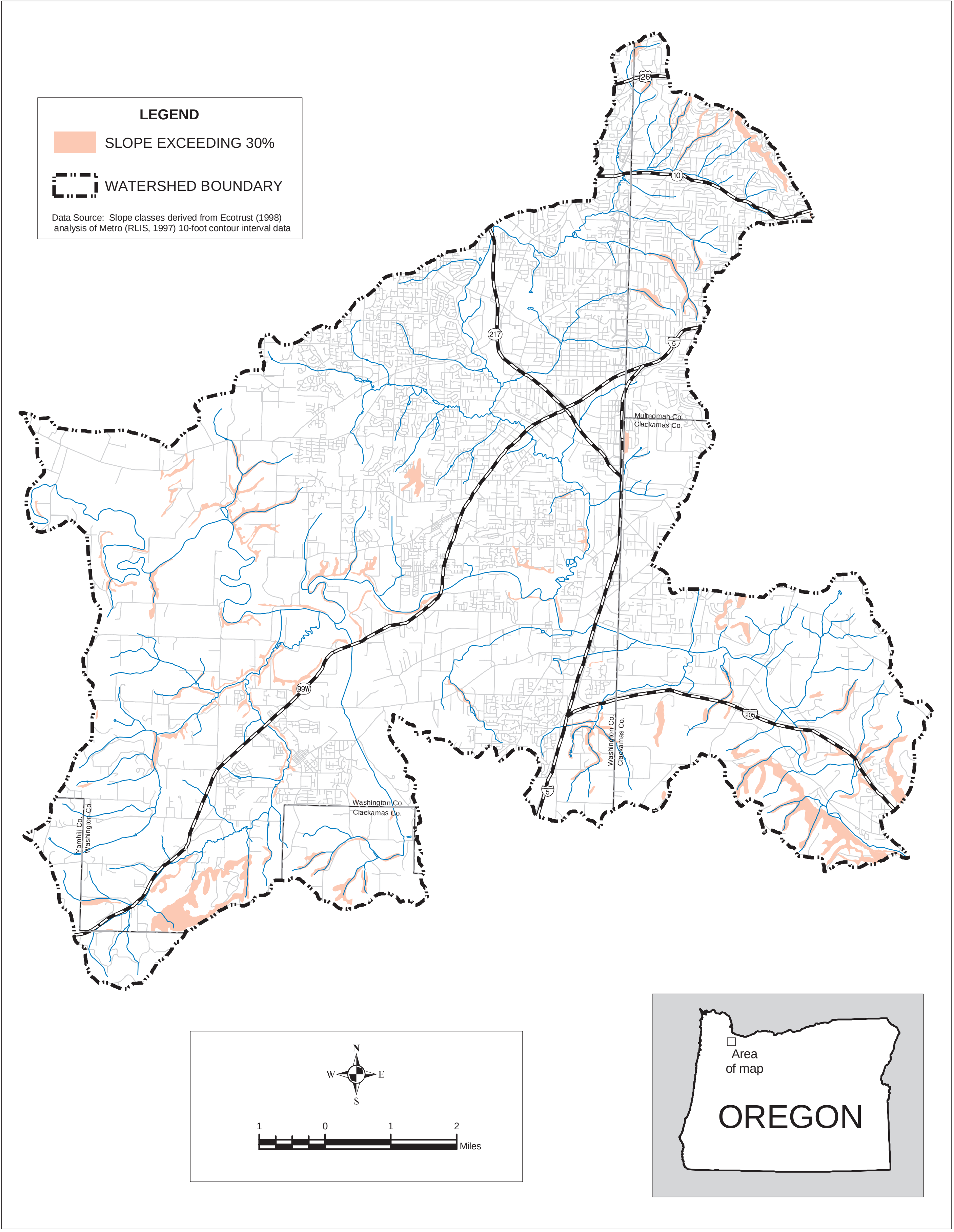
In the Tualatin Plain, slopes are generally low. Where soils are exposed to rainfall energy, they are readily detached. However, the ability to transport eroded soils to stream systems is limited by the low gradient of the valley floor. Where erosion takes place far from stream channels and roadside ditches, eroded soils are usually deposited prior to delivery to the streams. Localized erosion and delivery to streams occurs on both terraces and streambanks.

3.1.1.2 Mass wasting

Mass wasting (landsliding and related processes) provides substantial sediment inputs to the stream system. Earthflows and large rotational slumps have been identified as the most frequent mass wasting mechanism in the Portland Hills (Burns et al. 1998). There are several indicators for determining risk of mass wasting.

Slope is an important indicator of landslide susceptibility within the watershed. During an inventory of landslides associated with the 1996 storm events, Burns et al. (1998) found that 92% of slides in the Portland Metropolitan Area occurred on slopes exceeding 60% (30 degrees). Virtually all other landslides occurred on slopes exceeding 30% (15 degrees). Mass wasting potential is low where slope does not exceed 30%. (Dave Michael, ODF, Personal communication).

Topographic maps and GIS layers are often useful for performing a preliminary screening of risk of slope failure. However, it should be noted that decisions should not be made using these tools alone. Due to generalization, maps are typically insensitive to local changes in topography. GIS slope layers



Map 3-1 -- Slope Classes of the Lower Tualatin Watershed.

often share this insensitivity, and in many cases have errors in the source data. The results of this slope analysis are to be taken as general indicators of landslide susceptibility and are not to be used for site-specific assessments.

Map 3-1 shows areas in the watershed with slope exceeding 30%. Steep slopes are relatively uncommon within the Lower Tualatin Watershed. Slopes exceeding 30% comprise 2,500 acres, or four percent of watershed area. About 1/5 of this total, or 500 acres, are comprised of slopes exceeding 45%. Slopes exceeding 60% are virtually nonexistent at the scale of the source map. (However, it should be noted that steep slopes occur at a finer scale than that expressed on the map, particularly where human activities have altered slope characteristics.) The steepest slopes are found along canyon walls adjacent to streams, particularly in the Tualatin Mouth, Cedar Creek, Lower Tualatin-Scholls, Upper Fanno Creek, and Chicken Creek subwatersheds.

Lithology plays an important role in determining mass wasting susceptibility. Burns et al. (1998) found that the Portland Hills Silt was extremely susceptible to landslides. This geologic unit, which caps the upper portion of the Tualatin Mountains, quickly loses strength when saturated (Burns et al. 1998). Although the landslide inventory did not extend to the Chehalem Mountains, it should be noted that a similar silt loess unit caps this area, as well.

In conjunction with Metro, the Portland State University (PSU) Geology Department identified several areas within the watershed as having an enhanced landslide hazard. These landslide hazard maps can be accessed at the Metro website (www.metro-region.org). Subwatersheds with areas of enhanced landslide hazard include Upper Fanno Creek, which includes most of the headwater streams contributing to Fanno Creek. High hazard was also identified in the lower Tualatin watershed. The hazard was highest in canyons adjacent to streams. Moderate landslide hazard was also identified along stream gorges on Cooper Mountain and Bull Mountain. Although the PSU effort did not extend to the Chehalem Mountains and Parrett Mountain, slope and geology suggest that similarly enhanced landslide hazard exists in this area, as well.

Urban and rural residential development is proceeding rapidly in the Portland Hills and Bull Mountain. These construction projects can potentially contribute to slope destabilization in these naturally unstable regions. Steep cutslopes reduce the strength of the hillslope, while poorly consolidated fills are weak and place an additional burden on the slopes below. Burns et al. (1998) identified human activities as contributing to 76% of landslides inventoried in the Portland Metropolitan area. Cutbanks for roads and driveways were most commonly implicated. Fills and poor runoff management were also identified as contributing factors.

Roads near streams and at stream crossings can provide a ready sediment delivery mechanism to streams. Analysis of roads within the watershed found that 13.5 miles of road occurred on slopes exceeding 30%. Most of these roads were located in the Upper Fanno Creek and Tualatin Mouth subwatersheds (Table 3-1). Of these roads on steep lands, 5.2 miles lay within 200 feet of streams. These road segments would have the highest potential for contributing sediment to streams.

Table 3-1. Subwatersheds with a high incidence of roads on steep slopes and/or rural roads near streams.

Subwatershed	Area (Acres)		Road Length (Feet)		
	Total	Slopes >30%	Slopes >30%	Near Streams	Slopes >30% and Near Streams
Ash Creek	2,812	31	2,436	44,113	1,236
Cedar Creek	5,797	445	6,118	41,880	1,182
Chicken Creek	4,958	176	2,973	26,578	1,305
Fanno Creek	5,392	32	1,691	59,612	335
Hedges Creek	2,466	18	1,816	16,693	1,816
LT-King City	4,103	146	2,407	50,545	814
LT-Oswego Canal	2,490	45	2,917	15,332	0
LT-Scholls	7,770	326	5,745	7,678	1563
S. Rock Creek	4,266	116	2,453	11,978	1,702
Saum Creek	2,946	142	2,373	21,806	1,671
Summer Creek	3,911	53	2,962	50,058	519
Tualatin Mouth	7,021	727	18,459	42,772	8,248
Upper Fanno	8,351	281	19,156	128,937	7,019

3.1.1.3 Surface and streambank erosion

Stream incision and associated streambank erosion are well documented in urban portions of the watershed. Kurahashi and Associates (1997) attributed somewhat more than half of the sediment "transported through the Fanno Creek system" to be the result of in-channel erosion. In a study of those portions of the Fanno Creek system within Multnomah County, Brown and Caldwell (1998) found unstable and eroding streambanks adjacent to "most of Fanno Creek, along many surveyed areas of Vermont Creek, and in isolated areas of Woods Creek". These conditions were attributed to stream incision, which itself was the result of increased surface runoff and decreased floodplain storage. Erosion on these banks was found to be most influenced by 1) oversteepened bank angles caused by incision, 2) diminished bank surface protection by vegetation, and 3) low root densities within the banks.

Streambank erosion also occurs in agricultural portions of the watershed, particularly along higher order streams that are not confined by valley walls. Although streambank erosion occurs under natural conditions, the magnitude of erosion has been increased due to altered hydrology, channelization and destruction of riparian vegetation by grazing livestock and other anthropogenic factors.

Both natural and human processes have created levees along the Tualatin River. During flooding events, sediment is deposited, resulting in increased elevation of streambanks. In many places, during peak flow, the stream water is higher in elevation than the surrounding floodplain. These streams often overtop the bank and flow into the floodplain. Where this occurs, the hydraulic energy of the floodwaters erodes the streambank and portions of the nearby floodplain. In an effort to combat this erosion, landowners and public works agencies repair breaches in the streambank and conduct streambank protection projects using resistant materials such as riprap. Further, bridges form hard barriers containing the channel at stream crossings. The result is that a system of artificial, resistant, levees has developed along many stream reaches.

Sheet, rill, and gully erosion, however, probably pose more important threats to water quality and long-term agricultural productivity than does streambank erosion. While streambank erosion occurs throughout the soil profile, the topsoil layers eroded through sheet, rill, and gully processes are the most likely to be enriched with nutrients and pollutants. Also, topsoil losses due to sheet, rill, and gully erosion represent a more significant resource loss to agriculture than does soil loss from streambank erosion.

Soils classified as "Highly Erodible Land" (HEL) by NRCS have steep slopes and are mostly located on foothill slopes. Rolling lands in valley landscapes, however, are also prone to sheet, rill, and gully erosion. HEL is distributed throughout hilly portions of the watershed. (It should be noted, however, that HEL data were not available for Multnomah County, which comprises approximately 9% of the watershed.) More than 63% of the Tualatin Mouth subwatershed is classified as HEL, while over half the land in the Chicken and Cedar Creek subwatersheds also is classified as HEL. These streams, and their associated aquatic resources, such as winter steelhead, are especially sensitive to land use practices.

3.1.1.4 Prohibited conditions

Under the Tualatin River Subbasin Agricultural Water Quality Management Area Plan, certain conditions potentially resulting from landowner management activities were specifically prohibited (OAR 603-095). Such prohibited conditions include excessive sheet and rill erosion, excessive gully erosion, lack of ground cover in riparian areas, summer discharge of irrigation water to streams, and placement of wastes where they would be likely to enter streams. An effort is currently underway to evaluate the existence and extent of these prohibited conditions. (Also see section 5.1.4.6.) These survey efforts, however, have not been systematically performed within the Lower Tualatin watershed. Spot checks and complaint investigations have identified prohibited conditions related to waste management, erosion, and unvegetated streambanks. The Washington County SWCD and NRCS are working with landowners to address these conditions.

Landowners have the option of developing a Voluntary Water Quality Farm Plan in conjunction with the SWCD, delineating an approach to protect water quality on their land. If such a plan is not adopted and a prohibited condition occurs, the Oregon Department of Agriculture (ODA) can take enforcement actions.

3.1.2 Hydrology and water quantity

3.1.2.1 Hydrologic characteristics

The precipitation regime of the Lower Tualatin watershed is rainfall dominated. Snowfall is not a major source of precipitation. Precipitation is seasonal, with most rain falling between November and March (Figure 1-1). Precipitation intensities in this watershed are light related to those prevailing in western (Coast Range) portions of the Tualatin subbasin. The 2-year, 24-hour precipitation event in the watershed ranges from 2.3 to 2.5 inches. Precipitation intensity is highest in the Portland Hills and in the Tualatin Mouth subwatershed (OCS 1997).

Due to the lack of storage as snow and groundwater, discharge is seasonal and largely follows the precipitation cycle. Flows are very high in winter and fall to very low levels between July and October.

In the Lower Tualatin watershed, the gage on the Tualatin River at West Linn (RM 1.75) provides the only long-term discharge records. This gage has been operated continuously by the United States Geologic Survey since Water Year (WY) 1929. Other gages, with shorter periods of record, are maintained by the Oregon Water Resources Department (OWRD) and provide continuous and seasonal monitoring (Table 3-2).

Table 3-2. Stream flow gages in the Lower Tualatin watershed.

Stream	RM	Location
Tualatin River	1.8	West Linn
	6.7	Oswego Canal
	8.9	Tualatin
	16.2	Farmington
Fanno Creek	1.2	Durham Road
	2.1	Bonita Street
	7.3	Tuckerwood Rd
	9.4	Scholls Ferry Rd
	12.6	SW 56th Ave
Ash Creek		Greenburg Rd
Summer Creek		Fowler School
Hedges Creek		Near Tualatin

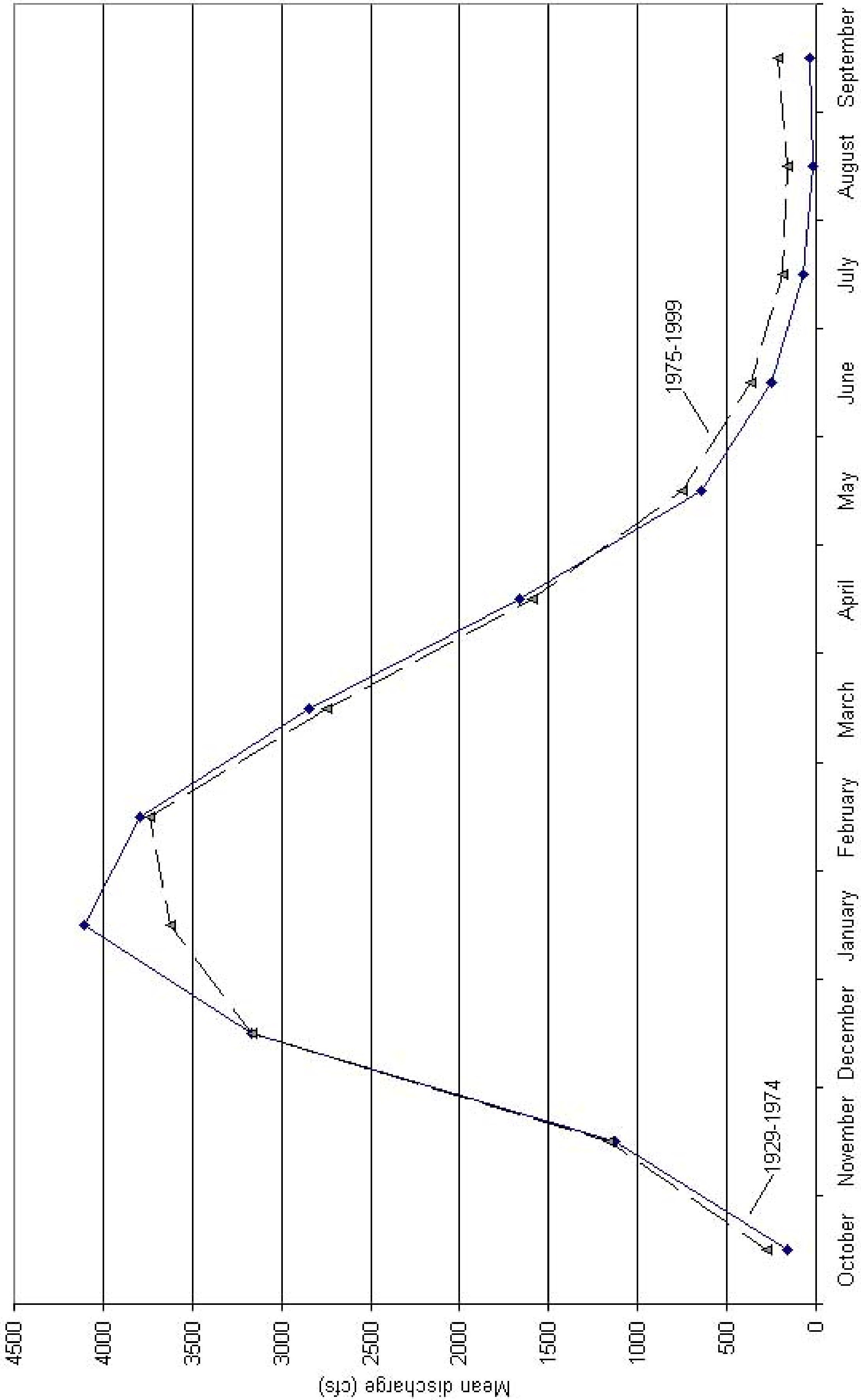
Figure 3-1 shows average flow characteristics of the Tualatin River at the West Linn gage site between the 1929 and 1974 water years, the period prior to flow regulation by Scoggins Dam. During this period, 84% of discharge passing the West Linn gage occurred during the November to March rainy period. Mean monthly January discharge was 4,104.1 cfs, while the mean August discharge was 21.5 cfs. The minimum recorded daily flow over this period, 0.2 cfs, occurred in August, 1966.

Figure 3-1 also displays the changes in discharge at the gage site following flow regulation. Mean annual discharge was essentially unchanged following construction of Scoggins Dam. Mean January discharge was 3,621.5 cfs, while mean August discharge was 158.6 cfs. Changes in mean monthly discharge also were relatively minor, with the exception of January and the June-September low-flow period. In January, discharge was reduced by 500 cfs. Discharge was augmented by more than 100 cfs during the June to September period. This represented an increase of 144% as compared to flow observed between 1929 and 1974.

3.1.2.2 Water quantity and water rights

Lack of summer streamflow is an important concern in the Tualatin subbasin. In summer, discharge is naturally quite low. Diversion during these natural low flow periods can create conditions where beneficial uses are not met. Additionally, natural drought cycles lead to a decreased natural pool of available water. Decreased stream volume can adversely affect water quality, with associated secondary impacts to instream life and to human uses. Water quality impacts include higher water temperature and decreased dissolved oxygen concentrations, while habitat impacts include decreased residual pool depth. Inadequate streamflow also leads to decreased availability for human uses, and can lead to aesthetically

Figure 3-1: Tualatin River at West Linn: mean monthly discharge, 1929-1974 vs 1975-1999



unpleasant water. Based on the 80% exceedance flow[8], OWRD has determined that surface water rights are overallocated in the watershed (Table 3-3). Generally speaking, the limiting basin is the Water Availability Basin (WAB)[9] comprising the Tualatin River upstream of West Linn, where OWRD has restricted new water rights allocations for direct diversion between June and November. In most cases, consumptive uses contribute substantially to the lack of available water (Table 3-4). Consumptive uses exceed one-tenth[10] of the 80% exceedance streamflow throughout the May-November period on the Tualatin River, and June through September on Fanno Creek. (The demand is greatest between July and September, when consumptive uses are greater than the 80% exceedance streamflow on the Tualatin River[11]. Although consumptive uses are a substantial portion of the 80% exceedance streamflow on Fanno Creek, they never exceed that critical streamflow criterion.

Table 3-5 shows the magnitude, by subwatershed, of permitted water rights for direct diversion from streams within the Lower Tualatin watershed. By far, the largest rate of diversion from streams occurs within the Lower Tualatin-Scholls subwatershed. Other subwatersheds with the high potential diversion include Fanno Creek, Chicken Creek, and Lower Tualatin-King City. This does not include the diversion of water transferred from Henry Hagg Lake, which accounted for an estimated 7 cfs within the watershed[12].

The largest single water right is owned by the Lake Oswego Corporation. This right, for 57.5 cfs, nearly equals the total for all other water rights combined. The Lake Oswego Corporation also has a water right of 3.36 cfs to support recreation. However, the Lake Oswego Corporation no longer diverts water in summer (Darrell Hedin, personal communication).

Irrigation accounts for much of the surface water diversion within the watershed (Table 3-6). Altogether, irrigation-related water rights add up to 55 cfs. If all of these rights were applied during low flow season, stream resources could become seriously overtaxed.

Agricultural water rights usually have a maximum cumulative annual withdrawal of 2.5 acre-feet per acre of irrigated land. However, this maximum is not typically fully utilized. In 1987, annual irrigation demand from the Washington County Water Resources Management Plan was estimated at 27,532 acre-feet distributed over 25,491 acres, or 1.08 acre-feet per acre (that is, a mean depth of 13 inches). A more recent study indicates that Tualatin Valley Irrigation District (TVID) provided 0.9 acre-feet of water for every acre that it serviced (WMG 1998).

In 1956, about 18 inches (1.5 acre-feet/acre) of irrigation water per growing season was considered necessary for optimal growth (Hart and Newcomb 1965). However, only about two-thirds of this total

---

[8] Statistically, discharge is expected to exceed the **80% exceedance streamflow** 80% of a given period (such as monthly). Calculation of exceedance streamflow is generally based upon historical data and/or modeling.

[9] OWRD subdivides stream systems into **Water availability Basins** (WABs) specifically for the purpose of determining the availability of water rights. Applications for water rights are evaluated relative to water availability within the WAB in which the prospective water right will occur.

[10] WPN (1999) suggested that subwatersheds with consumptive uses exceeding one-tenth of the 80% exceedance streamflow deserved special scrutiny from a water quantity standpoint.

[11] Here, **consumptive use** refers to total rights to divert water without replacement. Where consumptive uses exceed streamflow, this indicates a condition where streams could *potentially* go dry if all water rights were used.

[12] For this analysis, water from Henry Hagg Lake was allocated based on the number of TVID-irrigated acres in the Lower Tualatin watershed divided by the total number of TVID-irrigated acres in the Tualatin Basin. Based on this methodology, 7 cfs of water released from Henry Hagg Lake was allocated to the Lower Tualatin watershed.

Table 3-3. Water availability summary for sites in or near the Lower Tualatin watershed.

	Monthly Net Water Available (cfs) at 50% exceedance level											
Water Availability Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tualatin R. at Mouth	3,030	2,900	2,030	1,060	239	-14.5	-172	-207	-131	-17.1	227	2,670
Tualatin R. at West Linn	3,030	2,900	2,030	1,060	239	-13.9	-170	-206	-130	-16.2	227	2,670
Fanno Cr. at Mouth	103	102	70.3	42.2	17.8	7.29	2.03	0.08	0.88	2.69	22	95

	Monthly Net Water Available (cfs) at 80% exceedance level											
Water Availability Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tualatin R. at Mouth	981	1,220	977	511	48.7	-115	-229	-229	-188	-81.1	-103	665
Tualatin R. at West Linn	982	1,220	978	511	50.1	-114	-227	-228	-187	-80.2	-102	665
Fanno Cr. at Mouth	46.6	52.9	41.4	23.5	9.44	2.99	0.19	-0.44	-0.12	0.5	6.29	30

Source: OWRD WARS database.

Table 3-4. Consumptive use summary for sites in or near the Lower Tualatin watershed.*

	Consumptive Use as a Percentage of 50% Exceedance Streamflow											
Water Availability Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tualatin R. at Mouth	1.77	5.08	3.12	5.29	*18.18*	*60.25*	**148.72**	**217.91**	**135.22**	*28.53*	6.97	1.80
Tualatin R. at West Linn	1.76	5.05	3.07	5.22	*18.02*	*60.20*	**148.04**	**216.81**	**134.26**	*27.75*	6.80	1.76
Fanno Cr. at Mouth	0.37	0.37	0.51	0.76	5.83	*13.36*	*30.95*	*40.69*	*23.36*	5.64	1.29	0.39

	Consumptive Use as a Percentage of 80% Exceedance Streamflow											
Water Availability Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tualatin R. at Mouth	4.59	*10.28*	5.63	8.76	*26.67*	*91.80*	**242.10**	**288.75**	**300.49**	*63.63*	*19.53*	5.52
Tualatin R. at West Linn	4.56	*10.21*	5.54	8.64	*26.39*	*91.72*	**241.00**	**287.29**	**298.35**	*61.90*	*19.03*	5.39
Fanno Cr. at Mouth	0.79	0.70	0.84	1.29	9.55	*21.57*	*43.01*	*46.21*	*30.21*	9.37	3.51	1.16

*Months where consumptive uses exceed total streamflow are denoted in **bold**. Months where consumptive uses exceed 10% of streamflow are *italicized*.

Source: OWRD WARS database

Table 3-5. Total surface water rights by subwatershed.

Subwatershed	# of rights	diversion cfs	Hagg Lake*	Total cfs.
Ash Creek	5	0.31		0.31
Cedar Creek	17	1.11		1.11
Chicken Creek	29	5.28		5.28
Fanno Creek	30	5.43		5.43
Hedges Creek	9	1.37		1.37
LT-King City	39	4.59	0.24	4.83
LT-Oswego Canal**	7	61.63		61.63
LT-Scholls	63	33.09	6.65	39.74
S. Rock Creek	28	3.48		3.48
Saum Creek	4	0.56		0.56
Summer Creek	8	0.60		0.60
Tualatin Mouth	1	0.02		0.02
Upper Fanno Creek	33	2.98		2.98
Total	273	120.44	6.89	127.33

Source: Analysis of OWRD point-of-diversion water rights information.

Table 3-6. Total surface water rights by type of use.

USE		number of water rights	Average (cfs)	Cumulative (cfs)	% of total
AG	Agriculture	2	0.890	1.780	1.48%
AS	Aesthetic	2	0.010	0.02	0.02%
DI	Domestic	1	0.010	0.01	0.01%
DO	Domestic	4	0.750	0.30	0.25%
DS	Domestic/stock	1	0.010	0.01	0.01%
FI	Fish	5	0.278	1.36	1.13%
FP	Fire protection	4	0.020	0.08	0.07%
IC	Irrigation	1	3.400	3.40	2.82%
ID	Irrigation and Domestic	1	1.400	1.40	1.16%
IL	Irrigation and Stock	1	0.005	0.01	0.00%
IM	Industrial/Manufacturing	3	1.019	3.06	2.54%
IR	Irrigation	232	0.199	46.36	38.50%
IS	Supplemental Irrigation	6	0.254	1.52	1.26%
LV	Livestock	5	0.033	0.17	0.14%
PW	Power*	1	57.500	57.50	47.75%
RC	Recreation	3	1.130	3.39	2.81%
WI	Wildlife	2	0.035	0.07	0.06%
	Total			120.43	100.00%

*Lake Oswego corporation no longer diverts water for this water right during summer.

Source: Analysis of OWRD point-of-diversion water rights information (February 2000).

was available at the time, resulting in sub-optimal irrigation for growth. Based on current irrigation figures, it appears that actual water use per acre of land has not changed appreciably since the 1950s. However, it is likely that modern farms are deriving more productivity per acre-foot of water (D. Moberg, NRCS, personal comm.). Some additional benefit could be attained by implementing Best Management Practices designed for water conservation.

Under Oregon law, conflicts over water rights are resolved under the doctrine of prior appropriation (OWRD 1997). In effect, water rights obtained first have first priority to available water. For this purpose, each water right permit is assigned a priority date, which is usually the date of the application for the permit. Water rights with earlier dates, thus higher priority, are termed "senior water rights".

On the Tualatin River and several tributary streams, water rights have also been assigned for instream uses. These rights are granted to promote sustenance of fish and wildlife. A list of minimum instream water rights is given in Table 3-7. The largest instream water right occurs on the Tualatin River, where instream water rights range from 94.5 cfs (September) to 250 cfs (November to March) as measured at West Linn gage. The water rights during the November to May period allocate additional water for spawning and migration of salmon and steelhead trout.

Although instream water rights are designed to benefit aquatic resources, their effectiveness is limited by their relatively junior priority dates. The priority date for the most senior of the mainstem Tualatin River rights is April 15, 1970, while the instream right for Fanno Creek has a priority date of August 5, 1993. Water rights holders with priority dates earlier than this date would have priority over these instream rights. Because of the large number of senior rights on these streams, instream water rights are subject to loss of regulatory protection from OWRD. Many of the more recent water rights permits restrict withdrawals between November and March, with the purpose of ensuring adequate water remains instream for salmonids.

Through its instream leasing program, OWRD offers incentives for water rights holders to lease their rights for instream uses. This program is particularly useful for rights holders who temporarily do not expect to use their full allocation of water. The holder's water rights are protected throughout the period of the lease. Minimum lease period is two years.

3.1.2.3 Flooding

Flooding is another important concern within the watershed. Although flooding is a natural part of a stream's hydrologic regime, it potentially conflicts with extensive agricultural development within the floodplain. Flooding is largely a function of watershed topography. Poorly drained alluvial silts and clays underlie much of the Tualatin Plain. Altogether, these soils cover 11 square miles, roughly 12% of the total watershed area. Although these poorly drained soils tend to concentrate near streams, they are distributed throughout lowland portions of the watershed.

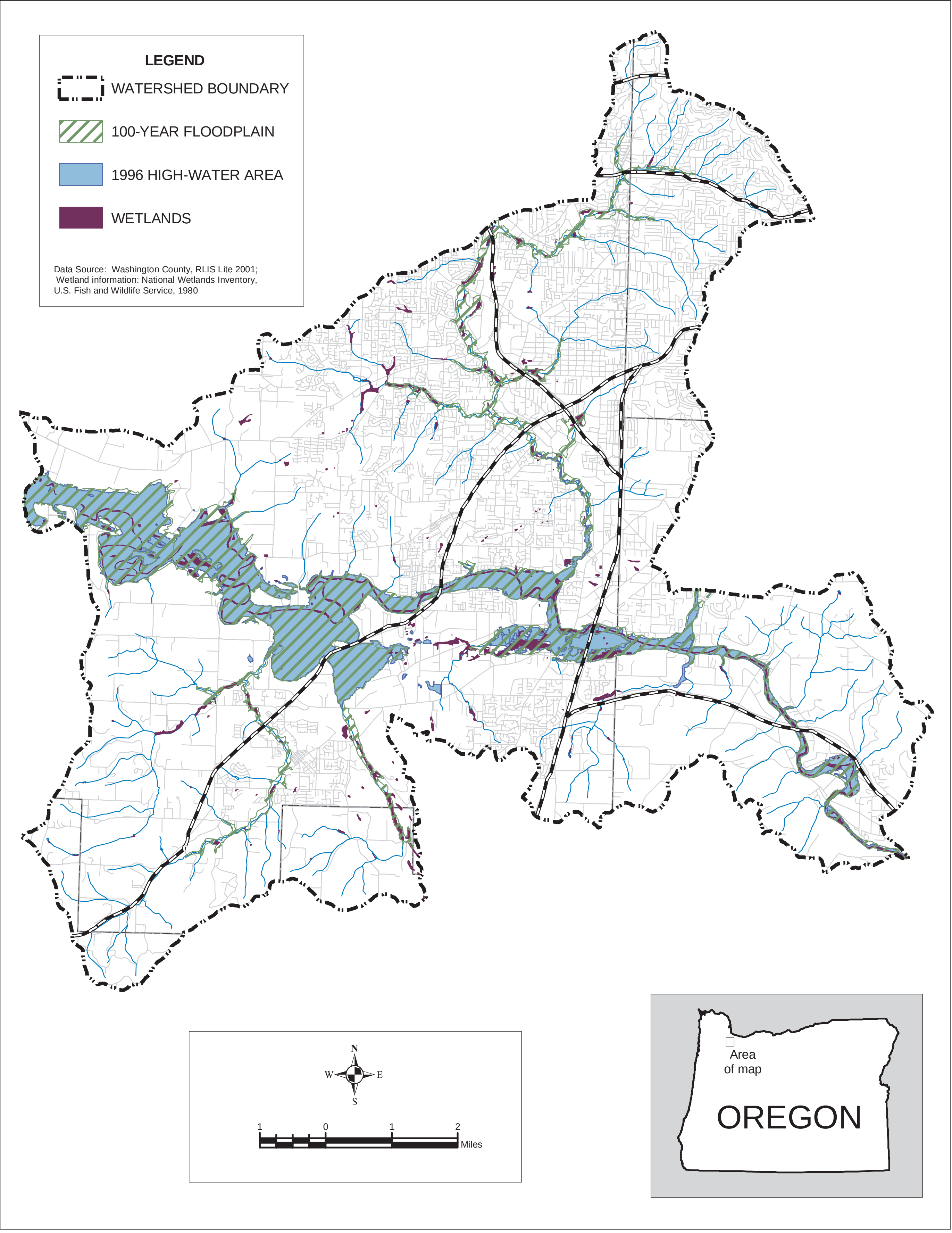
Extensive portions of the watershed lie within the 100-year floodplain (Map 3-2). In the western portion of the watershed, these lands are mostly in agricultural and rural residential uses. However, extensive urbanized portions of the eastern watershed lie within the floodplain. These areas lie along lower Cedar Creek, the Tualatin River downstream of Cipole Road, the City of Tualatin, and the Fanno Creek system. Historically, flooding has been a severe problem in these areas, particularly the City of Tualatin. Additionally, urbanization has increased in the watershed since the floodplain was last delineated. Thus, the 100-year floodplain likely extends beyond the area currently mapped. In recognition of the fact,

Table 3-7. Minimum perennial streamflow (cfs) as regulated by instream water rights in the Lower Tualatin watershed.*

Stream Name	Above	OCT	NOV 1-15	NOV 16-30	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL 1-15	JUL 16-30	AUG	SEP
Tualatin R.	Mouth	100	250	250	250	250	250	250	250	250	130	100	100	100	95
Tualatin R.	West Linn	100	250	250	250	250	250	250	250	250	130	100	100	100	95
Fanno Cr.	Mouth	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Source: OWRD WARS and WRIS databases

*The most senior of the Tualatin River water rights have a priority date of April 15, 1970. Water rights on Fanno Creek have a priority date of August 5, 1993.



Map 3-2 -- Floodplains and Wetlands of the Lower Tualatin Watershed.

CWS is currently undertaking research to model the 100-year floodplain under current and planned urbanization.

Retention of floodwaters in floodplains helps to moderate flood peaks at downstream sites. Increased impervious area, stream channelization and drainage projects such as drain tiling have reduced the amount of time that water is detained at these floodplain sites. Nevertheless, floodplain storage continues to contribute to flow moderation.

3.1.2.4 Groundwater

Both confined and unconfined aquifers provide important sources of groundwater in the Lower Tualatin watershed. The most productive confined aquifers are found in the Columbia River basalt. Wells tapping this aquifer sometimes produce several hundred gallons per minute. However, this aquifer has a limited storage capacity, and in areas of heavy usage, withdrawal can exceed recharge (Hart and Newcomb 1965, Schlicker 1967).

Such depletion has occurred in much of the Lower Tualatin watershed, especially the area surrounding Bull Mountain. Wells within this area have been known to go dry during the summer (USFWS 1992). The Cooper Mountain/Bull Mountain Critical Groundwater Area includes the watershed west of Fanno Creek and north of the Tualatin River. Within these boundaries, groundwater withdrawals from the basalt aquifer are only permitted for domestic uses. On parcels of 10 acres or more, up to ¼ acre of lawn or garden may be irrigated.

South of the Tualatin River, virtually all of the watershed falls into one of three officially designated Groundwater Limited Areas: Chehalem Mountain, Parrett Mountain, and Sherwood-Wilsonville. In addition to irrigation, water may be withdrawn from the basalt aquifer in these Groundwater Limited Areas for purposes of rural fire protection, and by permit, water-efficient irrigation.

Seasonally high recharge can lead to circumstances where the water table rises to the surface, particularly in December and January. At these times, seasonal wetlands become flooded. Much of the valley is underlain by soils of low permeability, which contributes to wetland flooding.

3.1.2.5 Human impacts on hydrology

The natural flow regime has been altered through several anthropogenic influences. These include:

1. Decreased infiltration rates. Extensive urbanization in the eastern and northern portion of the watershed has resulted in increased area covered by impervious surfaces such as pavement and rooftops and decreased vegetative cover. Similarly, agricultural areas are subject to decreased soil organic matter and decreased vegetation cover relative to the natural condition. These factors all increase peak runoff rates and may decrease low flow rates in the summer.

2. Channelization. Many tributary streams in urbanized and agricultural portions of the watershed have undergone extensive channelization for drainage and flood control. Past surveys along Fanno Creek and its tributaries have described substantial channelization (Brown and Caldwell 1998, Kurahashi and Associates 1997). Analysis of aerial photography indicates that the most severe channelization lies within the Rock Creek (South), Upper Fanno Creek, and Hedges Creek subwatersheds. These are areas where extensive channel straightening accompanied wetland

drainage projects. Additionally, canals have been dug along the lower channel of Chicken Creek, and between the Tualatin River and Lake Oswego.

The analysis using aerial photographs only identified large-scale channel straightening. Field studies indicate that other types of channelization are extensive throughout the urban area (Brown and Caldwell 1998, Kurahashi and Associates 1997). Potential effects of channelization include hydrologic separation of the stream from its floodplain, reduced water detention, and increased downstream flooding. Stream cleaning and straightening associated with channelization reduce resistance to flow and locally increase the stream gradient, resulting in increased velocity and erosion. Additionally, channel straightening tends to destroy riparian vegetation, and reduces the length and diversity of instream and riparian habitats.

3. Diversions. As discussed earlier in this section, water diversions (irrigation pumping stations) are distributed throughout agricultural portions of the watershed. Impacts of these diversions include reduced discharge, which in turn leads to increased summer water temperatures and decreased instream habitat for aquatic life. Where these diversions are unscreened, they also pose a hazard to fish, which may be drawn into the pump and killed.

4. Vegetation changes. Removal of vegetation and large wood from channels reduces resistance to flow, thus increasing the velocity of stream discharge. Although this has the potential benefit of reducing local flooding, it increases the prospect of downstream flooding, reduces the quality and diversity of available riparian and aquatic habitat, and increases erosion.

5. Flow regulation. The Tualatin River project, including Scoggins Dam, has altered flows in the watershed. Summer flows have been augmented along the mainstem. January peak flows have been reduced on the mainstem (although these reductions have been minor). Although high water temperature persists on the mainstem, flow augmentation from Henry Hagg Lake and Barney Reservoir are considered to improve other aspects of water quality by reducing algal growth and pool stratification.

6. Drainage. Surface and subsurface ("tile") drains provide drainage to agricultural areas. This has increased peak winter flows and decreased summer flows in the Tualatin River and its rural tributaries. This flow alteration can lead to increased streambank erosion and channel sedimentation, decreasing habitat diversity, quantity, and quality.

3.1.2.6 Relative importance of human management factors to hydrologic change.

The OWEB methodology was used to determine the relative effects of each land use upon watershed hydrology (WPN 1999). The separate analyses, along with their limitations, can be found on the Washington County SWCD website (http:\\www.swcd.net). The results are as follows.

Agriculture. Enhanced peak flow from agricultural activities was estimated to be less than 0.5 inches. Using the OWEB criteria, this was considered to provide a low flow enhancement potential. However, the methodology does not consider the effects of tile drainage. The extensive amount of tile drainage within rural parts of the watershed would suggest additional effects on watershed hydrology.

Forest and rural roads. Forest and rural roads were found to occupy less than 4% of subwatershed area in each subwatershed. Using the OWEB criteria, this indicates that peak flow enhancement potential from these road types is low within the watershed.

Urban and rural residential uses. The OWEB methodology includes an option where road density is used as a surrogate for total impervious area. (Subwatersheds with less than one square mile of urban or rural residential area were not included in the analysis.) Urban portions of all subwatersheds were found to have road density exceeding 9 miles road per square mile of land surface area. According to the OWEB criteria, the potential for peak flow enhancement from urban land uses was very high. Rural residential areas also seemed to produce a greater risk of peak flow enhancement than agriculture and forestry activities. However, definitive conclusions were difficult to draw because of the small extent of individual rural residential areas.

3.1.3 Stream channel

3.1.3.1 Stream morphology and sediment transport processes

Major streams in the watershed were channel typed according to size, gradient, and confinement characteristics (Map 3-3)[13]. In order to characterize the channel structure within the watershed, a channel typing methodology patterned after the Oregon Watershed Enhancement Board[14] (OWEB) approach was employed (WPN 1999). This approach offered the advantage that the assessment could be performed rapidly using topographic maps, as contrasted with other methods that require more intensive fieldwork. Office-based channel typing using the OWEB methodology is useful for rapid stratification of watershed stream reaches for characterization and preliminary planning. However, field study should precede any site-specific project planning.

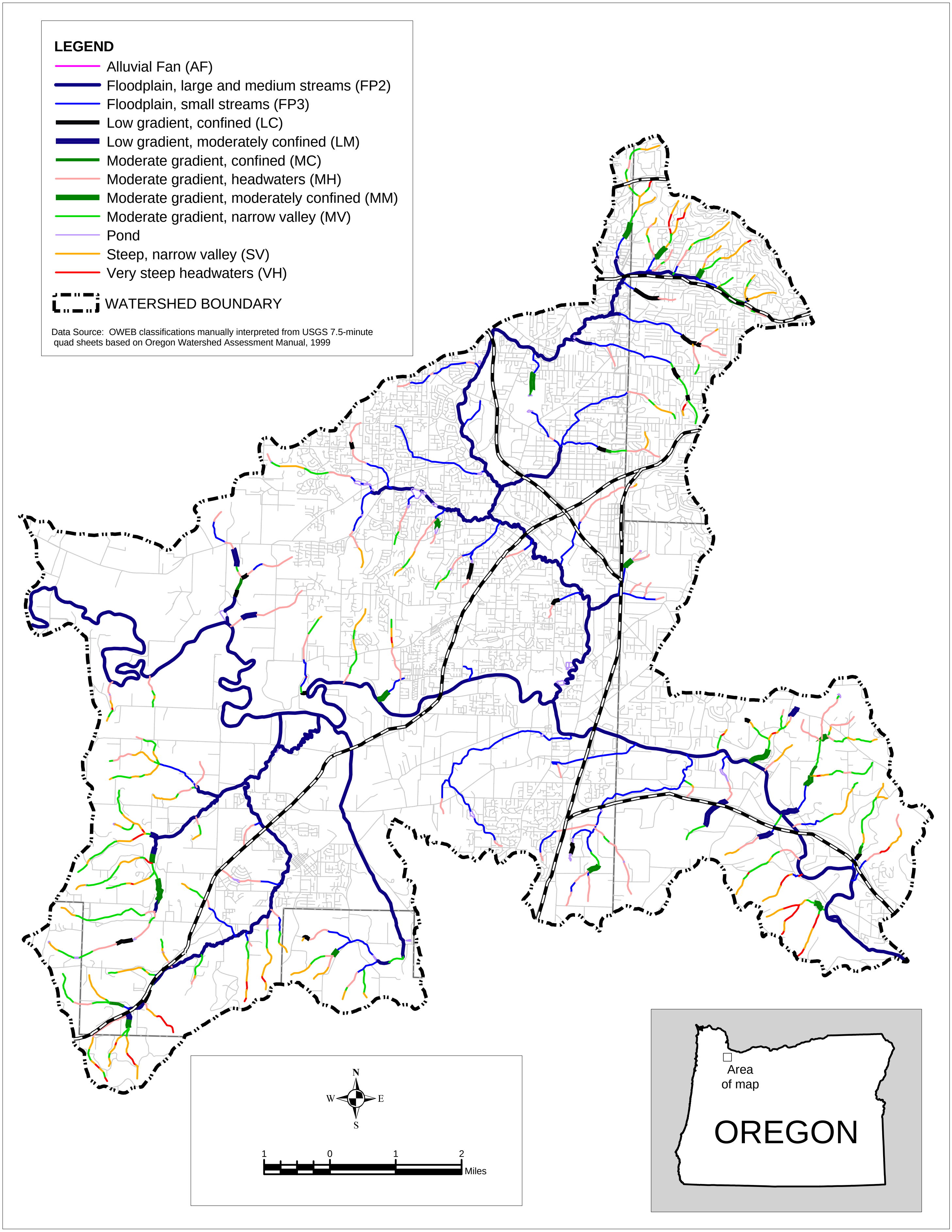
Limited ground reference data was collected, and reports analyzed, to determine the character of channels within the watershed (Tables 3-8 and 3-9). These studies indicated that channel typing accuracy was greatest for floodplain type channels and for steep gradient channels. Typing of moderate-gradient channels was somewhat less reliable. Additionally, many channels within the urban area have been so extensively altered that they do not resemble their original characteristics. Thus, great care should be taken with the use of Map 3-3.

Moderate and steep channel types within the watershed have a higher proportion of fine (sand, silt, and clay) sediment than is indicated in the OWEB manual. This is partially a result of human activities and partially the result of the fine-textured material that dominates surface geology within the Lower Tualatin watershed.

---

[13]Channels are typed according to their unmodified characteristics. Where channel structure has been extensively modified, the probable type of the unmodified channel was reconstructed based on gradient and floodplain characteristics. Channel modifications are addressed at a separate stage of the OWEB methodology.

[14] Formerly the Governor's Watershed Enhancement Board (GWEB)



Map 3-3 -- Stream Channel Types in the Lower Tualatin Watershed

Table 3-8. Stream drainage characteristics of subwatersheds of the Lower Tualatin watershed. (Based on GIS analysis using Tualatin River Watershed Information System).

Subwatershed	Total Area (miles^2)	Total Stream Length (miles)	Drainage Density (mi/mi^2)	Length Channelized (mi)*	Percent Channelized
Ash Creek	4.39	7.31	1.66	1.77	24%
Cedar Creek	9.06	19.42	2.14	0.50	3%
Chicken Creek	7.75	19.81	2.56	0.56	3%
Fanno Creek	8.42	14.17	1.68	2.27	16%
Hedges Creek	3.85	4.56	1.18	2.06	45%
LT-King City	6.41	10.68	1.67	0.73	7%
LT-Oswego Canal	3.89	5.35	1.38	2.41	45%
LT-Scholls	12.10	18.75	1.55	1.63	9%
S. Rock Creek	6.67	8.99	1.35	4.19	47%
Saum Creek	4.60	8.10	1.76	0.98	12%
Summer Creek	6.11	10.95	1.79	1.93	18%
Tualatin Mouth	10.90	27.22	2.50	0.11	0%
Upper Fanno Creek	13.00	30.64	2.36	9.05	30%
Watershed Total	97.15	185.97	1.91	28.19	9%

*This only represents those instances of channel straightening and similar processes that were readily observable from aerial photography. Actual channelization is likely to be higher, especially in urban subwatersheds.

Insert Table 3-9

Table 3-9. OWEB channel types in the Lower Tualatin watershed (based on bluelines in USGS 7 1/2 minute quads).

Channel Type	Description	Length (Miles)	% Type	Confirmed Fish Use	Channel sensitivity to disturbance of: LWD	Fine Sed	Coarse Sed	Peak flow
FP2	Large to Medium Floodplain	60.84	34.64%	96.9%	High	Moderate	High	Low
FP3	Small Floodplain	31.60	17.99%	44.0%	High	Mod-High	High	Low
LC	Low Gradient Confined Channel	3.00	1.71%	37.1%	Low-Mod	Low	Moderate	Low-Mod
LM	Low Gradient Moderately Confined	2.08	1.18%	33.7%	Mod-High	Mod-High	Mod-High	Moderate
MC	Moderate Gradient Confined	0.81	0.46%	59.8%	Low	Low	Moderate	Moderate
MH	Moderate Gradient Headwaters	27.26	15.52%	28.1%	Moderate	Moderate	Mod-High	Moderate
MM	Moderate Gradient Moderately Confined	3.65	2.08%	51.2%	High	Moderate	Mod-High	Moderate
MV	Moderate Gradient V-shaped	22.05	12.55%	35.5%	Moderate	Low	Moderate	Moderate
SV	Steep Gradient V-Shaped	20.27	11.54%	17.1%	Moderate	Low	Low-Mod	Low
VH	Very Steep Headwaters	4.06	2.31%	26.6%	Moderate	Low	Low-Mod	Low
Total		175.62	100.00%	55.3%				

3.1.3.2 Effects of human influences upon stream morphology

Anthropogenic influences have had several effects upon stream morphology. Most notably, channelization has straightened naturally sinuous streams in the alluvial portion of the watershed. This has reduced floodplain connectivity and riparian area, and resulted in a general loss of habitat for aquatic and riparian-dependent species. Additionally, channel straightening reduces stream length, thereby increasing local stream gradient and potentially increasing bank erosion, bank failure, and channel downcutting. In the Tualatin subbasin, Ward (1995) attributed the lack of undercut banks to the effects of channelization.

Riparian buffers along many of the streams in the watershed have been diminished. In several areas, the thin riparian buffers appear to be associated with accelerated bank erosion. Brown and Caldwell (1998) identified inadequate riparian and instream vegetation as contributing factors to erosion on upper Fanno, Woods, and Vermont creeks. When sediments produced by such erosion are redeposited, they often change stream morphology by embedding gravels and contributing to pool fill. Clearing of riparian vegetation also removes the amount of wood and other roughness elements available to the stream, thus limiting the stream's ability to maintain or develop pools.

3.1.4 Water quality

3.1.4.1 Beneficial uses

The beneficial uses of water in the Tualatin subbasin include:

Public domestic water supply;
Private domestic water supply;
Industrial water supply;
Irrigation;
Livestock Watering;
Anadromous fish passage;
Salmonid fish rearing;
Salmonid fish spawning;
Resident fish and aquatic life;
Wildlife and hunting;
Fishing;
Boating;
Water contact recreation;
Aesthetic quality; and
Hydropower.

The water quality parameters that these beneficial uses are dependent on include water temperature, nutrient levels, suspended sediment/turbidity levels, dissolved oxygen and bacterial levels.

3.1.4.2 General indicators of water quality

Although headwater streams in the Tualatin subbasin generally have better water quality than downstream points, it is difficult to apply this generalization to the Lower Tualatin watershed. This is because much of the headwater areas of the Lower Tualatin watershed are in the heavily urbanized Fanno Creek system. These streams are subject to high thermal loadings and polluted runoff from impervious surfaces. Monitoring and survey data indicate substantial water quality problems begin near the headwaters of these streams (Aroner 2000, Brown and Caldwell 1998, ODEQ 2000). These include warm water temperatures. Although data are lacking for headwater sites in the Chicken Creek system, it is likely that water quality in the headwaters is good relative to downstream sites.

To address water quality problems, ODEQ, CWS, TVID, and the Oregon Graduate Institute (OGI) are conducting a cooperative study of pollution sources and water quality in the Tualatin subbasin (Table 3-10). Over the course of the monitoring, the ODEQ water quality index (WQI) has been determined for numerous sites in the Lower Tualatin watershed. Water quality at all sites has been found to range from poor to very poor. The highest scores occurred at monitored sites on Chicken and Hedges creeks. The other sites, all in the Fanno Creek drainage, scored quite poorly. By far, the worst water quality was found between 1990 and 1992 at the Ash Creek monitoring site, where the average WQI was 36 (out of a possible 100). Due to lack of subsequent monitoring, however, it is uncertain whether these measurements represent current conditions. Among recently monitored sites, the lowest WQI was determined to occur on Fanno Creek at Scholls Ferry Road (Aroner 2000).

Three sites in the Lower Tualatin watershed have relatively long-term WQI. These include two sites along the Tualatin River and one site on Fanno Creek. Although the WQI for all sites continued to indicate poor to very poor water quality, there appears to be a demonstrable trend toward improvement of water quality. ODEQ (2000b) attributed this improvement in water quality to improved management practices.

3.1.4.3 Macroinvertebrate sampling in the Lower Tualatin watershed

Macroinvertebrate surveys provide an excellent indicator of water quality, sedimentation, sediment pollutant loadings, habitat diversity, and biodiversity. In connection with monitoring efforts by CWS, Alaska Biological Research, Inc. (ABR) conducted macroinvertebrate surveys in streams of the Tualatin subbasin (Cole 2000). Macroinvertebrates were sampled at 44 sites, 14 of which were within the Lower Tualatin watershed. These included 13 urban sites in Fanno Creek and its tributaries, as well as Hedges Creek, Cedar Creek, and lower Cedar Creek. Additionally, one rural sampling site was chosen on

Table 3-10. USA tributary water quality monitoring sites in the Lower Tualatin watershed. Adapted from Aroner 2000.

USA location code	EPA Code	Stream	Location	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
					Samples per year																		
3701002		Tualatin River	Weiss									7	37	33	38	65	40	39	40	38	38	24	38
3701018		Tualatin River	Hwy 212					1			1	5		1									
3701054		Tualatin River	Stafford							21	116	12	38	37	94	115	68	66	66	70	38	41	39
3701087	3701080	Tualatin River	Boones Ferry			1		1		38	44	12	38	33	81	115	68	66	66	75	38	24	38
3701116		Tualatin River	Hwy 99W											2	48	50	28			15			
3701165	3701162	Tualatin River	Elsner	12	12	13	12	12	13	47	118	12	38	33	81	116	77	66	66	78	38	41	40
3835020		Chicken Creek	Scholls Ferry?											2	33	51	49	39	40	36	38	23	37
3836005		Cedar Creek	Edy										29	27									
3836025		Cedar Creek	Sunset										27	25									
3837002		Hedges Creek	Tualatin Park											25									
3837040		Hedges Creek	Avery															31	40	28	8		
3837044		Hedges Creek	105th															31	17				
3838002		Nyberg Creek	Nyberg Lane											24	26	25							
3839005		S. Rock Creek	Hwy 99W											25	26	25	7						
3840004		Fanno Creek	Foot Bridge																28	23			
3840012	3840008	Fanno Creek	Durham	1	1	1	1	1	1	16	15	12	34	32	60	83	68	39	40	14	38	31	55
3840024		Fanno Creek	Bonita Road																31	33			
3840055		Fanno Creek	Tigard Street										27	25									
3840066		Fanno Creek	Scholls Ferry											25	18								
3840074		Fanno Creek	Tucker												7	26	30	28	32	34	37	23	37
3840085		Fanno Creek	Denney											25									
3840095		Fanno Creek	near Allen											25	25	26	30	29	32	35	37	32	55
3840100		Fanno Creek	86th											25									
3840126		Fanno Creek	56th																			8	17
3840135		Fanno Creek	39th										27	25	26	26							
3843005		Hiteon Creek												25									
3844018		Summer Creek	135th											25									
3845002		Ash Creek	Greenburg											23	26	25							
3845012		Ash Creek	Locust												25								
3846002		Red Rock Creek																	23	29	24	8	

Table 3-10. Continued: USA tributary water quality monitoring sites in the Lower Tualatin watershed. Adapted from Aroner 2000.

Non USA monitoring sites

Station	Agency	Stream	Location	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
14206950	USGS	Fanno Creek	Durham												5	2	19	9	5		
14207500	USGS	Tualatin River	West Linn	7	7	5	4	4	4	4	4	4	4	4	4	16	26	16	10		
3834001	Portland	Sylvan Creek	Mouth														17	45	51	52	41
3838002	USA/CL	Nyberg Creek												24	26	25		X	X	X	12
3839047	Clack	S. Rock Creek	MG															X	X	X	11
3840117	Portland	Fanno Creek	Oleson														21	45	51	54	41
3840123	Portland	Fanno Creek	60th											25							
3840126	Portland	Fanno Creek	56th											5	28	20	21	45	51	53	41
3840135	Portland	Fanno Creek	39th St/Shattuck															7	12	12	12
3842001	Clack	Carter Creek	I-5															X	X	X	12
3842002	Clack	Carter Creek	Kruse Way															X	X	X	13
3845030	Clack	NF Ash Creek	Garden Home											5	6	3		7	12	12	12
3863004	Clack	Fields Creek																X	X	X	10
3864001	Clack	Ribera Lane	TB															X	X	X	11
3865004	Clack	Ek Road	TB															X	X	X	10
3866005	Clack	Athey Creek																			13
3867004	Clack	Saum Creek	Halcyon																		12
3867017	Clack	Saum Creek	65th																		12
3869002	Clack	Childs Road	TB																		8
3879001	Clack	Pecan Creek																X	X	X	13
3880001	Clack	Shadow Wood	TB															X	X	X	12
3881013	Clack	Wilson Creek																X	X	X	10
3882002	Clack	Johnson Road	TB															X	X	X	12
3889002	Portland	Pendleton Creek												5	5	3		7	12	12	12
3890002	Portland	Vermont Creek												5	2	3		7	12	33	43
3891005	Portland	Woods Creek	Oleson											5	5	3		7	12	12	12
3892010	Portland	SF Ash Creek	Taylor's Ferry											5	5	3		7	12	12	12
402126	ODEQ	Tualatin River	Boones Ferry	14	12	13	11	15	23	53	18	8	11	12	12	11	12	12	13	10	10
402128	ODEQ	Tualatin River	Elsner Road				1		8	54	16		7	13	10	12	13	11	12	11	10
402139	ODEQ	Fanno Creek	Bonita Road					1		50	28	11	4	7	12	12	14	12	16	12	12
407145	ODEQ	Redrock Creek	RM 0.39																		
407146	ODEQ	Redrock Creek	Hwy 217																		

Chicken Creek. Generally speaking, the most degraded conditions were found in the urban streams. As a group, the sites within the Lower Tualatin watershed had the poorest scores within the Tualatin subbasin. The poorest conditions appeared to be at the Lower Summer Creek, Upper Fanno Creek, and Upper South Rock Creek sites. Species diversity and the proportion of pollution-intolerant species were very low at these sites. Conversely, the Upper Chicken Creek site scored very high on these indices, and was considered a reference stream within the Tualatin subbasin. The Upper Cedar Creek site was the most highly placed "Urban" stream within the subbasin.

3.1.4.4 Streams on the 303(d) list

The Lower Tualatin watershed has the highest concentration of 303(d) listed streams of any watershed in the Tualatin subbasin. An estimated 74 stream miles in this watershed are on the ODEQ 303(d) water quality limited list (Map 3-4). These streams are listed in Table 3-11. Every subwatershed except Saum Creek has stream mileage on the 303(d) list. The most common criteria for listing include high levels of bacteria and high water temperature. Low dissolved oxygen, poor fish diversity, and high levels of chlorophyll *a* are also criteria for listing in some streams. Draft Total Maximum Daily Load allocations (TMDLs) have been developed for temperature, bacteria, dissolved oxygen, and chlorophyll *a*. Streams will be removed from the 303(d) list for these parameters once the TMDLs are fully in place. As of December, 2000, ODEQ tentatively planned to have the allocations in place by mid-2001 (G. Geist, ODEQ, personal communication).

3.1.4.5 Parameters of concern

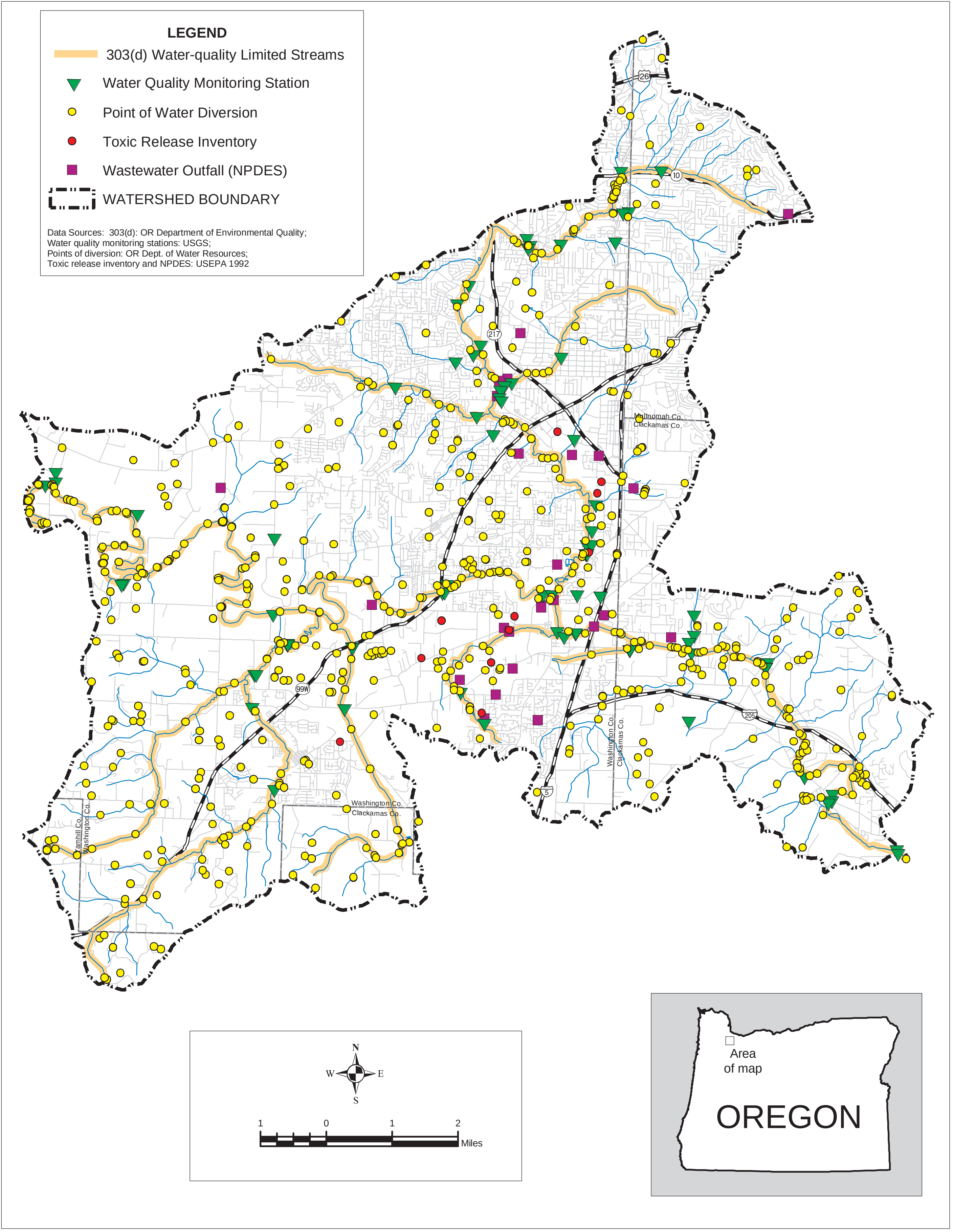
3.1.4.5.1 Bacteria

E. coli is an important indicator of inputs of fecal bacteria to stream systems. High bacteria levels can cause disease, and restrict the beneficial uses of water for humans, such as water contact recreation. ODEQ (2000) found that high bacteria levels in urban areas were strongly associated with runoff. Pet waste, illegal dumping, septic system failure, and sanitary sewer cross-connections and overflows were identified as potential bacteria sources.

Bacterial impairment is widespread throughout the Fanno Creek system (Aroner 2000). Although high bacterial concentrations persisted throughout the year, they were highest during the May-October sampling season (Table 3-12). The degree of bacterial impairment was the greatest on Fanno Creek at the Scholls Ferry Road and Oleson road sites, and on Vermont Creek.

Bacterial impairment is also a severe problem on rural streams. On Chicken Creek at Scholls-Sherwood Road, the only monitored rural site within the watershed, summer bacteria levels exceeded state standards more than 50% of the time.

Studies by CWS indicated that elevated bacteria levels in rural areas are largely the result of livestock farms with inadequate manure storage, manure management, or grazing management (Aroner 1998). ODEQ (2000) also identified hobby farms and ranchettes as potential sources of animal-related bacterial waste. Septic systems and illegal dumping were identified as other potential bacteria sources.



Map 3-4 -- Water Quality and Water Supply for the Lower Tualatin Watershed

Table 3-11. Streams on the 1998 ODEQ 303(d) list.

Stream	Location	Parameter	Affected Beneficial Use	Period	WQ standard
Ash Creek	Mouth to Headwaters	Bacteria	Water contact recreation	Year round	400 fc
		Biological Criteria	Fish		30 IBI
		Dissolved Oxygen	Cool-water aquatic	May-October	6.5 mg/L
		Temperature	Salmonid rearing	May-October	17.8 C
Cedar Creek	Mouth to Headwaters	Bacteria	Water contact recreation	Year round	400 fc
		Biological Criteria (PC)	Fish		30 IBI
		Chlorophyll a		May-October	15 ug/L
		Dissolved Oxygen	Cool water aquatic	May-October	6.5 mg/L
		need data for Temperature	Salmonid rearing	May-October	17.8 C
Chicken Creek	Mouth to Headwaters	Bacteria	Water contact recreation	Year round	406 *E. coli*
		Dissolved Oxygen	Cool water aquatic	May-October	6.5 mg/L
		Need Data for temp			
Fanno Creek	Mouth to Headwaters	Bacteria	Water contact recreation	Year round	406 *E. coli*
		Biological Criteria (PC)	Fish		30 IBI
		Chlorophyll a		May-October	15 ug/L
	Mouth to Headwaters	Dissolved Oxygen	Cool water aquatic	May-October	6.5 mg/L
		Temperature	Salmonid rearing	May-October	17.8 C
	Mouth to Headwaters	Toxics: Arsenic		Year round	2.2ng/L
		Toxics: Iron		Year round	300 ug/L
	Mouth to Headwaters	Toxics: Manganese		Year round	50 ug/L
Hedges Creek	Mouth to Headwaters	Bacteria	Water contact recreation	Year round	406 *E. coli*
		Biological Criteria	Fish		30 IBI
		Dissolved Oxygen	Cool water aquatic	May-October	6.5 mg/L
		Temperature	Salmonid rearing	May-October	17.8 C
Nyberg Creek	Mouth to Headwaters	Bacteria	Water contact recreation	Year round	61 enterococcus
		Chlorophyll a		May-October	15 ug/L
		Dissolved Oxygen	Cool water aquatic	May-October	6.5 mg/L
		Temperature	Salmonid rearing	May-October	17.8 C
Rock Creek (S)	Mouth to Headwaters	Bacteria	Water contact recreation	Year round	406 *E. coli*
		Biological Criteria	Fish		30 IBI
		Chlorophyll a		May-October	15 ug/L
		Dissolved Oxygen	Cool water aquatic	May-October	6.5 mg/L
		Temperature	Salmonid rearing	May-October	17.8 C
Summer Creek	Mouth to Headwaters	Bacteria	Water contact recreation	Year round	400 fc
		Biological Criteria	Fish		30 IBI
		Dissolved Oxygen	Cool water aquatic	May-October	6.5 mg/L
		Temperature	Salmonid rearing	May-October	17.8 C
Tualatin River	Mouth to Dairy Creek	Bacteria	Water contact recreation	Year round	406 E. coli
		Temperature	Salmonid rearing	May-October	17.8 C

3.1.4.5.2 Dissolved oxygen

High levels of dissolved oxygen (D.O.) are essential for cold-water aquatic species. D.O. levels are affected by temperature, aquatic growth, nitrification, and oxygen demand imposed by decomposition of organic material. High water temperature reduces the amount of D.O. that can be stored in the water column. Decomposition of organic matter consumes oxygen, leading to low levels of instream D.O.[15]. As gases are often most easily transferred in turbulent waters, lack of turbulence, with accompanying pool stratification, can also lead to low dissolved oxygen levels.

In the past, high ammonia levels contributed to decreased D.O. levels. Oxygen was required to convert the ammonia to nitrates (that is, through nitrification). Additionally, ammonia posed a toxicity problem to aquatic life. These problems have been greatly reduced since the implementation of upgraded wastewater treatment processes by CWS. Presently, ammonia is considered a minor contributor to dissolved oxygen reductions within the watershed (ODEQ 2000).

During recent studies related to TMDL establishment, ODEQ determined that high temperature and sediment oxygen demand (SOD) were the primary contributors to D.O. deficits in streams in the watershed. In some cases, the other factors were potentially significant contributors, particularly in urban streams. The lowest dissolved oxygen levels between 1989 and 1998 were found in the Fanno Creek system. The reach of Fanno Creek between Scholls Ferry Road and Cook Park had median observed summer concentrations below the salmonid rearing standard of 6.5 mg/L. Conditions were worst between Scholls Ferry Road and Allen Road, where spot measurements less than 3.0 mg/L were recorded. D.O. levels gradually improved downstream on Fanno Creek (ODEQ 2000). Ash and Summer Creek, with median summer D.O. levels of 3.5 and 1.9 mg/L, respectively, were found to contribute to D.O. deficits in Fanno Creek. Although D.O. levels appear to have improved since the early 1990s, these parts of the Fanno Creek system, together with Vermont Creek, continue to have low D.O. levels (Aroner 2000).

Different levels of dissolved oxygen (D.O.) are needed for successful spawning and fish rearing. Higher dissolved oxygen levels are necessary for successful fish spawning and incubation than for rearing. This is because high interstitial levels of dissolved oxygen are necessary to facilitate oxygen transfer and waste removal in gravel redds.[16] Where this oxygen supply is impaired, decreased survival, deformities, and altered hatch timing often result (Bjornn and Reiser 1991). Within the Lower Tualatin watershed, portions of Chicken Creek support spawning of winter steelhead trout. Fanno Creek also contains suitable gravel for spawning and is considered by ODFW to support steelhead trout spawning, although documentation of use is sparse. Additionally, several streams support spawning of resident cutthroat trout. Thus, these streams should receive special attention to ensure their ability to maintain high dissolved oxygen levels during the appropriate seasons.

Within the watershed, most recorded dissolved oxygen levels below federal standards occurred between May and October, when salmonid rearing was the most likely beneficial use to be affected (Aroner 2000). However, the Fanno Creek site at Tuckerwood showed dissolved oxygen levels below the spawning standard of 11.0 mg/L during the November to April period (Table 3-12).

---

[15] Oxygen demand created by decomposition of organic material in the water column is referred to as **biochemical oxygen demand (BOD)**, while decomposition of organic materials stored in sediment creates a **sediment oxygen demand (SOD)**.

[16] **Interstitial** gases are those gases stored between sediment particles. **Redds** are the gravel nests into which salmonid eggs are deposited.

Insert Table 3-12

Table 3-12. Percent of time water quality was exceeded at monitoring stations in the Lower Tualatin watershed, 1999.

USA location code	EPA Code	Stream	Location	Annual					Summer							Winter	
				Temp.	D.O.	pH	Bacteria	Chl a	Temp.	D.O.	pH	Phosphorus	Bacteria	Ammonia	Chl a	D.O.	Bacteria
3835020		Chicken Creek	Scholls-Sherwood	0%	1%	0%	**50%**	0%	*0%*	*10%*	0%	**90%**	**50%**	*0%*	0%	0%	*10%*
3840012	3840008	Fanno Creek	Durham	*10%*	1%	0%	**50%**	1%	*25%*	*10%*	0%	**90%**	*25%*	1%	*10%*	0%	*25%*
3840024		Fanno Creek	Bonita Road	25%		0%											
3840066		Fanno Creek	Scholls Ferry	*10%*	*10%*	0%	**75%**		*25%*	*25%*	0%	**90%**	**75%**	*10%*		0%	*25%*
3840074		Fanno Creek	Tuckerwood	*10%*	1%	0%	**50%**		*25%*	*10%*	0%	**100%**	*25%*	1%		*10%*	*25%*

Non USA monitoring sites

Station	Agency	Stream	Location	Temp.	D.O.	pH	Bacteria	Chl a	Temp.	D.O.	pH	Phosphorus	Bacteria	Ammonia	Chl a	D.O.	Bacteria
3834001	Portland	Sylvan Creek	Mouth		1%	0%	*25%*	0%	*25%*	*10%*		**100%**	*25%*	0%	0%	0%	*25%*
3840117	Portland	Fanno Creek	Oleson	1%	1%	0%	**50%**	0%	*10%*	1%	0%	**90%**	**50%**	0%	0%	0%	*25%*
3890002	Portland	Vermont Creek			*10%*	0%	**75%**	0%	1%	*10%*	0%	**100%**	**50%**	0%	0%		
402139	ODEQ	Fanno Creek	Bonita Road	*25%*	0%		*25%*	0%	*25%*	0%	0%	**100%**	0%	0%	0%	0%	**50%**
407145	ODEQ	Redrock Creek	RM 0.39									**100%**					

Source: Aroner 2000

Note: Aroner (2000) reported these monitoring data in terms of an exceedance range: 0, 0-25%, 25-50%, 50-75%, 75-100%, and 100%. Numbers reported here represent the lower extent of that range.

3.1.4.5.3 Phosphorus

In many natural aquatic systems, phosphorus is the limiting nutrient to aquatic growth. When streams are enriched by phosphorus inputs, it can lead to algal blooms, decreased dissolved oxygen concentrations, fish kills, and bad odors.

Phosphorus is a major parameter of concern within the Lower Tualatin watershed. Phosphorus levels exceed TMDL standards in monitored streams throughout the watershed (Table 3-12). During 1999, the highest median May-October phosphorus concentration occurred on Fanno Creek at Tuckerwood and Scholls Ferry, and on Vermont Creek. The highest recorded maximum phosphorus measurements, however, occurred on Sylvan Creek near its mouth.

3.1.4.5.3.1 Potential sources of phosphorus

Both urban uses and agriculture are important sources of phosphorus to aquatic systems. Conversion of forest to these land uses generally results in increased fertilizer use and soil destabilization (Wolf 1992). Where these fertilizers and soils are able to reach an aquatic system, they often transport a phosphorus load to the stream.

Urban and rural residential land uses, as well as agriculture, often implement practices that contribute organic material to streams. Contributions of easily decomposed organic matter (e.g. manure, straw, leaves, grass clippings) increase the sediment oxygen demand. This can lead to anaerobic conditions in the stream bottom during the summer, which tends to chemically mobilize phosphorus that has been adsorbed to iron and aluminum oxides in sediment.

3.1.4.5.4 Stream temperature

In the Tualatin Basin, concern over water temperature generally relates to the fitness of streams to provide suitable conditions for cold-water aquatic species, such as salmonids. For most streams in the basin, the salmonid rearing/migration standard of 17.8 C (64° F) is applied. This standard is applied based on a seven-day moving average of daily maximum temperatures (OAR 340-41-006).

In conjunction with monitoring efforts, CWS conducted continuous monitoring, and ODA collected biweekly measurements,of water temperature at many urban and rural sites within the watershed (Tables 3-11 and 3-12). In 1999, most monitored sites routinely exceeded the 17.8 C standard during the May to October period (Aroner 2000). This standard was most frequently exceeded at the Sylvan Creek site, although most sites monitored on Fanno Creek also exceeded the standard 25% of the time. Over the same period, the standard was not exceeded at the monitoring site on Chicken Creek.

The Tualatin Basin Watermaster maintains constant summer temperature measurements at three mainstem Tualatin River sites in the watershed. These monitoring sites are located at Elsner Road (RM 16.2), Oswego Canal (RM 6.7), and West Linn (RM 33.3). In 1999, the Elsner Road site recorded 89 days with a 7-day running mean maximum temperature exceeding the 17.8 C standard. This standard was exceeded on 104 days at the Oswego Canal site, and on 112 days at West Linn (TRFMTC 2000). These constantly increasing temperatures may reflect several factors, including pool stratification, slow flow, river width and exposure, tributary contributions, ambient temperature, and increased downstream urbanization.

In 1999, ODEQ conducted an intensive monitoring study of several streams within the Tualatin subbasin, including Chicken and Fanno creeks (ODEQ 2000). This study found that all sampled sites on these creeks exceeded the 17.8 C water temperature standard at some point over the summer sampling period. The maximum 7-day average temperature in the Fanno Creek system ranged from 17.7 C at the Fanno Creek at 30th Street site to 23.5 C at Ash Creek near its mouth. Downstream of 56th Street, water temperature regularly exceeded 17.8 C. All monitored tributaries contributed warm water to the Fanno Creek system.

Water temperature was somewhat cooler in the Chicken Creek system. The Kruger Road site, which was well below the headwaters, had a maximum 7-day average temperature of 18.4 C, while the maximum temperature farther downstream at Edy Road was 21.3 C.

Among the monitored sites, Sylvan Creek and Summer Creek displayed the greatest impairment due to temperature. Over the course of the monitoring period, stream temperatures at each of these sites exceeded 21.1 C for more than 400 hours. The longest total duration of excess, 533 hours, occurred at the Sylvan Creek site. These sites, along with all Fanno Creek sites below Nicol, spent more than 1,000 hours of the total monitoring period above 17.8 C.

In many reaches, streams are exposed to large amounts of summer heating because of impaired riparian canopy. Recent surveys conducted in connection with the Watersheds 2000 effort found that the vast majority of Ball, Rock (South), Sylvan, and Woods creeks had riparian buffers less than 25 feet in width (CWS, unpublished Watersheds 2000 data). Additionally, most vegetation on Nyberg was scrub-shrub or herbaceous. Most surveyed portions of Nyberg and Rock Creek (South) had less than 60% canopy coverage.

Analysis of RLIS Lite digital aerial photography showed that substantial portions of rural subwatersheds lacked riparian vegetation and/or provided insufficient shade (Metro 2001). Many tributary reaches lacked riparian vegetation. The mainstem Tualatin River, on the other hand, usually had a forested buffer, but the river was often too wide to provide complete shade. Subwatersheds where shading seemed exceptionally low were Ash Creek, Rock Creek (South), and Upper Fanno Creek.

3.1.4.5.5 Other parameters of concern

Through evaluation of 1993 monitoring data, the United States Geologic survey (Bonn 1999) found sampled sites on Fanno and Ash Creek to be contaminated by heavy metals and organic compounds. Samples taken on Fanno Creek at Nicol Road and Denney Road exceeded EPA Tier two screening values for 17 out of 22 chemicals. (The EPA considers that, at this level of contamination, adverse effects on aquatic life are possible, but occur infrequently.) These chemicals covered a wide spectrum of pollutants, including heavy metals, pesticides, and polyaromatic hydrocarbons (PAH). Additionally, the Ash Creek site exceeded Tier 1 guidelines for a phthalate, indicating probable adverse effects to aquatic life. The researchers concluded that high levels of PAHs in these streams were likely the result of automobile exhaust.

High levels of chlordane and PCBs were found in fish tissue at the Fanno Creek sites. These concentrations are likely the residual effect of past pest-control and industrial practices, as these chemical compounds have not been used since the 1980’s.

Generally speaking, sites on the Tualatin River at Elsner Bridge and lower Chicken Creek were less contaminated than were the Fanno Creek sites. As was the case throughout the Tualatin subbasin, these sites had high levels of heavy metals, including chromium, copper, and nickel, and zinc. The prevalence of these metals throughout the watershed possibly indicates a natural source for these elements. Mercury was also found on Chicken Creek, while arsenic was found at the Elsner Road site.

3.1.4.6 Water quality trends

Based on 15 years of data, the CWS study, (Aroner 2000), found several notable water quality trends in the Tualatin Basin. Those shared by streams within the Lower Tualatin watershed include:

- Declining phosphorus (May-October, Chicken Creek and Fanno at Durham)
- Increasing dissolved oxygen (May-October, Chicken, November-April, Fanno at Durham)
- Decreasing chemical oxygen demand (year-round, all streams)
- Decreasing ammonia concentrations (year-round, Chicken and Fanno at Durham)

Fanno Creek at Bonita Road displayed a trend for increasing ammonia concentration during the May-October period.

3.1.5 Aquatic species and habitat

3.1.5.1 Cold-water fish

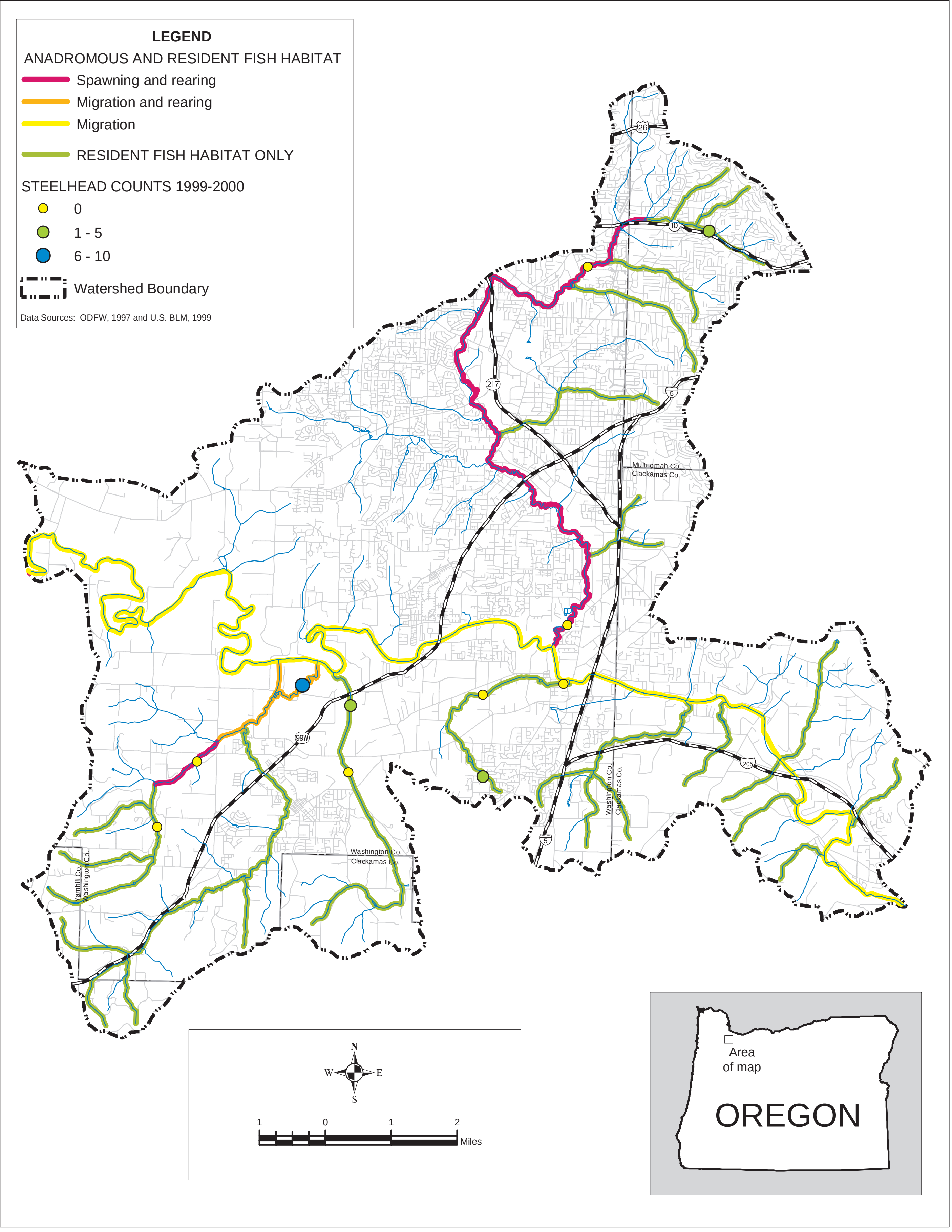
3.1.5.1.1 Distribution and life history

Fanno Creek and Chicken Creek are considered by ODFW to contain potentially important habitat for spawning and rearing of anadromous steelhead (Map 3-5). Additionally, these streams and their tributaries support resident cutthroat trout and coho salmon. Cutthroat trout and steelhead trout are native to the system. Coho salmon were first introduced in the 1920's and have since become naturalized (ODEQ and USA 1982). Common native non-salmonids include dace and sculpin. Pacific lamprey and brook lamprey are also present. A list of fish species within the watershed is given in Table 3-13.

Table 3-13. Anadromous and resident fish known to inhabit the Lower Tualatin watershed.

Anadromous Fish		Resident Fish	
Common Name	**Scientific Name**	**Common Name**	**Scientific Name**
Coho salmon*	*Oncorhynchus kisutch*	Cutthroat trout	*Oncorhynchus clarki clarki*
Steelhead trout	*Oncorhynchus mykiss*	Western brook lamprey	*Lampetra richardsoni*
Pacific lamprey	*Entosphenus tridentatus*	Reticulate sculpin	*Cottus perplexus*
		Largescale sucker	*Catostomus platyrhynchus*
		Redside shiner	*Richardsonius balteatus*
		Speckled dace	*Rhinichthys osculus*
		Northern pikeminnow	*Ptychocheilus oregonensis*
		Largemouth bass*	*Micropterus salmoides*
		Bluegill*	*Lepomis macrochirus*
		Warmouth*	*Lepomis gulosus*
		Yellow perch*	*Perca flavescens*
		Crappie*	*Pomoxis sp.*

* Species introduced to the Tualatin subbasin



Map 3-5 -- Fish Distribution in the Lower Tualatin Watershed.

Steelhead trout are considered by ODFW to spawn and rear in Chicken Creek between Edy Road and Kruger Road, and in Fanno Creek downstream of Columbia Creek (ODFW database, 1999). Additionally, the mainstem Tualatin River provides a migratory corridor for these fish.

The degree to which steelhead utilize Fanno Creek for spawning and/or rearing is uncertain. The fish have been sporadically observed in the stream and a spawned-out female was observed in 1989 (Hughes and Leader 2000, Fans of Fanno Creek 2000). However, the infrequency of these observations lead some scientists to believe that they may be the result of fish straying, rather than regular spawning or rearing (Greg White, personal communication).

Although survey data are limited, it is likely that cutthroat trout spawn in Fanno Creek above Sylvan Creek, and in the headwaters of Chicken Creek (ODEQ 2000). Rearing of cutthroat trout occurs in Fanno Creek, Chicken Creek, Cedar Creek, and Rock Creek (South). During surveys, small numbers of cutthroat trout were also found in Hedges Creek (Hughes and Leader 2000).

Additionally, the Tualatin River provides a migratory corridor for chinook salmon. These fish infrequently utilize the Tualatin subbasin.

Winter run steelhead trout migrate into the Willamette basin between February and May. Spawning occurs April through June, with peak spawning occurring in May (Busby et al. 1996). Juvenile steelhead trout rear in streams for two years prior to smolting. Most trout rearing takes place in tributaries. Some migration to mainstem reaches may take place in fall and winter (Ward 1995). After smolting, they migrate to the ocean between April and June. Steelhead trout typically spend two years in the ocean prior to returning to their natal streams to spawn. Steelhead trout do not necessarily die after spawning, but may go back to the ocean and return in subsequent years to spawn again.

Coho salmon migrate into the upper Willamette basin in fall. Spawning occurs in November and December. Juvenile coho salmon rear in streams for one year prior to smolting, with outmigration taking place from March through May. In summer, most rearing takes place in tributaries. Some migration to mainstem reaches may take place in fall and winter (Ward 1995). After smolting, they migrate to the ocean. Coho salmon typically spend three years in the ocean prior to returning to their natal streams to spawn. Following spawning, they die.

In this watershed, cutthroat trout exhibiting both resident and potamodromous life histories are present[17]. Potamodromous migration occurs between the Lower Tualatin watershed and the Willamette River. Additionally, localized movement will occur in an attempt to find superior habitat conditions. Although cutthroat trout can be found spawning most times in the year, their peak spawning season in the Tualatin subbasin is from February to April (G. White, fisheries biologist, personal communication 2001).

Life history of Pacific lamprey is complex. They typically migrate into the Willamette basin between April and September, and spend one winter in fresh water prior to spawning. Spawning occurs in June and July in stream reaches with abundant gravel. After hatching, lamprey spend four to six years in the larval, or ammocoete, stage. Ammocoetes migrate downstream to lowland reaches with mud substrates, where they remain until attaining juvenile stage. This stage, which is marked by physiological changes including the development of eyes, usually takes place between July and October, and is usually marked by a migration to stream reaches with fast flow and gravel substrate. As juveniles grow to adulthood,

[17] *Potamodromous* fish practice seasonal migration within a stream system for spawning purposes, but remain in fresh water throughout their life history.

they outmigrate to the ocean, usually between late fall and spring. Off of the Oregon Coast, adult lamprey spend 20-40 months in the ocean prior to returning to fresh water to spawn. They die three to 36 days after spawning (Close et al. 1995).

3.1.5.1.2 Potential hazards

The greatest hazard faced by salmonids is generally considered to be the lack of quality habitat. For anadromous fish, in particular, habitat is limiting. Up to 13 miles of spawning habitat in the Lower Tualatin watershed is accessible to anadromous fish (ODFW 1999). Most of the best rearing habitat also lies within the reaches used for spawning. Since the amount of habitat is so limited, any degradation is significant. Threats to salmonid habitat in the watershed include loss of habitat diversity, diminished water quality (including elevated water temperatures and low dissolved oxygen), and low summer and fall streamflow. Further discussion of streamflow and water temperature characteristics occurs in the Hydrology and Water Quality sections (Sections 3.1.2 and 3.1.4).

Migratory impediments, stream diversions, predation, and competition are other factors affecting salmonid populations. Poorly sized and placed culverts, in particular, can impede migration by creating jumps and velocity barriers (See Section 3.1.5.1.6). Stream diversions can entrain migrating and rearing salmonids and remove them from the stream system, often resulting in fish mortality in nearby upland habitats. While predation and competition are natural ecological processes in aquatic systems, human activities can increase pressures from these sources by reducing the amount and diversity of available habitat, accidental predator introduction, and planting of hatchery fish.

3.1.5.1.3 Planting of hatchery salmonids

Steelhead trout were released in the Lower Tualatin watershed between 1984 and 1989 as mitigation for loss of habitat due to construction of Scoggins Dam. In 1984, 13,906 steelhead trout fry were planted in Chicken Creek. In 1989, 56 fry were planted in Fanno Creek. These numbers represent a very small proportion of the steelhead trout that were planted in the Tualatin subbasin over this period. In 1999, ODFW discontinued planting steelhead trout in the Tualatin subbasin. This change of policy was designed to “address concerns about the potential genetic risks associated with interactions between wild and hatchery steelhead stocks” (BOR 2001).

Coho salmon were planted in the watershed in 1983. In this year, 22,381 coho salmon fry were planted into Chicken Creek. In 1999, ODFW discontinued planting coho salmon in the Tualatin subbasin in response to steelhead trout listings under the ESA.

3.1.5.1.4 Prospects for salmonid populations

The Lower Tualatin watershed falls within the upper Willamette Evolutionarily Significant Unit (ESU) for steelhead trout. In March 1999, steelhead trout within this ESU were listed as threatened under the ESA. Through genetic analysis, the National Marine Fisheries Service (NMFS) determined that the steelhead trout in the Tualatin basin are of native stock, and therefore were included in the ESA listing. Although Nehlsen et al. (1991) did not consider these steelhead trout stocks to be at risk, more recent trends indicate a possible decline in population. Wide population fluctuations make trends difficult to determine. However, low populations indicate a possible risk of extinction (Busby et al. 1996).

On March 24, 1999, NMFS listed chinook salmon as threatened under the ESA. Although they are not considered by ODFW to spawn or rear within the Tualatin subbasin, the Tualatin River is accessible to chinook salmon. Thus, chinook salmon must be taken into account when determining the potential effects of management activities upon aquatic life.

On April 5, 1999 coastal cutthroat trout within the upper Willamette ESU were determined by NMFS to be "Not Warranted" for listing under the ESA (Federal Register 16397). However, the USFWS now has authority over cutthroat trout and are currently reviewing their status. Population trends for cutthroat trout within the Lower Tualatin watershed are unknown.

3.1.5.1.4.1 Non-salmonid populations and trends.

Little population information is available on cold water non-salmonid fish species in the watershed.

3.1.5.1.5 Distribution of habitat

Coho salmon, steelhead trout, and cutthroat trout vary in their seasonal habitat utilization but all require structurally diverse channels for the maintenance of healthy populations. In general, coho salmon occupy middle stream reaches while cutthroat and steelhead trout occupy upper reaches. During high flow periods associated with winter and spring, juvenile coho salmon, steelhead and cutthroat trout depend on the low velocity habitats provided by pools, backwaters, and off-channel alcoves. Adult salmon and trout also use pools and wood structure for shelter from predators and for resting. During low flow periods zero to one year old steelhead and cutthroat trout inhabit higher velocity areas associated with riffles, while coho salmon continue to use pools. Two year and older steelhead and cutthroat trout generally prefer the deepest pool habitat.

In Coast Range streams, large wood pieces and accumulations of large woody debris (LWD) play a vital role in maintaining channel complexity and fish populations. LWD creates scour, recruits and maintains spawning gravel, creates rearing pools and increases channel complexity. Although limited habitat surveys exist, most existing data indicate that LWD is far below optimal levels throughout the watershed. According to the OWEB manual, ODFW benchmarks for streams in forested basins indicate that less than 10 pieces of LWD (10 feet minimum length by 6 inch width) per 100 meters (328 feet) channel length is undesirable (WPN 1999). (Ideally, such streams should have more than 20 pieces of LWD per 100 meters channel length, with more than three “key” pieces exceeding 30 feet length by 24 inches diameter.) Although the majority of the Lower Tualatin watershed is not currently forested, these values provide a useful basis for comparison (CWS Watersheds 2000). Recent riparian surveys of 49 sites along Ball, Nyberg, Saum, Rock (South), Sylvan and Woods creeks found that 22 sites exceeded 1 piece of LWD per 100 meters. Of these, only seven sites exceeded 10 pieces/ 100 meters. Twenty-seven sites had no LWD. (It should be noted, however, that surveys averaged only 234 feet (71 m). The short length could lead to variable results.) The highest concentration of LWD was found along Saum Creek, while Rock Creek (South), Nyberg Creek, and Sylvan Creek generally had very little instream LWD.

The current characteristics of riparian vegetation further indicate that LWD recruitment potential is poor in most parts of the watershed. However, surveys on the aforementioned tributaries indicate a mixed picture for LWD recruitment. Of 39 sites evaluated for LWD recruitment potential, nine were described as having high potential, 13 moderate, and nine low. Eight sites were described as having no potential. Once again, the best conditions appeared to prevail on Saum Creek, although Sylvan Creek also rated highly. (This could indicate that poor instream conditions on Sylvan Creek are more likely to be remedied over the near term than is the case on other streams.) Once again, the lowest recruitment potential was found on Rock (South) and Nyberg creeks.

Tualatin River had somewhat higher recruitment potential than most tributaries, as many ash trees in the 12-24 inch dbh class were found interspersed among trees of smaller diameter classes. Additionally, conifers were frequently found to grow near the streambanks. This was not the case further upstream on the Tualatin River. Conifers contributed to the stream would typically remain instream much longer than hardwoods, prior to decay.

Lowland reaches typically have eroding banks, low pool density, high stream turbidity, and fine-textured substrates. In most streams, summer water temperature often exceeds 17.8 C. Suboptimal rearing occurs in these areas during the summer. However, some summer salmonid rearing does occur within these lowland streams. Surveys conducted in summer and fall of 1999 found that cutthroat trout were using sites along lower Chicken Creek and Middle Fanno Creek. However, these surveys were conducted at times when water temperature was well below 17.8 C (Hughes and Leader 2000, Leader and Hughes 2001).

3.1.5.1.5.1 Habitats for non-salmonid species

As described in section 3.1.5.1.1, Pacific lamprey have diverse habitat needs. They prefer cool water temperatures at all life stages. Substrate needs vary by life stage: During the ammocoete stage they utilize stream reaches with mud substrates. On the other hand, juveniles and adults need gravel substrates and flowing, well-oxygenated water. Thus, habitat concerns, such as high water temperature or low dissolved oxygen potentially affect lamprey, both in foothill and valley stream reaches.

3.1.5.1.6 Migration barriers

Barriers to fish passage include both natural and anthropogenic factors. Most migration barriers on smaller tributaries are a result of stream size, gradient, and naturally occurring low flows. On larger streams, migration impedance is partially or wholly due to human activities. Diversions can reduce stream depth, block upstream passage, and/or divert fish from the streams. Stream crossings can block fish passage, either through improperly placed culverts, or in some cases a lack of culverts.

The Oregon Department of Transportation (ODOT) performed a survey of 20 culverts within the watershed. Of these culverts, three were found to be structurally inadequate because of poor culvert condition, migratory impediment, or inadequate passage of high flows. Two of these culverts were on Cedar Creek: one at the Highway 99W crossing, and the other at Garibaldi Road. The third deficient culvert occurred where Old Highway 99W crossed an unnamed tributary of Cedar Creek. Although none of these deficient culverts occurred on streams used by anadromous steelhead, these culverts were considered to provide potential barriers to migration of anadromous lamprey and resident cutthroat trout. All of these culverts were considered to be a high priority for replacement.

3.1.5.2 Warm-water fisheries

Warm water fish are present in the mainstem Tualatin, the lower reaches of Chicken and Fanno creeks and other tributaries, and in ponds (Murtagh et al. 1992, SRI 1990). These include game species such as smallmouth bass, largemouth bass, and yellow perch, as well as non-game species such as yellow and brown bullhead. Fish communities in the Tualatin River mainstem are dominated by these non-native warm water species (SRI 1990).

3.1.5.3 Amphibians

Many amphibians depend on riparian and wetland habitats. Worldwide, the reduction in area of such habitats has resulted in a corresponding reduction in amphibian numbers. Additionally, native frogs in western states have largely been outcompeted by the introduced bullfrog (*Rana catesbiana*). For example, the bullfrog has contributed to the extirpation of the spotted frog (*Rana pretiosa*) from the Willamette Valley (Leonard et al. 1993). Riparian-dependent amphibian Special Status Species[18] in the Lower Tualatin watershed include the red-legged frog (*Rana aurora aurora*), and the western toad (*Bufo boreas*).

Northern red-legged frog (*Rana aurora*) (BS)

The red-legged frog is known to occur at numerous sites within the Lower Tualatin watershed. These frogs generally breed in marshes, small ponds and slow-moving backwater areas. During the non-breeding season they are highly terrestrial, commonly venturing into forested uplands. Past management practices that altered cool, moist riparian and forest floor habitats may have adversely impacted the quality and quantity of red-legged frog habitat within the watershed (Csuti et al. 1997).

Western Toad (*Bufo boreas*) (SV)

Western toads may be present within the watershed. This toad adapts to many habitat types, so it could be found in any aquatic or wetland setting. Although this amphibian is abundant in Oregon, it has been extirpated from many areas (Csuti et al. 1997).

3.1.5.4 Reptiles

Western pond turtle (*Clemmys marmorata*) (FC, SC)

This reptile occurs within the watershed. Populations in the Willamette Valley have experienced steep declines. Introduced predators including the bullfrog, red eared sliders, box turtles, and snapping turtles have been implicated in these population declines (Csuti et al. 1997).

Important habitat includes quiet water habitats, such as ponds, marshes, and slow moving floodplain streams. Pond turtles need basking sites, such as logs and rocks, adjacent to these aquatic habitats (Csuti et al. 1997).

Painted turtle (*Chrysemys picta*) (SC)

This reptile may occur within the watershed, although their main range lies east of the Columbia Gorge (Brown et al. 1995). Populations appear to be stable in most of their range.

Important habitat for painted turtles includes quiet water habitats with abundant vegetation, such as ponds, marshes, and slow streams (Brown et al. 1995).

---

[18] Special Status Species is a federal term incorporating species that are designated for special treatment or attention on various federal and state lists.

3.1.5.5 Other riparian and wetland-dependent species

Riparian and wetland areas provide habitat for many bird species in the Lower Tualatin watershed. These include migratory songbirds, as well as wood ducks and mallards, which nest in riparian areas. Seasonal flooding and farm ponds add to the available habitat for waterfowl. Species using such habitats include Canada geese, whistling swan, mallard, wood ducks, American widgeon, ring-necked duck, lesser scaup, green-winged teal, pintail, and American coot (ODEQ and USA 1982).

3.2 Terrestrial

3.2.1 Vegetation

3.2.1.1 Array and landscape pattern of vegetation

3.2.1.1.1 Vegetation in the Tualatin Plain and lower portions of the foothills

The watershed's valleys and adjacent foothills are within the interior valley zone described in Franklin and Dyrness (1973). Historically, the valley floors in this zone were dominated by overstories of Oregon white oak (*Quercus garryana*). (However, there is evidence that this was less the case in the Lower Tualatin Watershed. See Chapter 4.) Interspersed with the white oak were other tree species including bigleaf maple and Douglas-fir. Common understory plants included western hazel (*Corylus cornuta*), swordfern (*Polystichum munitum*), Saskatoon serviceberry (*Amelanchier alnifolia*), mazzard cherry (*Prunus avium*), common snowberry (*Symphoricarpos albus*), and Pacific poison oak (*Rhus diversiloba*). These hardwood forests were often interspersed with prairies, some of which were created through human actions such as burning. Under natural circumstances, riparian communities in this zone are often forested, with dominant vegetation consisting of bigleaf maple, black poplar, and various willows.

In the foothills, the oak woodlands of the valleys naturally grade into conifer forest. Douglas-fir is naturally a dominant component of the Willamette Valley foothills conifer forest, and under natural conditions, grand fir (*Abies grandis*) and bigleaf maple are also important components (Franklin and Dyrness 1973).

Currently, most of the eastern portion of the watershed has been urbanized. These urban portions comprise roughly 51% of the watershed[19]. Where urbanization has progressed, much of the native vegetation has been removed and replaced with buildings and impervious surfaces. Many exotic species have been introduced into these areas, resulting in a landscape dominated by a mélange of native and exotic species. The best chance for finding native communities in these areas is in special reserves such as the Tualatin Hills Nature Park where effort has been made to eradicate exotic species.

Most of the remainder of the Tualatin Plain and a portion of the adjoining foothills are in agriculture. These agricultural areas comprise roughly 26% of the watershed[20]. Much of the natural vegetation has

---

[19] Derived from analysis of Metro and Washington County land cover and zoning GIS data.

[20] These include lands zoned for agriculture and Ag/Forestry uses. Metro recently commissioned the classification of land use based on EOSAT imagery. This classified data indicate that 24% of the watershed is used for agriculture.

been removed from these areas. Where such vegetation exists in upland zones, it is typically comprised of small stands of Oregon white oak and Douglas-fir. The riparian zone is generally narrow and patchy, with vegetation types varying from riparian forest to herbaceous. The riparian forests are generally dominated by ash, red alder, Douglas-fir, and bigleaf maple (SRI 1990), while riparian shrublands are dominated by Himalayan blackberry, red-osier dogwood (*Cornus sericea*), wild rose (*Rosa nutkana*) and willows. Smaller tributaries and highly disturbed reaches are often vegetated with reed canarygrass and other herbaceous vegetation.

Width of the riparian buffer in the valleys is usually quite limited (Risley 1997). Surveyors connected with the Watersheds 2000 project collected riparian data within urban streams and adjacent rural streams. Sites surveyed within the watershed included Ball Creek, Rock Creek (S), Nyberg Creek, and Saum Creek. Riparian characteristics varied between these creeks, with most sites along all streams except Saum Creek having either non-forested buffers, or buffers less than 25 feet in width (CWS unpublished data).

The buffer along the Tualatin River is somewhat wider than along most tributaries. Aerial photographic analyses performed for the Watersheds 2000 project indicated that the vast majority of the river was bordered by mixed or deciduous forest. Mean buffer width was between 50 and 75 feet, although a quarter of the analyzed stream length was bordered by riparian forest greater than 200 feet in width. In most cases, these wide forested areas occurred on the inside of meander bends. Less than five percent of the riparian area along the mainstem was narrower than 25 feet in width.

3.2.1.1.2 Vegetation in the Tualatin and Chehalem Mountains

Upper portions of the watershed's foothills show characteristics transitional between drier portions of the western hemlock zone and the Willamette Valley foothill conifer forest described by Franklin and Dyrness (1973). Brown and Caldwell (1998) describe the headwater forests of Fanno, Vermont, and Woods creeks as being dominated by species typical of the western hemlock zone. These include Douglas-fir, western redcedar, and western hemlock. Downslope, precipitation generally decreases, and Douglas-fir and Oregon white oak comprise an increasing amount of the forest vegetation.

Currently, Douglas-fir dominates most forested stands in the foothills. These Douglas-fir stands are generally quite fragmented, being separated by residential developments and agricultural plots. The largest contiguous stands are on Parrett Mountain in the Cedar Creek subwatershed, and in the Tualatin Mouth subwatershed. Forest stands also occur in the upper portions of the Tualatin Mountain subwatersheds. These stands are potentially important when considered together with stands along the north face of the Tualatin Mountains (which lie outside the watershed). Forest stands are generally well-stocked, with 85% of these stands exceeding 70% canopy cover (BLM 1999) .

Riparian and frequently disturbed areas are commonly occupied by hardwood species, including red alder, bigleaf maple, and Oregon ash. This riparian forest provides an important (albeit often narrow) strip of connected wildlife habitat.

Stand condition in the watershed is shown in Table 3-14 and Map 3-6. The vast majority (90%) of lands are classified as nonforested (BLM 1999)[21]. Only 1 percent of land area is occupied by stands in the mature structural stage (that is, dominated by trees 20-29 inches diameter at breast height (dbh)). A

[21] It should be noted that the source imagery for this classification was based on Eosat images with a 25 meter pixel resolution. Thus, individual large diameter trees could be present in stands classified within the younger structural stages.

minute portion (0.01%) of land area is occupied by trees greater than 29 inches dbh, indicating that stands in the mature/old growth condition are extremely uncommon. These small stands are scattered throughout the watershed. More than half of these large tree stands are found in the Cedar Creek subwatershed. (However, Brown and Caldwell (1998) note the presence of isolated large trees in the headwaters of Fanno Creek and its tributaries. These urban forest remnants were omitted from the BLM WODIP inventory.) The lack of mature, large-diameter stands limits the ability of forested lands to provide snags, down wood, and instream large woody debris for ecological purposes (Section 3.2.2.3). Younger structural stages dominate forests in the watershed, comprising 9% of total watershed area. These stands are mainly in the small tree stage.

Table 3-14. Size classes of forest stands within the Lower Tualatin watershed.

Size class (inches)	Total area (acres)	percent of watershed
0 to 9	27	0.0%
10 to 19	3,037	4.9%
20 to 29	518	0.8%
over 29	8	0.0%
urban/agriculture	57,660	92.6%
other nonforested	992	1.6%
Total	62,242	100%

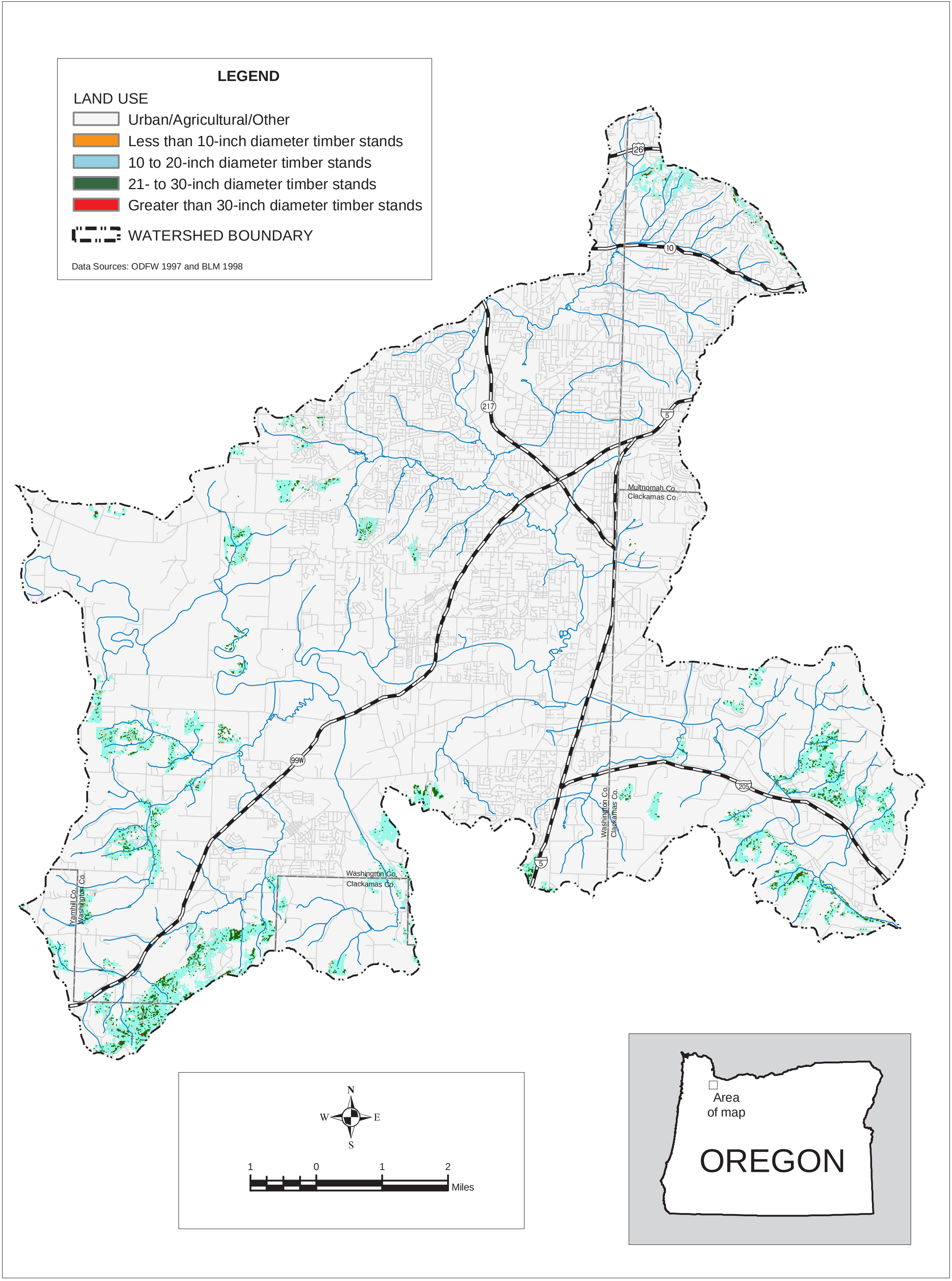
Source, BLM 1999

3.2.1.2 Exotic/Noxious Plants

Exotic weeds have become established throughout the watershed. Such species tend to outcompete native species, resulting in diminished populations of these species and reduced diversity. They tend to be aggressive colonizers on disturbed soils, and typically are found in fields, waysides, and similarly disturbed habitats. Eradication of these exotics is often difficult. In the Lower Tualatin watershed, common exotic plant pest species include Himalayan blackberry (*Rubus discolor*), reed canarygrass (*Phalaris arundinacea*), purple loosestrife (*Lythrum salicaria*), Scotch broom (*Cytisus scoparius*), English Ivy (*Hedera helix*), and thistles (*Cirsium sp.*).

These weed problems are pervasive throughout the watershed. Himalayan blackberry often forms the dominant vegetation in riparian zones. Reed canarygrass is also common in riparian zones, and is particularly pervasive in wetlands. Purple loosestrife is a potential wetland invader. Scotch Broom is common in disturbed areas throughout the watershed, while English ivy and Japanese knotweed are mostly concentrated within the more urbanized portions of the watershed.

In agricultural areas, certain exotic species are determined to be toxic to livestock, or otherwise have a substantial detrimental effect to agricultural operations. The Oregon Department of Agriculture (ODA) designates many such plants as noxious weeds. Listed weeds of particular concern in the Lower Tualatin watershed include Scotch broom (*Cytisus scoparius*), tansy ragwort (*Senecio jacobaea*), and spotted knotweed (*Polygonum sp.*). Although gorse (*Ulex europaeus*) has not been found in Washington



Map 3-6 -- Land Use and Land Cover in the Lower Tualatin Watershed.

County, patches have been found in Columbia, Tillamook, and Clackamas counties. As gorse is an ODA Target (priority) noxious weed, any sightings should be brought to the attention of ODA personnel.

Numerous groups are involved in weed control. ODA provides funds to finance special weed abatement projects and provide cost-share assistance to private landowners. Municipal authorities also sponsor weed abatement grants. These groups, together with OSU extension and the Washington County SWCD provide educational material related to weed control. Finally, community groups such as SOLV and the Tualatin Riverkeepers organize weed-abatement projects.

3.2.2 Terrestrial species and habitat

3.2.2.1 Abundance and habitat of terrestrial species

3.2.2.1.1 Economically important species

Urbanization and forest fragmentation limit the available habitat for big game species. Riparian corridors within the watershed provide habitat for black-tailed deer (SRI 1990, Brown and Caldwell 1998).

3.2.2.1.2 Special status and special attention species

3.2.2.1.2.1 Botanical Species

Special status species include federally listed species and those species listed by the Oregon Natural Heritage Program (ONHP). The ONHP lists species that are of concern because of diminished population or habitat. Those ONHP-listed botanical species potentially found in the Lower Tualatin watershed are displayed in Table 1-3. Of these species, tall bugbane was confirmed by ONHP to be present within the watershed. White rock larkspur is historically known to occur on Parrett Mountain. Comprehensive botanical surveys would likely find other occurrences of ONHP-listed species.

In the Lower Tualatin watershed, special habitats for sensitive species are found on both public and private lands. These include wetlands. The values for wetland habitats are especially important because they are a critical source of biological diversity. Wetland types include relatively large lowland marshes and forested wetlands of the Tualatin Plain, as well as small ponds in the foothills. The location of wetlands identified under the National Wetland Inventory (NWI) is displayed in Map 3-2. Characteristics of these wetlands are summarized in Table 3-15. The NWI represents a conservative estimate of wetland area, as many valley bottom lands that are regularly inundated are not included. Although these wetlands potentially provide habitat for sensitive botanical species, that potential has been reduced in the valley wetlands because of extensive modification related to human uses. In particular, species composition has been altered and exotics such as reed canarygrass have replaced much of the native vegetation.

The Beaverton Local Wetland Inventory (LWI) identified 47 wetlands within its jurisdiction and performed an OFWAM assessment to determine the remaining functionality of these wetlands. All sites except three were considered to provide limited support for wildlife. One site on Weir Creek and two on Woods Creek were considered to provide diverse support for wildlife. All wetlands that had formerly supported fish habitat had lost all or a portion of that function. Hydrologic storage, however, was somewhat better supported. Forty-five wetland sites were considered to have retained this function.

Table 3-15. Characteristics of NWI wetlands in the Lower Tualatin watershed.

System	Acres	%Type	Class	Acres	%Type	Water Regime	Acres	%Type	Modifiers	Acres	%Type
Lacustrine		0.00%	Aquatic Bed	8.1	0.72%	Permanently flooded	0.1	0.01%	Natural	942.5	84.27%
Palustrine	714.7	63.90%	Emergent	304.4	27.22%	Semipermanently flooded	1.4	0.12%	Beaver	0.0	0.00%
Riverine	403.7	36.10%	Forested	196.0	17.52%	Intermittently exposed	542.9	48.54%	Diked/Impounded	47.9	4.29%
			Open Water	536.9	48.00%	Seasonally flooded		0.00%	Excavated	96.2	8.60%
			Scrub-shrub	72.9	6.52%	Inter-Temporarily flooded	170.5	15.24%	Partially Drained/Ditched	31.8	2.84%
			Uncon. Bottom	0.1	0.01%	Saturated		0.00%			
			Uncon. Shore	0.0	0.00%	Sat/Semiperm/Season	403.6	36.08%			
Total	1118.4	100.00%		1118.4	100.00%		1118.4	100.00%		1118.4	100.00%

Source: Analysis of GIS data on Tualatin River Watershed Information System.

Prospects for enhancement for most of these wetlands ranged from moderate to low, although three sites on Fanno Creek had high enhancement potential.

Current efforts to restore wetland habitats have largely been focused on the Tualatin National Wildlife Refuge. Additionally, numerous small wetland restoration activities have taken place, usually in parks or as mitigation projects within the Urban Growth Boundary (UGB). Given willing landowners, there may be potential for wetland restoration outside the UGB. Agencies and organizations such as NRCS and Ducks Unlimited work with landowners to restore and enhance wetlands. However, certain obstacles exist. The cost of permits for wetland projects is often high. Additionally, these projects often require a high degree of maintenance if natural plant communities and wildlife support are desired functions.

Although ponds and other wetland areas in the foothills are generally quite small, they are potentially important sites for sensitive botanical species.

Other sensitive habitat types for botanical species include the few areas containing vegetation with late successional characteristics. Although the vegetation analysis indicates that this type of habitat is extremely rare within the Lower Tualatin watershed, there may be opportunities to encourage development of this habitat type.

3.2.2.1.2.2 Birds

Northern bald eagle (*Haliaeetus leucocephalus*) (FT)

Habitat- Bald eagles utilize snags for roosting and nesting, and prefer sites near open water to ensure food availability. Snags are not abundant in the Lower Tualatin watershed. Fragmented land use patterns will continue to limit the development of habitat for bald eagles within the watershed.

Sites-Bald eagles are known to nest near the Tualatin River National Wildlife Refuge (ONHP 2001).

Pileated woodpecker (*Dryocopus pileatus*) (SV)

Pileated woodpeckers are known to exist within the watershed. Pileated woodpeckers have been observed in the Portland Hills (Brown and Caldwell 1998).

Pileated woodpeckers are dependent on some components of older forests such as large snags for drumming, roosting, nesting and foraging and a good supply of large snags and down wood for foraging. These woodpeckers are often observed foraging in young stands or even clearcuts if large stumps, snags or down wood are present. Current management strategies on the majority of private lands involve shorter timber harvest rotations, which could limit the maintenance or development of habitat for pileated woodpeckers on these lands and potentially lead to local extinction.

Great blue heron (*Ardea herodias*)

Great blue herons are closely associated with wetland, open water, and agricultural habitats within the watershed (Johnson et al. 2001). They are also known to inhabit low and moderate density urban areas when the necessary habitat elements are present. Trees or snags exceeding 15” dbh are necessary for nesting and roosting, while herbaceous habitat is important for feeding. Fields and pastures provide important wintering habitat for herons. Although Oregon populations are considered to be stable, habitat loss in breeding and wintering areas has been suggested as potentially contributing to a decline in heron populations (Johnson et al. 2001).

Aleutian Canada goose (*Branta canadensis leucopareia*) (FT)

Aleutian Canada geese migrate through the watershed in two periods: September through November, and February through March. They are closely associated with herbaceous wetland, open water, and agricultural habitats (Johnson et al. 2001). They prefer to feed in areas where herbaceous vegetation does not exceed six inches in height. Open water habitats are used for refuge from predators.

Peregrine falcon (*Falco peregrinus*) (FE, SE)

Peregrine falcons are potentially present within the watershed. They are generally associated with many habitat types (Johnson et al. 2001). They prefer to nest in cliffs, ledges, and rocky outcrops, but will occasionally nest in snags.

3.2.2.1.2.3 Mammals

Bats

One of the leading factors in the decline of worldwide bat populations is the destruction of roost sites and hibernacula. Most bat species occurring in the Pacific Northwest roost, reproduce, and hibernate in protected crevices that fall within a narrow range of temperature and moisture conditions. There is a strong concern that the loss of snags and decadent trees from the widespread conversion of old-growth forests to young, even-aged plantations, human disturbance and destruction of caves and mines, old wooden bridges and buildings have significantly reduced the availability of potential roost sites.

Bat species that would benefit from additional habitat protection include the fringed myotis, long-eared myotis, long-legged myotis, and the silver-haired bat. All of these bat species are known to inhabit immature coniferous forest and may forage near riparian areas, open areas, and along forest edges. In addition to caves, mines, and abandoned wooden bridges and buildings, large hollow trees may be used for roosting, hibernating, and maternity colonies.

There is little or no information concerning the population health or distribution of these species within the watershed. However, based upon the low abundance of suitable roosts they are expected to be present in low numbers or even absent from the watershed. There are no known sites within the watershed although there are a few specific areas that seem to have potential for occupancy.

During a recent survey, bats were found to be roosting under 18% of Washington County bridges (WCDLUT 2000).

Long-eared myotis (*Myotis evotis*, SU), Fringed myotis (*Myotis thysanodes*, SV) and Long-legged myotis (*Myotis volans*, SU)

These three species potentially found in the Lower Tualatin watershed are small nonmigratory, crevice-roosting bats with widespread distributions that use snags, decadent trees, buildings, bridges and caves for roosting and hibernating.

Silver-haired bat (*Lasionycteris noctivagans*)

The silver-haired bat is a relatively large, migratory, widely-distributed snag and decadent tree-roosting bat, although it may occasionally use buildings and caves for roosting.

3.2.2.1.3 Exotic pest species

Several exotic animal species that were introduced to the Tualatin subbasin have created difficulties to ecological systems and/or economic efforts within the watershed. Nuisance species that occur within the Lower Tualatin watershed include the bullfrog and the nutria.

Bullfrog predation has been responsible for the reduction of populations of many species throughout the western United States. In Oregon, affected species include the Western pond turtle and the spotted frog, which has been extirpated from the Willamette Valley. Outside of the Tualatin subbasin, bullfrogs have been found to be associated with declines in waterfowl production (Leonard et al. 1993).

Nutria (*Myocastor coypus*) were introduced to the United States by fur ranchers between 1899 and 1940. Their diet normally consists of a variety of wetland plants. In the Willamette Valley, they have become a nuisance to farmers by devouring crops and by burrowing into drainage canals. They also devour riparian plantings, thus complicating riparian and wetland revegetation efforts (CSE 2000).

3.2.2.2 Effect of ownership upon habitat management opportunities

The character of the landscape pattern is strongly influenced by management practices within the watershed. While urban and agricultural patterns dominate most of the watershed, the remaining forested lands are strongly dominated by early and mid-seral stage habitats. As a result, the few patches of mature forest in the watershed are dominated by high contrast edge habitat, with the watershed providing virtually no interior late-successional forest habitat. With increased urbanization, this pattern is likely to be perpetuated (and further fragmented) by intensive management on private lands.

As a result of the general landscape pattern the ability of species dependent upon late-successional habitat to disperse within the watershed and the adjacent landscape has been limited. For these species, this has created a high degree of regional isolation.

Successful habitat management depends upon cooperation between landowners. Partnership efforts are complicated by a fragmented ownership pattern. The presence of many owners with differing management emphases complicates coordination of management efforts and contributes to habitat fragmentation.

3.2.2.3 Current distribution and density of snags and down wood

Snags and down wood are characteristically produced by forest stands in mature/old-growth condition. Very few of the timber stands in the Lower Tualatin watershed are in this condition. Incidence of snags and down wood in the watershed appears to be correspondingly low. However, Brown and Caldwell (1998) noted the presence of snags near the headwaters of the Fanno Creek system. Although none of the surveyed areas were considered to be “snag rich”, this does show a limited ability to support functions associated with this habitat element. Additionally, dead ash trees were observed adjacent to the Tualatin River during field surveys connected with the Watersheds 2000 effort. These trees may provide some snag habitat. It is anticipated that many of these trees will eventually fall into the river, where they will provide instream large woody debris.

3.2.3 Forest resources

3.2.3.1 Forest productivity, diseases, and other pathogens

Laminated root rot, caused by the fungus *Phellinus weirii*, is present within forested portions of the Lower Tualatin watershed. *P. weirii* readily infects and kills highly susceptible conifer species such as Douglas-fir and grand fir. Western hemlock is considered intermediately susceptible and western redcedar is thought to be resistant to the disease (Hadfield 1985). All hardwood species are immune. Tree-to-tree spread is through root contacts with infected roots or stumps (Hadfield et al. 1986). Affected trees are often windthrown when their decayed root systems are no longer able to provide adequate support (Thies 1984). Other trees often die standing. Douglas-fir beetles often attack and kill infected trees weakened by the disease. This disease, therefore, results in production of snags and down wood.

P. weirii infection centers often appear as openings in the forest containing windthrown, standing dead, and live symptomatic trees, along with a relatively well-developed shrub layer (Hadfield 1985). Centers may also contain hardwoods and less-susceptible conifers. Disease centers range in size from less than one acre to several acres in size. Centers expand radially at the rate of about one foot per year. Douglas-fir timber productivity levels in *P. weirii* infection centers are generally less than one-half of those in uninfected areas (Goheen and Goheen 1988). Timber losses in diseased stands may double every 15 years (Nelson et al. 1981). High levels of *P. weirii* infection (>25 percent of the area infected) generally preclude commercial thinnings in Douglas-fir stands, especially if disease centers are not well defined.

Insects also have the potential to threaten the health of forest stands. The Douglas-fir bark beetle, *Dendroctonus pseudotsugae*, causes most of the insect damage in the Lower Tualatin watershed. This beetle typically attacks trees that have been weakened by other factors (USDA and USDI 1997). Beetle infestations may reach levels of concern at sites where large amounts of relatively fresh dead wood are present.

3.3 Social

3.3.1 Human uses

3.3.1.1 Economic Uses

3.3.1.1.1 Urban/Rural residential

Washington County is the fastest growing county in Oregon in terms of population. Rapid growth has characterized Washington County throughout the latter half of the 20^{th} Century. Between 1960 and 2000, county population grew by 383% (US Census Bureau 2000). Much of this growth has taken place within the Lower Tualatin watershed. This growth trend is anticipated to continue, generating additional demands upon watershed resources.

Approximately 52% of the watershed is presently developed and/or zoned for urban uses. Urbanization within these portions of the watershed will continue to alter the region's hydrology and place new demands on infrastructure.

Most growth in southwestern portions of the watershed is expected to be associated with rural residential uses. About twenty-two percent of the land in the watershed is zoned for this land use type, primarily in the Tualatin Mouth and Saum Creek subwatersheds. Although land use is less intensive than is the case with urban uses, rural residential uses provide their own challenges. In some cases, they can lead to accelerated erosion and mass wasting. Additionally, rural residential uses typically rely on septic systems, which, if faulty, can contribute to water quality problems.

3.3.1.1.2 Agriculture

Agriculture is an important economic activity in the western portion of the watershed. In 1999, the total value of crops in Washington County was estimated at $197,781,000, with livestock activities adding $13,291,000 in value (USDA and ODA 2000). As the Lower Tualatin watershed contains about 10% of the agricultural land in Washington County, it is reasonable to believe that the watershed produces about $21 million in agricultural products annually.

Economically, nursery crops were the leading agricultural product in Washington County, with 1999 sales of $76 million. Christmas trees and small woodlots, which were grouped together, had 1999 sales of $20 million. Grain and legume seeds were close behind with sales of $19 million. Small fruit and berries ($18 million) and tree fruit and nuts ($12 million) were also important contributors to the economy (OSU Extension 1999).

The 1997 agricultural census summarized land area devoted to crop production for Washington County. These figures showed that the most cropland was devoted to wheat (17,020 acres), with hay (14,539 acres), orchard crops (8,403 acres), and vegetable production (8,167 acres) being the most widespread crops. Wheat and vegetables tended to be grown on relatively large farms, with mean plot sizes of 85 and 66 acres, respectively. Hay and orchard crops were typically raised on smaller farms. Twice as many farmers raised these crops as raised wheat, but mean plot sizes for hay and orchard crops averaged 33 and 18 acres, respectively.

3.3.1.1.3 Forestry

Forestry occurs on a relatively small portion of the Lower Tualatin watershed. Less than 1% of the watershed is zoned for forestry. An additional 9% is zoned for mixed agriculture and forestry, of which an undetermined amount is used for forestry.

The majority of forestry activities take place in small woodlands. The economic importance of these activities is hard to determine because harvest from small woodlands is grouped with Christmas tree production for reporting purposes. Together, these two activities are responsible for estimated 1999 sales of $20 million (OSU extension 1999. See section 3.3.1.1.3). The forest products produced on these lands include timber, firewood, and miscellaneous products such as posts and poles. Additionally, these lands can provide values for wildlife habitat, watershed protection, and aesthetics.

3.3.1.1.4 Mining

Sand, gravel, and crushed rock are all important mineral commodities within the watershed. Sand and gravel are mined from unconsolidated fluvial deposits, particularly in the Rock Creek (South) subwatershed. Basalt is quarried from the Columbia River basalt and the Boring lava units and is commonly used for construction and road maintenance. According to the Oregon Department of Geology and Mineral Industries (DOGAMI) GIS coverage of Oregon mineral resources (contained in Ecotrust 1998) there are currently twenty-seven active quarries and sand and gravel pits in the Lower Tualatin watershed (Table 3-16). Additionally, there are a number of abandoned rock pits (Table 3-17).

Table 3-16. Current quarries in the Lower Tualatin watershed.

Subwatershed	Site	Product	Lat	Long
Cedar Creek	O K BRICKYARD	CLAY	45-21-57N	122-50-58W
Cedar Creek	STILLER QUARRY	STONE	45-21-20N	122-50-11W
Cedar Creek	CORNELL PIT	STONE	45-21-20N	122-50-11W
Cedar Creek	COFFEE LAKE PIT	SAND & GRAVEL	45-21-09N	122-50-28W
Chicken Creek	SAND PIT	SAND & GRAVEL(SAND)	45-22-55N	122-50-03W
Chicken Creek	STEINBAN	SAND & GRAVEL	45-22-49N	122-50-52W
Fanno Creek	DURHAM QUARRY	STONE(BASALT)	45-23-58N	122-45-09W
Hedges Creek	GRAVEL PIT	SAND & GRAVEL	45-22-27N	122-48-29W
Lower Tualatin-King City	GRAVEL PIT	SAND & GRAVEL	45-24-17N	122-48-32W
Lower Tualatin-Scholls	QUARRY	STONE	45-25-32N	122-54-26W
Rock Creek (South)	THOMPSON SAND COMPANY	SAND & GRAVEL	45-23-12N	122-48-26W
Rock Creek (South)	BRINEGAR-BARSTAD	SAND & GRAVEL	45-23-10N	122-48-28W
Rock Creek (South)	ALLPOINT PIT	SAND & GRAVEL(SAND)	45-23-08N	122-48-40W
Rock Creek (South)	VALLEY YARD SUPPLY/ALBERTSON	SAND & GRAVEL	45-23-07N	122-48-39W
Rock Creek (South)	DALES SAND & GRAVEL	SAND & GRAVEL	45-23-02N	122-48-44W
Rock Creek (South)	GRAVEL PIT	SAND & GRAVEL	45-22-59N	122-48-51W
Rock Creek (South)	JOHN D. HAGG	SAND & GRAVEL	45-22-36N	122-48-32W
Rock Creek (South)	QUARRY	SAND & GRAVEL	45-22-31N	122-48-29W
Rock Creek (South)	COMPTON/STILLER	STONE	45-21-32N	122-48-08W
Rock Creek (South)	TONQUIN ROAD QUARRY	STONE(BASALT)	45-21-14N	122-48-45W
Rock Creek (South)	EATON SAND AND GRAVEL	STONE	45-21-11N	122-48-52W
Rock Creek (South)	TONQUIN QUARRY	STONE	45-20-44N	122-48-16W
Summer Creek	TOPSOIL PIT	SAND & GRAVEL(TOPSOIL)	45-26-23N	122-48-46W
Summer Creek	PROGRESS QUARRY	STONE(BASALT)	45-25-46N	122-49-54W
Tualatin Mouth	PYNNS ROCK QUARRY	STONE	45-21-15N	122-39-15W
Tualatin Mouth	SAND PIT	SAND & GRAVEL(SAND)	45-20-56N	122-39-53W
Tualatin Mouth	RAY KIZER CONSTRUCTION CO	SAND & GRAVEL	45-20-20N	122-40-12W

Source: DOGAMI data on Tualatin River Watershed Information System.

Table 3-17. Historical quarries in the Lower Tualatin watershed.

T	R	Sec	Subsec	Subwatershed	Site name	Product
2S	1W	9	SE1/4	LT-King City	Beef Bend Quarry	Basalt
2S	1W	21	SE1/4	Rock Creek S.	Cipole Sand Pit	Sand
2S	1W	33	Center	Rock Creek S.	Gun Club Prospect	Basalt
2S	1W	21,2	N1/2	Rock Creek S.	Onion Flat Sand Pits	Sand
2S	1W	33	SE1/4	Rock Creek S.	Rogers Sherwood Quarry	Basalt
3S	2W	11	NW1/4	Cedar Creek	Sanders Quarry Prospect	Basalt
3S	1W	3	NW1/4	Rock Creek S.	Sudal Quarry Prospect	Basalt
2S	1W	13	Center	Fanno Creek	Tigard Sand and Gravel Pit	Sand/Gravel
2S	1W	24	SE1/4NE1/4	LT-Oswego Canal	Tualatin Abandoned Quarry	Basalt
3S	2W	12	SW1/4NW1/4	Cedar Creek	Votaw Quarry Prospect	Basalt

Source: Schlicker 1967.

3.3.1.2 Recreational opportunities

Recreational opportunities vary between urban and rural portions of the watershed. Urban areas typically have developed recreation opportunities, both indoor and outdoor. Sites supplying outdoor opportunities include parks and golf courses.

Public agencies administer more than 70% of parklands within the watershed. Of these the USFWS, the city of Portland, and the City of Tigard manage the greatest extent of lands. Yet, collectively, these agencies are only responsible for management of 30% of parklands and greenspaces. Thus, management is divided among many different jurisdictions. Metro and individual municipalities are seeking additional opportunities for greenspace preservation in the face of continuing urbanization. Metro sponsors the Greenspaces Technical Advisory Committee (GTAC), which is currently evaluating and prioritizing lands for future acquisition.

Recreational activities afforded by these parks vary with the size and type of the park. Cook Park, for example, affords opportunities for hiking, bicycling, and education. On the other end of the spectrum are small neighborhood pocket parks that provide picnicking and limited sporting activities. Developed facilities within the watershed, such as the Garden Home Recreation Center, afford opportunities for organized sporting activities.

Recreational opportunities in rural portions of the watershed are less common and typically dispersed. Such activities include nonconsumptive activities such as bicycling, walking, jogging, and wildlife viewing. These activities should generally offer low impacts, although there is potential for wildlife disturbance and localized soil compaction. Additionally, the scenery of the area offers opportunities for pleasure driving. This activity places the same demands and risks upon the watershed as other driving activities.

At present, lands administered by USFWS offer limited potential for recreational activities. As yet, visitor facilities have not been developed on Tualatin River National Wildlife Refuge lands. Under most circumstances, public access to these lands is not permitted.Boating is an important activity on the Tualatin River. Metro and individual municipalities are developing access points for boating activities.

Many of these access sites are associated with parks or existing bridges. Additionally, many private docks are present along the river, and private boat rentals are common.

3.3.1.3 Cultural resources

Numerous discoveries of Native American artifacts have been recorded throughout the watershed. A significant archaeological site has been discovered on the Tualatin River National Wildlife Refuge. However, no specific cultural resources issues have been identified in conjunction with this watershed assessment

3.3.2 Roads

3.3.2.1 Road density

There are approximately 906 miles of roads within the Lower Tualatin watershed, as listed on the roads layer of the Tualatin River Watershed Information System ((TRWIS) Ecotrust 1998). Road density provides an indication of the degree of habitat fragmentation caused by roads, as well as potential road-related mass wasting and sedimentation problems. For the watershed as a whole, mean road density was 9.3 miles road per square mile of watershed area. The density of roads varies among the subwatersheds, ranging from 17.2 mi/mi^2 in the Ash Creek subwatershed to 3.4 mi/mi^2 in the Lower Tualatin-Scholls subwatershed (Map 3-7). These figures were determined through use of GIS. Due to legacy roads and new roads, actual road density may be somewhat higher than the numbers cited.

These roads are mostly concentrated in the urbanized subwatersheds. It is expected that most new road construction will take place in and around these subwatersheds as infill takes place within the UGB and rural residential construction occurs adjacent to the UGB. This is of particular concern in the subwatersheds of the Tualatin Mountains, where increased urbanization occurs on steep, unstable slopes.

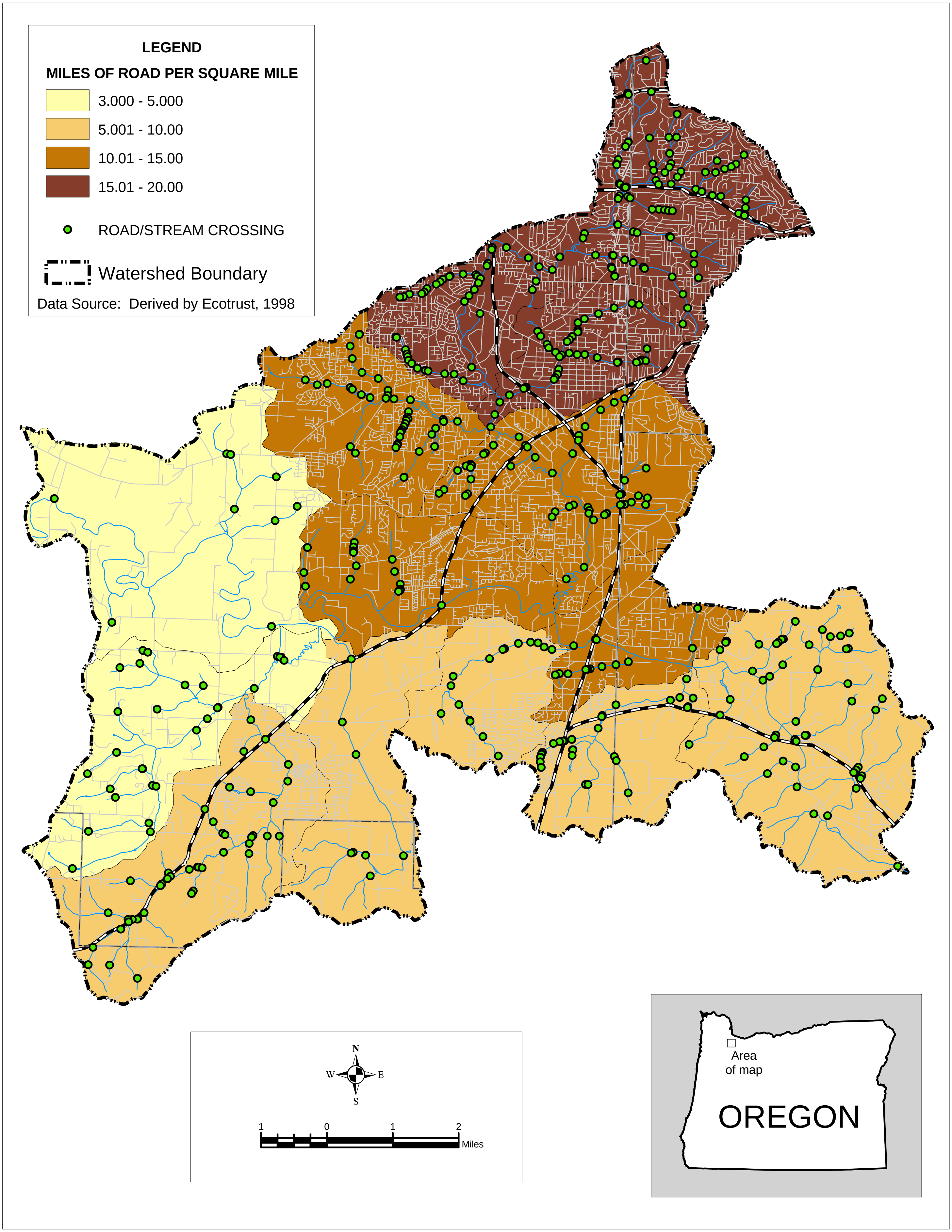
Most issues related to roads are addressed in the report sections devoted to erosion and sedimentation, hydrology, and aquatic species and habitat.

3.3.2.2 Stream crossings

Stream crossing density provides an indicator of the potential for road-related migration impediment and sediment delivery to streams. The TRWIS identifies 486 stream crossings within the watershed[22]. For the watershed as a whole, mean stream crossing density was 5.0 crossings per square mile of watershed area. High stream crossing densities were concentrated in the highly urbanized subwatersheds draining to Fanno and Saum creeks. The highest density of stream crossings, 10.2 crossings per square mile, was found in the highly urbanized Upper Fanno Creek subwatershed.

---

[22] Attribute data within the "T6" sixth field watershed shapefile.



Map 3-7 -- Road Density and Road/Stream Crossings in the Lower Tualatin Watershed.

Chapter IV: Reference Conditions

4.1 Introduction

Reconstruction of reference conditions largely depends upon two sources. First, limited records are available giving the impressions of explorers and pioneers as they first saw this region. Although their information was not collected according to the scientific method, it offers valuable firsthand insights into the general distribution of landscape characteristics at the advent of Euro-American settlement. To a large degree, their impressions taken at specific locations can be extrapolated to describe strata within the entire watershed. That is, upland characteristics described at a specific valley location would be expected to be similar to nearby upland valley sites, and would likely be different from the characteristics of valley riparian zones.

The second source is the extrapolation of these impressions based upon geographical, geomorphic, and biological principles. For purposes of this report, the reference conditions are assumed to describe the period prior to European settlement. At that time, geological and climatic influences would be similar to those currently experienced. Given pioneer accounts of the vegetational structure of the watershed, along with scientific studies, we can formulate reasoned deductions related to erosion, hydrology, stream channel, and water quality parameters. Such deductions form a major part in the formulation of the reference conditions described below. They are not to be taken as absolute truth, but rather a reasonable description of assumed watershed condition prior to the extensive changes that accompanied European settlement.

4.2 Erosion

Prior to human settlement, the majority of the Lower Tualatin watershed was heavily forested, with a large proportion of the watershed in old-growth timber. Such conditions would have provided little opportunity for surface erosion. Most surface erosion would occur in episodic pulses for about 20-40 years following stand replacement fire events. Although intervals between these fire events would vary widely, it is reasonable to believe that low surface erosion rates characterized the watershed most of the time (Agee 1993, BLM 1997). Additionally, local increases in surface erosion would have occurred at locations where the tree canopy had been disturbed by large storms, wind, or disease.

Mass wasting processes would also have been episodic, being mainly associated with fires and major storm events. The rate of mass wasting (as well as surface erosion) would have been lower than those presently observed. Although many hillslopes were naturally unstable, they lacked the cuts, fills, and exposed soil surfaces typically associated with roads, residences, and agriculture.

Streambank erosion would probably have occurred at lower rates than those presently observed. Survey data and pioneer accounts from the 1850's indicate that near-stream areas of the Tualatin subbasin were heavily vegetated (Preston 1852; Hesse 1994, SD#1 1951, Martinazzi and Nygaard 1994). Although natural stream meandering would have resulted in bank erosion, the increased resistance provided by vegetation, roots, and large wood in streams would have slowed this process.

Where erosion did occur, less sediment would probably have been delivered to streams than is presently the case. Due to high relative humidity and lower fuel temperatures, many riparian zones were more resistant to fire than upland sites (BLM 1997). This effect was strongest in lower watershed elevations. Where riparian vegetation and surface cover remained intact, it would have provided resistance to surface flow and encouraged sediment deposition. Substantial wetland areas and floodplains would also have provided opportunity for sediments to settle outside the active channel.

These erosion processes would likely have increased following settlement by Native Americans. The use of fire would have increased the frequency of exposed soils, thus leading to increased surface erosion. The use of nearstream habitats could also have contributed to a higher incidence of streambank erosion. However, the magnitude of such increases is unknown, and appears to be negligible relative to the erosional changes that occurred later with European settlement.

4.3 Hydrology and water quantity

4.3.1 Foothills

In the foothills, it is likely that hydrologic processes were characterized by greater infiltration and less surface runoff than is currently observed. Forested conditions would have led to high rates of interception. Thick layers of forest duff would readily have allowed infiltration. The net effect of increased infiltration on subsurface water supplies is unclear, because forested conditions would also have led to increased rates of transpiration.

Stand replacement fires (both natural and human-caused) would have altered the surface hydrology. Diminished soil infiltration capacity, along with decreased ground cover would have resulted in increased surface storm runoff. Reductions in evapotranspiration rates could have increased the quantity of water available to streams for a number of years following these fires. During this period, increased summer flow would likely have resulted. These flows would gradually diminish as the fire-stricken areas revegetated themselves. Where these stands were replaced with phreatophytic hardwoods, evapotranspiration rates may have been above original levels, resulting in decreased streamflow (Meehan 1991).

Given the low frequency of natural disturbances, it is likely that much less of the watershed was covered with hardwoods than is presently the case. With fewer hardwoods, less evapotranspiration would have occurred, resulting in increased water availability for aquatic life.

4.3.2 Tualatin Plain

Although the hydrology of the Tualatin Plain was substantially different than that now experienced the nature of those differences are unclear. Flow modeling by the Tualatin River Flow Management Technical Committee indicate that natural flows in the Tualatin River were lower than those currently experienced (TRFMTC 1999). The river would have lacked the flow augmentation that is currently provided by impoundments and releases from wastewater treatment plants. This would have been partially offset, however, by the lack of flow diversion.

Peak flow characteristics would also have been different. Although reservoirs would not have provided flood storage, peak flows would likely have been lower due to retention in floodplains and wetlands. Additionally, relatively low proportions of impervious area would have contributed to detention of flow.

During winter flooding events, water would have been stored for substantial periods of time in these floodplain and wetland areas. In addition to benefits for sediment control and wildlife, these detained waters would have seeped slowly back into the creeks, thus moderating flood peaks and increasing the water available during lower flows. Some of this water would also have become available to replenish subsurface supplies. Additionally, greater in-channel vegetation and large woody debris would have reduced flow velocity and dissipated stream energy during high flows.

Although upstream floodplains and wetlands would have helped to moderate flood peaks, flooding would have been a frequent occurrence. Factors contributing to the flooding of the Tualatin River include the low gradient of the stream, topographic constriction just downstream of the City of Tualatin, and under reference conditions would have included the congested nature of the channels.

4.3.2.1 Extent of wetlands in the early Lower Tualatin watershed

Early trapper reports note that most lowland portions of the Tualatin subbasin were wet and swampy (Cass and Miner 1993). Physical factors played the greatest role in creating these wetlands. Flat topography impeded the flow of surface water, while low soil permeability decreased infiltration. Additionally, locally high water tables would rise to the surface in the winter, creating standing pools of surface water (Hart and Newcomb 1965).

Large beaver populations in the Tualatin subbasin significantly contributed to wetland area (Cass and Miner 1993). Beaver dams blocked streams, resulting in decreased water velocity and extensive flooding. The ponds and marshes created by these dams recharged the water table. Additionally, they improved water quality by removing sediments and nutrients from the water column. The nutrients stored in the wetlands were subsequently processed to forms more useful to many types of aquatic life (Shively 1993). These shallow wetland areas provided habitats suitable for many amphibian, aquatic and botanical species.

No record exists of the exact extent of wetlands under reference conditions. However, the former extent of lowland wetlands can be estimated by determining the total amount of the watershed underlain by hydric soils. By this measure, about 6,500 acres of the watershed were wetland under reference conditions. Based on historical records and soils, it appears that the majority of this wetland would have been seasonally flooded.

Extensive wetland areas were described during 1851 and 1852 surveys. Although the largest wetlands lay along Rock Creek (South) and Hedges Creek, virtually every lowland tributary upstream of (and including) Saum Creek was bordered by swamps. Additionally, portions of Fanno Creek upstream of Summer Creek also were identified with extensive swamp area.

4.4 Stream Channel

Stream channel characteristics would presumably have been relatively stable prior to the time of human influence. Large inputs of woody debris during major storms were likely to have been relatively stable over time, and would likely have persisted through the periods between disturbances. Sediment would have been input to streams and transmitted through the stream system in pulses corresponding to periods of high landslide rates. The routing of water and sediment through the watershed was controlled by the extent and condition of riparian vegetation, especially in the lower watershed where gradients are lower and the floodplain more developed.

As indicated by early surveys and historical accounts, most stream channels throughout the Lower Tualatin watershed likely had abundant riparian vegetation (Preston 1852; Martinazzi and Nygaard 1994). In most areas, the natural vegetation was riparian forest. Riparian trees and their roots restricted channel width (Shively 1993). Additionally, stream channels commonly had jams of woody debris. At times, these log jams were very extensive along the Tualatin River. Jams ranging from 300 to 5,000 feet in length were observed in the valley reaches (Sedell and Luchessa 1982). The abundance of woody debris would have contributed to diverse instream structure.

More information exists regarding channel planform than cross-sectional geometry. Then, as now, the Tualatin River upstream of the riffle and the lower reaches of some tributaries displayed a sinuous pattern. Although few historical accounts of channel bank height and width exist, the high silt-clay content of channel banks and substrate indicates that channels were deep and narrow. Downstream of the city of Tualatin, channel planform would have been determined by the hills confining the channel. Thus, the stream channel would bear the same, relatively straight, configuration that is currently in evidence.

4.5 Water Quality

Water quality prior to human intervention was partially a function of the condition and extent of riparian vegetation. Water quality would generally have been good, but would have varied during periods of riparian disturbance.

Under undisturbed conditions, abundant stream canopy on the tributaries would have provided for stream temperatures cooler than those currently experienced. On the Tualatin River mainstem, likewise, there are indications that water temperature would be somewhat cooler under natural conditions. During water temperature modeling based on 1994 climatic conditions, Risley (1997) found that simulated "natural" summer water temperatures would be substantially lower than those currently prevalent. However, water temperatures would still exceed 17.8 C for a substantial period within the summer months. Although there would have been no wastewater releases to the river and maximum canopy is assumed by the model, the width of the river would still have exposed substantial surface area to solar heating. Additionally, the river traverses a substantial length of valley upstream of the watershed. This, together with slow water velocity, indicates that water would have had substantial opportunity to heat to ambient levels.

During periods of major disturbance of riparian vegetation from fire or windthrow, water temperatures were elevated. Stream temperature would gradually be reduced to predisturbance conditions as new riparian vegetation grew in these disturbed areas.

It is unclear what the temperature regime would have been for wetland areas, nor for water contributed to streams from these wetlands. Although water stored in wetlands would have received solar heating, much of the wetland contribution to streamflow would have proceeded through subsurface pathways, where temperature would have been moderated by the adjacent soil.

Sediment levels were similarly affected by disturbance events. Where the riparian vegetation was intact, it would tend to restrict sediment delivery to streams, both through binding of soil and detention of sediment-laden runoff. Following disturbance, these factors limiting sediment contributions would be reduced, leading to accelerated sediment contribution to streams.

Nutrient levels in streams are likely to have been low under reference conditions. This is indicated by the low erosion rates, lack of human inputs, and the large amount of wetland storage that is considered to be prevalent at the time. Although some phosphorus would have been contributed through groundwater inputs from sedimentary rocks, valley sediments, and wetlands, surface inputs from erosion and runoff would have been low. For the same reasons, instream concentrations of nitrogen would have been lower than current levels. Nutrients would have been available from naturally occurring organic detritus. However, contributions of these substances from fertilizers, livestock, sewage and urban runoff would have been absent.

These factors indicate that stream water had relatively high concentrations of dissolved oxygen. Lower water temperatures would have increased stream capacity for oxygen, while reduced inputs of organic waste and nutrients would have reduced the biochemical demand for oxygen.

Contributions of bacteria would have been supplied by wildlife. However, these contributions were probably much lower than those presently attributable to livestock raising and septic systems.

4.6 Aquatic Species and Habitat

4.6.1 Fish

Historical fish habitat information is not available at this time. The amount and condition of fish habitat can be inferred from general vegetation descriptions of the land and estimated human impacts. It can be assumed that prior to extensive settlement, land use conversion, and road construction, fish habitat was in better condition. For example, the prevalence of large woody material in stream channels created diverse instream structure and pools desirable for fish production and survival. Dams, water diversions, and culverts did not impede fish passage. Water quality was generally better except after major fires, landslides, and other large-scale catastrophic events.

Due to the mature state of most of the riparian timber in the watershed, streams received ample contributions of large woody debris. The abundant log jams would have contributed to pool development and instream habitat diversity, which would have been beneficial to aquatic life. Additionally, mature riparian timber provided ample shade for tributary streams. The resulting low water temperatures and high dissolved oxygen levels would have benefited salmonids and many other cold-water aquatic organisms.

Benefits from large woody debris would have extended to streams within the valleys. The extent of spawning habitat would likely have been greater than presently exists because less fine sediment would have covered the spawning gravels (Greg White, 2001 personal communication). Additionally, instream LWD would have helped to retain these gravels in suitable locations. The increased incidence of LWD-induced pools, as well as lower temperatures, would have provided better salmonid rearing habitat than is now currently available.

Prior to stream clearing and channelization, stream meanders would have provided greater length of total aquatic habitat. Additionally, this habitat would have been more complex. Instream wood provided cover elements for fish, as did tree roots in the banks and hanging vegetation.

It is likely that steelhead trout were the only native anadromous salmonid species with substantial populations in the Lower Tualatin watershed during the reference period. Although chinook salmon occasionally migrate along the mainstem of the Tualatin River, it is unlikely that the Tualatin subbasin ever supported a large population of chinook salmon (Ward 1995).

Other streams throughout Western Oregon have documented declining trends for most salmonid species over the last century. This, along with the availability of better habitat, indicates that the watershed's historic populations of cutthroat trout and steelhead trout were larger than those occurring today. However, historical references to fish populations and habitat within the watershed are difficult to find.

4.6.2 Wetland and riparian dependent species

The relatively large extent of wetland and riparian areas would have provided a high carrying capacity for species dependent on seasonal, shallow wetland habitats. Historical accounts from nearby watersheds indicate that great numbers of waterfowl utilized these habitats (Fulton 1995). Small wetlands created by beavers provided particularly important habitat for pond turtle populations. Trees felled by beavers would have provided habitat for basking, foraging, and refuge (Altman et al. 1997).

These extensive wetland habitats could also have sustained large amphibian populations. Amphibian communities would have consisted of native frog and salamander species. Many of these species, as well as the Western pond turtle, have dwindled since the introduction of the exotic bullfrog.

4.7 Vegetation

4.7.1 General regional characteristics

The watershed lies within the interior valley zone described by Franklin and Dyrness (1973). These authors note that climax vegetation within this zone is uncertain, although climatic factors indicate that these areas would naturally have been dominated by forest . Depending on location, these forests could have been dominated by Douglas-fir, grand fir, or Oregon white oak. Although early settlers found oak savannas and prairies throughout much of the Willamette Valley, this was largely an artifact of burning by Native American tribes. It is likely that a substantial portion of the Lower Tualatin watershed was covered by extensive tracts of old-growth forest broken by patches of younger forest, recently burned areas, and wetlands. According to Oliver and Larson (1990), the general structural features of these old-growth stands typically include large, live trees; large, standing dead trees; variation in tree species and sizes; large logs on the forest floor in various stages of decay; and multiple-layered canopies. These stands also have a great deal of horizontal and vertical diversity.

To gain an appreciation of the characteristics of these forests, we can refer to the interim minimum standards for old-growth Douglas-fir described by Franklin et al. (1986). These include:

- Two or more species of live trees with a wide range of sizes and ages.
- Eight or more large (>32 inches diameter at breast height (DBH)) or old (>200 years) Douglas-fir trees per acre; however, most stands have 15 to 45 trees per acre, depending on stand age and history.
- Twelve or more individuals of associated shade-tolerant species per acre, such as western hemlock or western redcedar, that are at least 16 inches DBH.
- More than 15 tons of down logs per acre, including 4 pieces per acre more than 24 inches in diameter and greater than 50 feet long.

- Four or more conifer snags per acre. To qualify for counting, snags must be greater than 20 inches in diameter and more than 15 feet long.

Other features of these old-growth forests include a dense, multiple-layered canopy; decadence in dominant live trees as evidenced by broken or multiple tops and decay; and shade-tolerant species, such as western redcedar, in canopy gaps created through the death of the dominant Douglas-fir trees.

Wildfire, wind, and disease were the primary disturbance agents influencing the development of these stands. Wildfire appears to have been the most significant of these agents (BLM 1997). In western Oregon, these fire events were episodic: they occurred at irregular, generally widely spaced events. Although estimates of fire frequency in western Oregon vary, one widely used reference figure estimates an average interval of 230 years between these events (Agee 1993). These fires were typically associated with east wind events (Teensma et al. 1991). These rather infrequent fires, however, were high-intensity, catastrophic, stand-replacement events.

Following Native American settlement, the incidence of fire increased. Although the proportion of the fires attributable to human action is uncertain, it seems likely that human-caused fires dominated the pattern of fire occurrences in the region both before and after European settlement. Lightning was probably not a major cause of fires; especially since fire protection and cause determination began in 1908.

Fire results in both the creation and loss of down wood from the system. Large pulses of down wood have been noted following stand-replacement fire events (Spies et al. 1988). Following fire in an old-growth western hemlock/Douglas-fir forest, there was a 10-fold increase in snags. In addition, the total biomass of down wood increased from 244 tons/acre in the old-growth stand to 565 tons/acre in the newly burned stand (Agee and Huff 1987).

Major wind events associated with winter storms also may have influenced the development of these stands. Windthrown trees add down wood to the forest floor, as well as creating various-sized canopy gaps that support species such as western hemlock and western redcedar. In addition, major windthrow events create conditions for population build-up of the Douglas-fir beetle. Subsequent tree killing by these beetles further adds to the snag and down wood component of these forests as well as creating additional canopy gaps.

Laminated root rot, caused by the fungus *Phellinus weirii*, is widespread and probably had an important influence on the structure of many stands in the watershed. *P. weirii* is a native root pathogen that readily attacks and kills Douglas-fir (Thies and Sturrock 1995). *P. weirii* and similar pathogens creates snags and gaps in the canopy where shrubs, hardwoods, or shade- and disease-tolerant conifer species occupy these various-sized openings. In addition, infection predisposes trees to windthrow. Live infected trees are susceptible to attack and killing by the Douglas-fir beetle. This disease, therefore, is a major source of down wood and snags.

Prior to European settlement, exotic weed species were not abundant on the landscape. There were, no doubt, a few populations of exotic species introduced through animal migration and Native American travel. Many of the exotic species currently within the watershed were brought into the area as ornamentals, to control erosion processes, or entered as seeds or spores on vehicles or clothing.

4.7.2 Vegetational characteristics of the foothills

Prior to European settlement, vegetation characteristics for the foothills would have been similar to those described in the previous section. The land would have been mostly forested with timber in the mature/old-growth structural stage. Interspersed in this sea of old-growth were stands of younger timber where stand-replacement fires had occurred.

The landscape that the pioneers described indicates that the majority of the foothills were well forested. The Portland hills, for example, are described as being forested with “timber fir, cedar, maple and dogwood, considerable dead and fallen”. It is not immediately apparent whether the dead and fallen timber was the result of fire or natural senescence. However, it does indicate the existence of a sizeable amount of down wood. Similarly, other hills within the watershed as described as being covered with fir forest, often associated with cedar and maple.

Fire appears to have played an important role in development of the 1850s era foothill vegetation pattern. An 1852 survey map describes Bull Mountain as being vegetated with “burnt, dead, and fallen timber” (Preston 1852). Similar descriptions have been found for the portions of the Chehalem Mountains outside the watershed.

4.7.3 Vegetational characteristics of the valleys

In the mid-1800s, the Tualatin Plain was a forested region interspersed with wetlands and prairies. These prairies, which generally lay adjacent to swamps or riparian forests, provided valuable grazing and farmland. In the Lower Tualatin watershed, however, these prairies were relatively uncommon, a factor which contributed to the relatively late settlement of this region (Bourke and DeBats 1995). The largest of the prairies within the watershed occupied an area of 160 acres near the mouth of Chicken Creek (Preston 1852). Other prairies were described by early surveyors east of Onion Flat, and along the Tualatin River between Rock Creek (South) and Fanno Creek.

The majority of the Tualatin Plain was forested with Douglas-fir, often associated with ponderosa pine, western redcedar, and bigleaf maple . The understory in these forests varied according to forest density and structural stage. In the dense forest between Tualatin and Moore’s Mill, it is described as “thick”. However, a more open forest is suggested for Middle Fanno Creek, where dominant undergrowth of fern, hazel, salal, thimbleberry, rose, and briers is mentioned.” Amidst these fir forests, openings are mentioned.

The Willamette Valley ponderosa pine would likely have been an important component of stands that Euro-American settlers found in the mid-1800’s. Unlike the eastern Oregon subspecies, the Willamette Valley ponderosa pine has the ability to thrive under moist soil conditions. Additionally, mature trees develop thick bark that enables them to resist low and moderate intensity fires. Thus, the increased fire frequency that accompanied burning by natives would have resulted in stands of pine and oak adjacent to the prairies (T. Nygren, forester, personal communication 2000).

Oak woodlands appear to have been uncommon in the watershed. Surveyor accounts only mention white oak in the middle Fanno Creek area, where they describe it as an associate with fir and yellow pine.

4.7.4 Wetland vegetation

The vegetation of the wetlands within the watershed would have varied with wetland type and period of flooding. Although most swamps shown on 1852 survey maps are not accompanied by vegetation descriptions, those that are usually refer to a forested wetland type. For example, the swamp along Rock Creek (South) is noted as being vegetated with "willow, alder, hard-hack, and western ash". (However, Martinazzi and Nygaard (1994) states that the area around Cipole was not forested.) This is similar to the description for the wetlands adjacent to Beaverton Creek.

Other wetland types were also present in the watershed. Cass and Miner (1993) describe marsh grasslands within the prairies. Because of the spread of herbaceous invasive plants, it is difficult to ascertain the dominant species within these marsh communities.

4.7.5 Sensitive plant species

It is difficult to reconstruct the abundance and distribution of sensitive plant species during the reference period. Factors complicating historical information regarding survey and manage species and other sensitive plants are as follows:

- These species were only recently designated as sensitive or endangered. Thus, they would not have attracted special attention from biologists;
- Many of these species were not discovered or described until recently;
- Survey and inventory in the past has predominantly been limited to vascular plants (even vascular plant surveys are very limited);
- Sightings are few and widespread for most plant species, indicating large gaps in range information;
- Only the most rudimentary of ecology data is available for many species; therefore, habitat requirements are essentially unknown for most of these species, historically and presently; and,
- Sighting location information is often general, with little specific information available.

Those species dependent upon old-growth forest habitat, as well as riparian and wetland species, would have had a large area of available habitat relative to current conditions. It is likely, therefore, that these species were more abundant, and more broadly distributed, than is currently the case.

4.7.6 Terrestrial species and habitat

Prior to human settlement, the Lower Tualatin watershed was made up of larger blocks of later seral stage forests comprised of a wide range of tree sizes, large amounts of down wood, and abundant large snags. This situation undoubtedly provided habitat for those species dependent upon, or which would utilize larger blocks of interior forest old-growth habitat. Species that are presently of concern in the Tualatin subbasin such as the pileated woodpecker benefited from the historical habitat condition.

The contiguous nature of the landscape pattern facilitated the free movement of these species throughout the watershed and throughout the region. Old-growth habitat conditions extended down into moist riparian areas and shaded the streams, which contained numerous pools as a result of many large logs and debris jams. These riparian areas functioned as corridors for wildlife including amphibians, otter, elk, and cougar.

Abundant habitat suitable for spotted owl existed prior to settlement. The owls benefited from extensive old-growth forest that would have provided many sites for nesting and roosting.

The structure of these forest stands would have provided habitat for other sensitive avian species. These forests would also have provided abundant snags for bald eagle nesting. This, together with abundant fish stocks, would have contributed to bald eagle populations.

The Columbian white-tailed deer (*Odocoileus virginianus*) occupied prairie habitat throughout the Willamette Valley and the valleys of its tributary streams (Verts and Carraway 1998). Shortly after settlement, these deer were extirpated from most of their range in Oregon. Remnant populations are found in Clatsop, Columbia, and Douglas counties. The Columbian white-tailed deer is currently listed as endangered under the federal Endangered Species Act.

4.8 Human

4.8.1 Historical changes in landscape pattern

Human occupancy in the Lower Tualatin watershed has been a major source of change (Table 4-1). The progression of some of the activities leading to changes in watershed conditions is given below.

4.8.1.1 Human uses prior to European settlement

The Tualatin Indians (also known as the Tuality, or Atfalati), occupied a number of small villages in the Tualatin subbasin. Tribal use appears to have extended throughout the watershed, and numerous accounts abound of Tuality camps and artifacts (e.g. MacWilliam and Mapes 1984, Sherk 1936, Martinazzi and Nygaard 1994).

Undoubtedly, Tuality settlement resulted in some changes to watershed conditions. Although these changes are difficult to quantify, they were much smaller than those that ensued following Euro-American settlement. Many tribal activities occurred near bodies of water. This could have resulted in changes to water quality.

It is likely that greatest changes that the Tuality brought to watershed processes were through the use of fire. Evidence exists that the Tuality used fire for agriculture, although not to the same degree as other Oregon tribes (Cass and Miner 1993). For example, early accounts indicate that such burning regularly took place on the Chehalem Mountains (Laurel Ladies Social Club 1977). During dry, east wind conditions, some of these fires likely became very large and consumed some of the old-growth forest in the area. Where burning frequently occurred, this would have favored species composition toward oaks, shrubs, and herbaceous plants (Agee 1993, Franklin and Dyrness 1973). Besides altering the vegetation of these areas, this burning would have increased surface runoff and erosion.

Table 4-1. Timeline of events in the Lower Tualatin watershed since the 1830s.

Date	Event
1846	Augustus Fanno settles on 640 acres near Progress. Part of the claim lacks trees.
1847	Fanno makes land claim on September 22. This is the first land claim in Washington County.
1847	J.M. Moore establishes claim at Mouth of Tualatin.
1849	J.M. Moore builds lumber mill and grist mill near mouth of Tualatin.
1850s	Indians have campsite "just north of Graham land claim, where they gather wild bulbs, seeds, and aromatic herbs."
Early 1850s	Pioneers hold camp meetings at Progress.
1850s	Sweek builds sawmill in Tualatin to provide ties for the railroad.
1850s?	Cummins drains swamp near Cipole and becomes "first to raise onions in Cipole area".
1850	Denney makes land claim along Fanno Creek and soon builds a sawmill and dam on the creek.
1850	At an unidentified date prior to this time, an Indian village located near mouth of Fanno Creek.
1851	Mr. Brown states that two feet of water over rapids at his ferry during low flow.
1852-53	Massive flooding in Tualatin.
1853	A.Z. Hall establishes land claim at site of Sherwood. He soon builds a sawmill along Cedar Creek.
1853	W.V. Johnson records that Tigard area is late being settled because of heavy timber. (first settlers around 1851).
1854	J.A. Taylor establishes ferry.
1856	Narrow gauge railroad completed from Lake Oswego to the Tualatin River, thus facilitating log transport to the Willamette.
1856	Galbreath ferry in Tualatin is replaced by a bridge.
1856	Hillsboro-Portland (Canyon) Road completed.
1857	J.A. Taylor builds toll road into Portland.
1858	J.A. Taylor replaces ferry with bridge.
1861	Flood on Willamette
1865	Albert Alonzo Durham settles near mouth of Fanno Creek. He soon builds gristmill and sawmill.
1870s	Taylor's Ferry Road, a corduroy road, is only road from Tualatin Valley to Portland.
1870's	Augustus Fanno is "main producer of onions in Oregon".
1873	Lake Oswego Canal completed.
1879	George Saum buys property along Saum Creek, dams the creek and establishes a mill there. The original mill is capable of 1,000 board-feet per day.
1880	Grain from Tigard is hauled to Durham to be milled.
1880	Major storm blows down trees and fences. Tualatin River near Tigard recorded as "very high and still rising".
1883	Gristmill owned by J.C. Smock about 1 mile north of Sherwood burns to ground. He rebuilds "on site of Claire Smock House".
1885	J.C. Smock lays out Sherwood in response to construction of railroad.
1886	First Tigardville post office established.
1887	Construction of Oregon-California railroad leads to end of steamboat travel on the Tualatin.
1888	Letter notes that Tualatin River "has become choked up since 1880"
1890s	Court orders Lake Oswego industrial interests to stop putting flashboards up in Lake Oswego Dam (because of neighbors' flooding problems).
1890s	Smiths buy Savage sawmill (in Tualatin) and move it closer to the Tualatin River.
1890	Brickyard built in Smockville. Topsoil spoil piles from this operation were still present in 1935.
1890	Flooding in Tualatin.
1891	Electric rail line built to haul cord wood to paper mills. An average of 100 cords a day are hauled.
1891	Cows and pigs "run at large" on Smockville streets.
1891	"Road [from Sherwood to] four corners was so narrow that anyone traveling in a buggy or wagon needed to take care that the hazel brush didn't switch him in the eyes."
1892	J.L. Smith clears a log jam 3/4 mile in length about five miles below Scholls Bridge.
1893	Land near junction of Beef Bend and Elsner Road need extensive clearing to be farmed. Similar difficulties are recorded elsewhere in Tigard in 1910.
1893	Smockville brickyard ceases production.
1894	Tualatin River channel clear between Lake Oswego Dam and Hillsboro through efforts of Oswego Iron Company
1895	Minimum low water depth of Tualatin River between Hillsboro and the Lake Oswego Dam is recorded as 3 feet.
1895	Fourteen bridges cross the Tualatin River.
1895	Cipole is known on maps as "Sand Pit".
1895	George Saum buys Durham Mill and moves it onto his property. This upgrades his capacity to 5,000 board-feet per day.

late 1890s	Photo shows logging at RM 0.5 of Tualatin River. Tree diameters are very large. Logging appears to be taking place to river edge.
1900	About this time, Oregon Iron and Steel company raises dam by two feet. Dam is destroyed by locals in 1906.
1901	Oregon City Mills receiving sawlogs from Tualatin.
1901	Charles Spaulding Company makes log drive of one million board feet down Tualatin River to Oregon City paper mill.
1901	"Wood camps on the Tualatin River, Clackamas County, are cutting 400 cords daily, of which 200 cords are going to the Oregon City paper mills."
1903	Standard Brick and tile company formed in Sylvan.
1906	Rock hauled into Sherwood to improve decrepit streets.
1907	William Schamoni settles in Tigard and afterwards builds Germania Hall, the first building in downtown Tigard.
1907	Smith builds brickyard in Tualatin. About this time, Nyberg is quarrying stone from his land.
1907	Boone's Ferry Road converted from corduroy to gravel.
1910	Gustav Schnoerr builds 15-acre park at the foot of Pete's Mountain near the mouth of the Tualatin.
1910	Smith dies, and his mill and brickyard cease operation.
1911	Prior to this time, Smith Brothers run two sawmills in Tualatin. Second is near Tualatin City Park.
1912	Sherwood begins to install sanitary sewer system. The project is completed in 1925.
1913	Concerns surface that outhouses may be contaminating the groundwater supply in Tualatin.
1918	Oleson Road is recorded as being a hard-surfaced road.
1918	Graves cannery built near Sherwood City Park.
1900s	Durham rock crusher catches fire. (1920s according to photo)
1926	Sherwood streets are paved and storm sewer system built.
1933	Tualatin River records the highest flood on record.
1939	Lake Oswego Canal widened to 40 feet. Work completed in 1948.
1939	Pacific Highway widened.
1939	Tualatin City well dug. This well goes dry in 1963.
1930s-40s	Recreational parks flourish along banks of Tualatin.
1949	Cutthroat trout "disappeared [from Fanno Creek] around 1949 (Norman Fanno)". [Although they are still present, this may represent a severe population at this time.]
1950s	Bacterial pollution makes Tualatin River unsafe for swimming, signalling the end of commercial recreational parks along the river.
1954	I-5 constructed near Tualatin, facilitating growth in that area.
1960	Frank Fanno sees cougar on family homestead.
1960	During periods of low flow, there's not enough water to supply the Oregon Iron and Steel Company's 1906 water right of 57.5 cfs.
1963	Time magazine refers to the Tualatin River as "the most polluted waterway in America".
1967	City of Tualatin connects with Lake Grove's water district.
1973	Lolita Carter states that water is so hot on lower Tualatin River that it kills bottom animals.
1974	Joe Jackson expresses fears that urbanization will lead to flooding on upper Fanno Creek.
1974	Major flood event.
1974	Water quality very poor in Tualatin River.
1974	Major deposition (as in 13 feet) of sediment described along lower Tualatin River.
1974	Local resident testifies that crayfish no longer are able to live in Tualatin River near Durham.
1974	Concerns are expressed that road fills across floodplains are inadequately bridged.
1974	Large-scale bank erosion recorded along Fanno Creek during flood.
1992	Prior to this time, 85% of total phosphorus entering the Tualatin River is from point sources, including sewage treatment plants.

Sources: Payne 1979, West Linn Bicentennial Committee 1976, Sherk 1936, Martinazzi and Nygaard 1994, Cass and Miner 1993, USACE 1974, Farnell 1978 American Local History Network 2001, Oswego Heritage Council 2001, City of Sherwood 2001

4.8.1.2 European settlement and agricultural conversion

The first recorded European settlement of the watershed occurred in 1846, when Augustus Fanno settled near Progress (MacWilliam and Mapes 1984). Thomas Denney settled nearby in 1850. They selected their land claims based on the presence of large clearings where they could easily homestead amidst the forested landscape, as well as the presence of water. Although several large clearings lay adjacent to middle and upper Fanno Creek, they were relatively uncommon in the remainder of the watershed; thus settlement occurred relatively late in these areas and most of the watershed was considered a “backwater” (Bourke and DeBats 1995).

Following European settlement, the pace of change accelerated. Settlers converted the woodlands and prairies of their land claims to agriculture. When the supply of available prairie land was exhausted, newer settlers attempted to claim farmland from the forests. This was a difficult task in the densely forested region from Beef Bend to the mouth of the Tualatin. It would take years for these settlers to clear the land. After trees were cut, stumps were burnt in a long, extended process (Payne 1979). Often, this process took longer than a year. Meanwhile, crops were planted amidst the stumps. In many cases, the forests were cut down and the timber burnt onsite, without any attempt made to produce lumber (Hesse 1994).

Early agriculture in the watershed emphasized production of livestock and wheat. Settlers also planted orchards on better-drained lands, with the fruit being used for domestic consumption. Hops were an early, important crop on these relatively well drained lands. Onions were an important crop on poorly drained swamplands (Martinazzi and Nygaard 1994).

The production of wheat necessitated the construction of flour mills. Several gristmills were established within the watershed. In 1849, J.M. Moore built a gristmill near the mouth of the Tualatin River. Albert Alonzo Durham followed with a mill near the mouth of Fanno Creek in 1865. About 1880, J.C. Smock built a mill along Cedar Creek in Sherwood. Later, there was a mill in Tigard. These mills generally ran on water power. Moore, for example, had dammed the Tualatin River to provide power for his gristmill and sawmill.

The settlers also accelerated the pace of vegetation change through fire. In Western Oregon, it was estimated that “approximately seven times as much land was burned from 1845 to 1855 as in any of the three previous decades.” (Morris 1934 as cited in USDA and USDI 1997). By 1852, the portions of the watershed on Bull Mountain had been recently burned, although the degree to which human activity was responsible for this burnt land is not immediately clear.

4.8.1.3 Timber operations

Logging activities soon followed Euro-American settlement. Initially, logging was performed to clear homesteads. However, commercial logging began soon afterward. Sawmills were built throughout the watershed. In 1849, J.M. Moore built a sawmill near the mouth of the Tualatin River, and in the next year Thomas Denney built a mill along Fanno Creek north of Progress. Other mills were built along Hedges and Cedar creeks in the 1850s, and by 1865, major log drives were occurring on the Tualatin River (Farnell 1978).

In addition filling the lumber needs of the Portland area, logs from the Tualatin Valley were vital to industry. Cordwood from the Tualatin Valley was used to fuel the paper mills of Oregon City, as well as the steel mill at Lake Oswego.

Early transport of logs was most efficiently performed by water. Between 1886 and 1905 numerous log drives occurred along streams within the Lower Tualatin watershed. In the early 1900s, many of these logs were floated the length of the Tualatin, to be shipped to mills in Oregon City. To facilitate the drives, streams would be cleared of obstructions and blocked off from wetlands and secondary channels (Shively 1993).

In the 1870s the Oregon Central Railroad was built. This, along with other railroads, gradually took over the task of transporting timber from the logging sites. Eventually, roads were built through the watershed and trucks became the dominant mode of transportation. Although these modes of transportation had less direct impact to the streams than did the log drives, they created new problems through increased exposed surface area and destabilized slopes. Many of these old railroad grades and logging roads continue to provide sediment to streams. At stream crossings they often provide migratory impediments to fish.

4.8.1.4 Stream cleaning and wetland conversion

Settlers cleared logjams, beaver dams, and tree roots from streams in order to reduce flooding, facilitate log drives, and improve boat passage. The first record of stream clearing in the watershed appears to date back to the 1880s, when J.L. Smith had cleared a jam near Scholls. This jam quickly reestablished itself (Farnell 1978). Successive efforts were made to clear the Tualatin River of its logjams. An 1888 letter stated that the Tualatin River had become “choked up” since 1880. At that time, 23 jams or drifts were noted on the Tualatin River (Farnell 1978). In 1894, the Oswego Iron Company noted that it had managed to clear the Tualatin River channel between Lake Oswego Dam and Hillsboro.

The wetlands covering much of the valley floors covered potentially productive agricultural lands, and wetland drainage followed settlement. Several notable wetlands were drained in this manner. One of the largest was the “beaverdam” wetland near Cipole. Shortly after arriving in the Cipole area in 1854, Cummins drained his land. About the same time, the Thompsons are recorded as draining their land along Nyberg Creek. Likewise, Augustus Fanno is referred to as a “pioneer in the draining of the ‘beaverdams’ adjacent to Fanno Creek (MacWilliam and Mapes 1984). Although portions of these wetlands still exist, they are greatly altered in size and function from the reference period.

These drainage projects resulted in an extensive loss of wetland habitat. Comparison of hydric soils to current NWI wetland area indicate that as many as 5,400 acres, or 83% of historic wetland area may have been lost due to wetland conversion and drainage. However, it should be noted that the NWI is a conservative measure of current wetland area, and indeed, many lowlands continue to experience ponding and flooding in winter. The type, function, and condition of the remaining wetlands have been substantially changed. Where many wetlands were historically inundated for four months of the year, by 1953 they were more typically inundated for 60 to 90 days (USACE 1953). Where many wetlands provided forested habitat, most of these seasonally ponded areas now are vegetated with exotic weeds such as reed canarygrass. This has seriously affected the ability of these wetlands to provide their historic hydrologic functions, and has altered the types of wildlife for which they are suited.

4.8.1.5 Urbanization

Settlement within the watershed was originally decentralized, consisting of a series of small, agriculturally oriented, villages (Bourke and DeBats 1995). During the 1800s, the watershed was comprised of forest and agricultural lands with a few small towns such as Tigard, Sherwood, and Tualatin. In the 1900s, settlement tended to accumulate around Beaverton. Urban growth accelerated after 1970. Initially, this growth was centered around the northeastern (Fanno Creek) portion of the watershed, where the proximity of Beaverton to Portland made these communities attractive for development. Growth along the Highway 99 corridor also took place, with the area near Portland filling in first. Growth in Tualatin did not take place until after the construction of I-5 in 1954, while most growth in Sherwood occurred in the 1990s. At present, most growth is occurs as infill in presently urbanized areas.

Urbanization has resulted in increased impervious surface area, which in turn has increased peak flows to streams, increased delivery of pollutants to these streams, and resulted in downcutting of stream channels. Often, development has resulted in diminished area available for wildlife, while the introduction of exotic plant species has been facilitated by urbanization patterns.

4.8.1.6 Roads

The advent of roads created changes in the landscape. Early roads were naturally surfaced and typically followed the courses of paths created by Native Americans. Initial road-related impacts would have been minor, as these roads were infrequently spaced. However, proximity to aquatic habitats may have contributed to stream sedimentation.

Impacts increased as additional roads were created to facilitate access to logging sites and farms. During these early years, there was little concern about the environmental impacts of road placement. Such factors as road steepness, stream crossings, wetland crossings, and culvert placement were left to the engineer's discretion, and decisions were often dominated by economic considerations.

Early road construction practices also employed little concern for environmental impacts. When building roads along steep slopes, material removed from cuts in the hillslope was often pushed downslope to build up the bank for the driving surface. Additionally, it was not unusual for waste materials to be pushed over the side of the road. Where these materials were deposited adjacent to a waterway, they posed a significant sedimentation threat to the adjacent stream. These materials often entered the stream directly through gravitational and erosional processes. Additionally, the weight of these sidecast materials also destabilized the underlying slope, increasing the landslide risk for many years following construction of the roads.

These road designs usually involved improperly placed and sized culverts. Often these ends of these culverts jutted out over the underlying ground. The water shooting out of these culverts would plunge to the ground below, cutting into the soil and loosening rocks and vegetation, resulting in massive erosion problems. Additionally, fish passage was not a consideration in culvert design and placement.

Roads on steep timberlands were often routed with steep slopes that offered the shortest route to the timber harvest site. This routing took less ground out of the resource base and had less of an impact on groundwater percolation than did more circuitous road designs, but the steepness of the roads could promote raveling, erosion, and sediment runoff.

Chapter 5: Synthesis

5.1 Aquatic

5.1.1 Erosion issues

5.1.1.1 Changes in erosion processes following settlement

As described in chapter 4, there is considerable evidence that human activities have altered the erosional characteristics of the watershed. In general, these changes tend to accelerate erosion. However, specific efforts have been made to implement policies that reduce erosion. In the past, forestry contributed to accelerated erosion and sediment production. Current changes to the erosion regime result from loss of vegetation, construction, and agricultural practices.

Land use activities following settlement have altered the rate and timing of erosion. Under reference conditions there were large increases in erosion rates associated with major disturbances such as fires and large storms, after which erosion rates dropped to relatively low levels. Following settlement, removal of vegetation and compaction and displacement of soil from construction have created a chronic increase in erosion rates. Conversion of forest to agriculture has resulted in local increases in sheet, rill, and gully erosion. In addition, the type of material delivered to stream channels and riparian areas from landslides has changed. Landslides were a major source of large woody debris in historical times, when there were large areas of older timber in the watershed. The large wood supplied through these processes was relatively stable in the stream system, providing structure and altering flow patterns to contribute to pool formation. With the non-forested conditions that dominate the watershed today, there is a reduced potential for large wood input to the channels from landslides. In many parts of the watershed, this is reflected in a lack of large wood and structure in the channel. The smaller wood provided by young timber is readily transported during high stream flows, and provides little lasting benefit to habitat structure.

These changes in watershed process have largely been the result of changes in management practices since Euro-American settlement. Although timber harvest activities originally contributed to the altered erosion regime, they currently comprise a very small portion of the watershed, and there is no indication that they are currently major contributors to erosion within the watershed. The greatest current contributors to erosion processes appear to be construction (urban, rural residential, and roads) and agricultural disturbances on steep lands.

Construction of roads and buildings cause many management-related erosional impacts in the watershed. In particular, construction on hillslopes contributes to the problem in several ways For example, these operations:

1. Remove portions of the slope above the road or building (the cutslope), thus making the slope less capable of bearing the weight above it;

2. Fill portions of the slope below the construction (the fillslope), thus placing an added burden to that slope;

3. Remove surface cover from the slope, thus making it susceptible to surface erosion. Additionally, drainage ditches create channeled flow, resulting in increased erosive power of runoff and increased sediment delivery to streams.

Agriculture is potentially a major contributor to erosion and stream sedimentation. Agricultural practices that tend to promote surface erosion include activities that loosen the soil and reduce vegetative surface cover. The greatest potential for such erosion occurs when agricultural activities occur on steep lands. Where such activities occur near a stream channel with an inadequate vegetation buffer, there is a high potential for sediment delivery to the stream. Additionally, the lack of vegetation on the stream bank increases its susceptibility to erosion from the stream.

5.1.1.2 Mass wasting

Steep and geologically unstable lands in the watershed remain susceptible to debris slides and slumping. Metro has identified most of the upper portion of the Portland Hills as a zone of increased landslide hazard. The largest proportion of landslides following the 1996 flood events occurred in this zone, which is underlain by Portland Hills silt. The Upper Fanno Creek subwatershed appears to be particularly unstable based on these factors. Portions of Cooper and Bull Mountains adjacent to streams were also identified as being unstable. Although no instability/landslide inventory exists for the Chehalem Mountains, their geologic similarity to the Portland Hills indicates potential instability in this region, also.

Roads appear to be related to many of these landslides. In the Upper Fanno Creek subwatershed, for example, a large proportion of the landslides identified in the 1996 report occurred along upper Scholls Ferry Road, Humphrey Road, Dosch Road, and Multnomah Boulevard. It follows, therefore, that many future landslides could be expected to occur along roads built on steep lands. These conditions are found most frequently in the Upper Fanno Creek and Tualatin Mouth subwatersheds. Similar considerations could be considered to apply to rural residential construction on steep slopes, where cuts and fills related to construction would apply the same sort of stresses to the hillslope as are caused by roads.

Hazard of sediment delivery is greatest where roads lie within 200 feet of streams (WPN 1999, Washington Forest Practices Board 1997). Stream crossings also provide a ready source of road-related sediment contributions to streams. Subwatersheds with the highest concentration of nearstream roads include Ash Creek, Upper Fanno Creek, Summer Creek, Lower Tualatin-King City, and Fanno Creek.

Given the above factors, it is to be expected that the greatest sediment hazard to streams would occur where nearstream roads cross steep slopes. By far, these conditions occur most frequently in the Tualatin Mouth and Upper Fanno Creek subwatersheds.

In the Chehalem Mountains and the Portland Hills, lands are used more intensively than in the mountains of the western portion of the Tualatin subbasin. Urban, rural residential and agricultural uses tend to reduce surface cover, resulting in increased surface runoff. Urban uses also increase the area of impermeable surfaces, resulting in vastly increased surface runoff. (Although rural residential uses also tend to increase impervious area, the effects on watershed hydrology appear to be minor.) Generally, these activities generate more ditches, thereby increasing the ability to transport sediment to channels. Additionally, these activities reshape the land in ways that tends to make it more erodible. The net effect of agricultural and rural residential activities in these areas is to accelerate erosion, particularly where slopes are steep.

5.1.1.3 Surface and bank erosion

An early contributor to erosion in the watershed's valleys and adjacent foothills was the extensive conversion of forestland to agricultural purposes during the latter half of the 19th century. Such conversion exposed extensive acreage to raindrop impacts and increased sheet, rill, and gully erosion. These effects would have been greatest on steep slopes and on highly erodible soils. As the conversion has largely been permanent, increased erosion remains to the present.

The degree of erosion risk is partially attributable to the natural erodibility of the underlying soils. In Washington, Clackamas and Yamhill counties, NRCS identified those rural lands considered to be at a high risk for erosion, based on factors such as slope and erodibility ("k") factor. The preponderance of highly erodible soils, as identified by NRCS, is located in the Tualatin Mouth, Chicken Creek, and Cedar Creek subwatersheds. In order to reduce erosion problems due to agriculture, the NRCS created site-specific HEL plans for all farms on these lands. However, compliance with these plans is not monitored annually on each farm (Dean Moberg, NRCS, Personal communication 2000).

Bank instability is prevalent throughout much of the watershed, and undoubtedly is largely related to natural factors. Along Woods Creek and other headwater streams, canyon slope is a major factor contributing to bank instability, while the naturally erodible soil makes banks susceptible to erosion in the lower portion of the watershed. Most of the Tualatin River within the watershed, as well as the lower portion of Fanno, Chicken, and Rock (South) creeks, are bordered by Chehalis and McBee soils, which have been identified by NRCS as being extremely susceptible to streambank erosion.

In some locations, poorly vegetated riparian buffers appear to be associated with unstable streambanks. On the Tualatin River, virtually all landslides identified through analysis of aerial photography were associated with poorly vegetated buffers. However, forested buffers may have masked small landslides along the river. Among urban tributary streams, upper Fanno Creek displayed a particularly high association between lack of riparian vegetation and streambank instability (Brown and Caldwell 1998). There is a strong indication that many other reaches would benefit from riparian revegetation efforts.

5.1.1.4 Trends in erosion management on rural lands

Prior to 1996, there was little regulation of farming activities in riparian zones. Riparian vegetation was often removed to the edge of the stream, resulting in increased delivery of surface sediments to streams, decreased bank stability and increased bank erosion. Recent changes in the administrative rules administered by the Oregon Department of Agriculture mandate increased ground cover in winter along streams in agricultural lands.

In many parts of the Tualatin subbasin, erosion due to agricultural sources has been reduced by implementation of agricultural Best Management Practices (BMPs). These practices are usually implemented as part of conservation plans administered by the Washington County Soil and Water Conservation District (SWCD) and NRCS. Certain BMPs, including planting of winter cover crops, mulch tillage, and filter strips, are designed to reduce erosion and sediment delivery to streams. Implementation of these practices has been accompanied by improvements in water quality, indicating that these practices are effective. However, the degree of effectiveness of individual practices is unclear, as no systematic methodology has been implemented to monitor effectiveness of the BMPs. Such a methodology, along with systematic data collection, would be valuable for improving the effectiveness of management systems. Despite the lack of this methodology, it seems apparent that further reductions in erosion and sediment delivery would be achieved by bringing a greater percentage of the agricultural community under Voluntary Farm Water Quality Management Plans. The Lower Tualatin watershed, in particular, has a high potential for improvement, as few landowners in the watershed currently participate in these plans.

In recent years, many agricultural operations have implemented practices that reduce erosion and sediment delivery to the Tualatin River and its tributaries. Partnerships with governmental conservation agencies have been instrumental in this process. For example, the Natural Resources Conservation Service (NRCS), Washington County Soil and Water Conservation District (SWCD), and the Farm Services Agency have worked with farmers to reduce erosion and improve water quality. Methods have included programs to share costs with farmers for implementation of erosion-reduction techniques, incentives to remove riparian lands from agricultural production, educational efforts, provision of technical assistance, implementation of conservation plans, and restoration projects.

Effective erosion control in rural portions of the Tualatin Plain will largely concentrate on reduction of source sediments from agricultural operations, and from riparian restoration. The former objective is most efficiently achieved through voluntary efforts spearheaded by the NRCS and SWCD in rural areas. These agencies have a long history of working together with farmers to reduce soil loss. Additionally, these agencies are able to offer economic incentives and cost-sharing programs to implement BMPs. Although enhanced riparian buffers would be beneficial throughout the watershed, the greatest return on effort would probably occur where the riparian buffers are most severely compromised. Because of steelhead trout use, the lower portion of the **Chicken Creek** subwatershed should also receive high priority for revegetation. .

Certain agriculturally related conditions that lead to accelerated erosion and sediment delivery to streams are prohibited under the Tualatin River Subbasin Agricultural Water Quality Management Area Plan (OAR 603-095). Such “Prohibited Conditions” are discussed in the Water Quality section (Section 5.1.4.6).

5.1.2 Hydrology and water quantity issues

5.1.2.1 Management effects on hydrology

Stream hydrology has been altered from reference conditions. In general, these changes have tended to increase winter peak flows, decrease summer low flows, and increase surface runoff.

The greatest impacts on hydrology have been experienced in urbanized portions of the watershed. Increased impervious surface area has resulted in decreased infiltration below the ground surface. This means that almost all of the water runs off to streams along the ground surface, with the net result that the water enters the stream more quickly than it would under natural conditions. Hydrologic effects include increased peak discharge, decreased base flow, and decreased groundwater recharge. This also creates secondary effects on the stream channel, as the stream’s ability to erode the channel is increased under peak flow conditions. Many stream channels within the watershed are entrenched for this reason. Most of these effects are to be found in the subwatersheds contributing to Fanno, Hedges, and Nyberg creeks.

Areas in agriculture have also had altered hydrology through tile drainage and channelization, although the effects appear to be smaller than those prevailing in urbanized areas. These effects are likely to be largest on lands of moderate to steep slope. It can be demonstrated that implementation of Best

Management Practices is effective toward reducing the hydrologic impacts of agriculture. This has subsidiary benefits to the landowner, as well as the public, because reduced surface runoff minimizes the loss of valuable topsoil.

Generally speaking, road density in rural subwatersheds is not sufficient to contribute appreciably to hydrologic alteration.

Under reference conditions, the stream channel was hydrologically connected with extensive floodplains and wetlands. The floodplains served to moderate the volume and velocity of peak flows. While floodwaters and ponded waters were stored in floodplains and wetlands, some of the stored water infiltrated to recharge groundwater supplies. Much of the rest was subsequently released to the stream to augment lower flows. Following Euro-American settlement, stream channelization cut off many portions of the stream channel from the floodplain, thus removing the ability of the floodplain to store and moderate flows. This resulted in higher peak flows, a reduction in low flows, and increased flow velocity. Additionally, channel straightening and brush removal associated with channelization also contributed to increased flow velocity. Channel straightening increased stream gradient, while brush removal removed resistance to flow. Stream channelization also reduced the amount of recharge to groundwater, resulting in a lower water table, and diminished low flows. These changes are relatively permanent, as these channels are maintained with an artificially straightened configuration and with impaired hydrologic connection to their floodplains.

The effects upon hydrology of wetland drainage projects were similar to those of stream channelization. Like stream channelization, wetland drainage normally involved ditching to drain ponded water into the stream system. In effect, this extended the channel system, thus contributing to peak flows while reducing the amount of recharge to groundwater. Where streams naturally had surface hydrologic connection with wetlands, wetland drainage was often associated with stream channelization. Areas impacted by wetland drainage include the extensive portions of the Rock (South), Hedges, and Nyberg Creek subwatersheds. Smaller wetlands were also drained. About 5,400 acres of seasonally and temporarily flooded wetlands were converted to agricultural and urban uses with greatly diminished flooding periods[23].

To a certain degree, storage and detention ponds at traditional wetland sites provide a detention function. A portion of this water may infiltrate and recharge groundwater.

Opportunities exist to restore natural hydrological functions to a limited amount of wetland. The greatest potential for such restoration exists at the Tualatin River National Wildlife Refuge, where active wetland restoration projects are ongoing. Smaller wetlands exist within the UGB. Based on the Beaverton Wetland Inventory, about half of these wetlands have compromised hydrologic function. Depending on design, time, and effort, it is to be expected that a "natural" hydrologic regime could be simulated for these wetlands. Additional wetland restoration activities through NRCS or other parties depend on the availability of willing landowners, as well as the flexibility of other governmental entities to remove barriers to these projects.

Flow regulation, through the Tualatin River Project and Trask Reservoir have changed the natural hydrology of the Tualatin River mainstem. Although storage in Henry Hagg Lake has a relatively minor influence on winter peakflows, summer releases (along with releases from wastewater treatment plants)

---

[23] Based on comparison of hydric soils with current NWI maps, supplemented by references from Hart and Newcomb (1965) and USACE (1953)

provide a substantially increased volume of summer low flows. These releases help to maintain water quality.

Other major changes to stream hydrology have been effected by instream diversions. These diversions, which are for municipal and agricultural purposes, generally take place in the summer low-flow season. Where flow has not been augmented by water from Henry Hagg Lake, these diversions diminish stream flows below natural conditions. Diversions are common throughout agricultural portions of the watershed, with the greatest cumulative diversion occurring in the Tualatin Mouth subwatershed.

5.1.2.2 Water rights allocations

Water rights appear to be fully allocated many parts of the year. No new surface water rights are available between June and November. This is largely a result of consumptive uses, although instream water rights significantly contribute to the deficit in Fanno Creek. As population increases within the watershed, greater demands, both for consumptive uses and for water rights, will be placed upon water resources.

During formulation of its action plan, the Tualatin River Watershed Council considered the procurement of additional water rights to supplement current instream water rights. OWRD has determined that the Lower Tualatin watershed, exclusive of Fanno Creek and its tributaries, falls within a primary effort area to procure additional instream water rights (Darrell Hedin, District 18 watermaster, personal communication). The greatest potential benefit to steelhead from supplementary instream water rights would likely accrue in Chicken Creek. Further field study is necessary to establish a need for enhanced instream water rights and to determine the best location to acquire these rights.

5.1.3 Stream channel issues

5.1.3.1 Management effects upon stream morphology

Current stream channel conditions have changed from reference conditions. These changes are variable, depending upon the relative effects of altered hydrology and sediment delivery. In urbanized portions of the watershed, increased peak discharges have resulted in stream entrenchment. In many urban and rural reaches, increased sedimentation and reduced riparian vegetation from past and current management practices have resulted in pool fill and shallower streams. Where valley walls permit, channels likely have become wider. Along many valley reaches, particularly along Rock and Hedges Creek, as well as the Fanno Creek system, streams have been channelized and confined rather than allowing natural meandering.

The loss of large woody elements from the stream system has created an extensive change in channel process throughout the watershed. Under reference conditions, mature forests along the streams supplied large woody debris to the channel, creating hydraulic characteristics suitable for pool formation and increased hydraulic diversity. Following settlement, timber harvest removed large wood from the riparian zone. Channel clearing and removal of roughness elements was practiced to facilitate navigation and log drives. In the mid-1900’s, stream clearing was considered to improve fish habitat and was conducted expressly for that purpose. Forest practices continued to emphasize clearing of wood from channels until the 1980's. These policies and practices have combined to generate a system severely deficient in large wood and lacking the roughness elements necessary to generate adequate numbers of pools. These circumstances have been major contributing factors to the lack of channel structure that currently characterizes many portions of the Lower Tualatin watershed.

Although current levels of instream Large Woody Debris are below ODFW benchmarks for forested streams, and historical levels throughout the watershed, the Tualatin River mainstem does continue to receive inputs of LWD. Field surveys indicate that these are largely the result of large (15-20" diameter) ash trees and conifers that are contributed to the channel through streambank sloughing or through windthrow. There are a number of trees with similar size characteristics currently on streambanks, indicating a high potential for LWD recruitment to continue at current levels. However, these inputs have a capacity to interfere with other management objectives on the Tualatin River.

Current instream woody debris, as well as recruitment potential, is quite limited on most tributaries. Although scattered large trees exist in riparian areas along the tributaries, such as the Fanno Creek tributaries (Kurahashi and Associates 1997), most reaches lack a dense, forested riparian cover. Where there is little available nearby seed stock for natural recruitment of conifers, it is unlikely that the characteristics of these riparian zones will change. Along most urban tributaries, it is unlikely that any substantial natural recruitment of large woody debris will occur in the forseeable future. It may be necessary to supplement long-term development of natural recruitment with interim measures such as artificial placement of large wood. Planting of conifers in riparian areas will also contribute to long-term prospects for recruitment of large woody debris.

5.1.4 Water quality issues

5.1.4.1 Management effects on water quality

Management activities have had substantial impacts on water quality. Under reference conditions, riparian forests provided shade to streams. Shading regulated water temperatures, resulting in cooler summer water temperatures and increased stream capacity for dissolved oxygen. Additionally, riparian forests provided stability to streambanks, minimizing erosion and accompanying contributions of fine sediments. Subsequent to settlement, many of these riparian forests were removed. As practices prior to 1980 made no allowance for riparian buffer strips, this removal increased stream exposure to sunlight, leading to higher temperatures and reductions in dissolved oxygen levels. Additionally, forest removal led to increased streambank erosion and reduced filtration of sediments from upland runoff. This resulted in increased turbidity and suspended solids.

Agriculture contributed to many of the changes in water quality in the valleys and adjacent foothills. Conversion of lands from forest to agriculture resulted in increased exposure of soils to energy from precipitation. Cultivated soils were more susceptible to erosion, leading to greater sediment loads in surface runoff. Together with compromised riparian buffers, these factors contributed to higher delivery of sediments, adsorbed nutrients, organic matter, bacteria and pesticides to streams. Fertilization also led to contributions of nutrients to streams, while livestock access to streams increased inputs of bacteria and ammonia nitrogen. Surface and subsurface drains increased peak runoff. Continual improvements in management practices have reduced the impacts of these activities upon water quality.

Urbanization has been responsible for many current water quality issues. The construction of the urban infrastructure requires substantial soil denudation and displacement. This, along with slope destabilization, often results in increased sediment delivery to streams. Impervious surfaces replace the natural cover, resulting in increased surface runoff, which often carries petroleum products, fertilizer, and other pollutants to streams.

Other land-use conversion activities have affected water quality. Filling of wetlands reduced their ability to filter out pollutants, sediments and nutrients prior to stream entry. This resulted in increased inputs to the active channel. Stream channelization destabilized banks and increased stream velocity, resulting in increased erosion rates and concentrations of suspended sediments.

With increased settlement came an increased need for waste disposal. Many of these waste disposal systems did not possess adequate safeguards against contributions of pollutants to surface water. It is likely that septic tanks associated with rural residential development have contributed bacteria and ammonia nitrogen to stream systems within the watershed.

Roads are notable contributors of sediment to surface water supplies. Drainage ditches associated with roads produce channeled flow, leading to increased erosion. Where these ditches lead to streams, or where roads are built in riparian zones or cross streams, an effective mechanism is created for accelerated sediment delivery and pollutant loading. This leads to higher levels of instream sediments, total suspended solids, and adsorbed particulates.

In general, flow augmentation from the Tualatin and Trask projects has had beneficial effects on water quality. Water released from Henry Hagg Lake and Barney Reservoir dilutes summer nutrient concentrations in the Tualatin River. Additionally, these releases help to increase water velocity and reduce the amount of time that water spends in the Tualatin River system. This diminishes pool stratification and helps to flush nutrients out of the system. These releases have been instrumental in helping to achieve water quality objectives over sizeable portions of the mainstem.

5.1.4.2 Streams on the Oregon 303(d) water quality limited list

Review of CWS monitoring data from 1997 and 1998 indicate that water quality problems persist in 303(d) listed streams. All sampled sites within the watershed significantly exceed phosphorus standards. Temperature, dissolved oxygen, and bacteria also pose widespread water quality challenges in summer. In general, water quality problems are the greatest at urban sites, with the greatest overall impairment appearing to occur on Fanno Creek and its tributaries. (Although it is likely that other urban streams are similarly impaired, the limited amount of sampling data limits the conclusions that can be drawn about these streams. More data would be useful.) However, some rural streams also have substantial water quality problems. Data collected by ODA indicate that Chicken Creek is severely impaired (for recreational use) by bacteria; while summer dissolved oxygen levels impair its ability to support salmonid rearing.

Although the degree of impairment varies, no sampled streams within the watershed were found to be free of water quality problems. This indicates that significant opportunities exist to improve water quality through application of Best Management Practices in all sectors.

5.1.4.3 Factors leading to high aquatic phosphorus levels

Although aquatic phosphorus levels in the watershed are naturally high, human inputs seem to account for much of the phosphorus found in streamflow. When revising the TMDL for phosphorus, ODEQ estimated median background phosphorus concentration at 0.10-.11 mg/L on the Tualatin River, 0.13 mg/L on Fanno Creek, and 0.14 on other tributaries within the watershed (ODEQ 2000).

CWS monitoring data indicates that many urban streams persistently have phosphorus concentrations substantially in excess of the background concentrations calculated by ODEQ. Monitored sites along Fanno Creek and its tributaries regularly exceed this phosphorus concentration. This indicates chronic phosphorus inputs from human sources such as fertilizers and sediments carried in urban runoff.

Additionally, a portion of the phosphorus in these streams may be imported to these sites from streams outside the Urban Growth Boundary. Although the only monitored rural site within the watershed, Chicken Creek at Scholls-Sherwood Road, does not appear to have phosphorus loads substantially above baseflow levels, streams in neighboring watersheds have indicated high levels of phosphorus from human sources. Most human phosphorus inputs could be expected to come from rural activities, such as fertilization and soil disturbance related to rural residential activities.

A considerable amount of uncertainty surrounds the magnitude of phosphorus loads attributable to various causes. As previously explained, the amount of winter phosphorus load that affects summer phosphorus concentrations is unknown. Manure from animals grazing in wetlands and riparian areas also provides an unknown phosphorus load to aquatic systems. The effect of the infrequent summer runoff events is also unknown. Additionally, it is uncertain to what extent inadequate septic systems add a phosphorus load to streams. This load would logically play a role in both summer and winter. Finally, there is a potential for future saturation of phosphorus sorption capacity on soils receiving large amounts of phosphorus fertilizer and/or manure. This could lead to leaching of phosphorus to tile drains, which flow to streams well into the summer months.

Thus, although reductions of aquatic phosphorus concentrations will vary between streams, it is still important for landowners of all sectors to implement BMPs for phosphorus.

5.1.4.4 Temperature

During summer low flows, virtually all monitored streams display some degree of temperature impairment. The periods of excess vary between stream reaches, with high temperatures prevailing for the greatest amount of time on tributaries of Fanno Creek. Sylvan Creek and Summer Creek appear to be especially impaired in this regard. In these cases, temperature impairment is a result of impaired riparian vegetation and altered hydrology.

Extended periods of high temperature are also observed along most of the length of Fanno Creek. This is of particular concern because ODFW considers Fanno Creek to provide potentially important habitat for steelhead trout spawning and rearing. Although the highest temperature and the longest duration of temperature impairment exist downstream of Ash and Summer creeks, monitoring by ODEQ indicates that high thermal loads occur well upstream.

Canopy restoration and streambank protection (to prevent widening) are potential strategies to promote temperature moderation in many reaches within the watershed. Many perennial tributary streams have inadequate shading and would benefit from canopy restoration/erosion control projects. This includes most urban streams, including Fanno Creek and its tributaries, as well as within the Nyberg Creek and Rock Creek (South) subwatersheds. Additionally, riparian enhancement along lower Chicken Creek is likely to provide benefit for steelhead trout rearing.

5.1.4.5 Bacteria

High levels of bacteria continue to persist on streams within the watershed. On monitored streams, the most severe impairment is found at Fanno Creek at Scholls Ferry Road, an urban site, as well as rural Chicken Creek. All other monitored sites (both urban and rural) were found to have beneficial uses moderately to severely impaired by bacteria.

ODEQ (2000) has identified urban runoff as a significant contributor to bacteria in streams. They further identified animal waste, illegal dumping, failing septic systems, and sanitary sewer overflows as potential sources of bacteria in urban runoff. Illegal dumping and direct deposition by animals were identified as potential sources during non-runoff periods.

In rural areas, ODEQ identified the same bacteria sources as for urban runoff. Additionally, ODEQ identified hobby farms, horse pastures, and ranchettes as additional potential sources of bacteria in runoff. Animal wastes were considered to be the largest potential source from agricultural operations.

5.1.4.6 Dissolved Oxygen

Low dissolved oxygen (D.O.) levels are a persistent source of impairment between May and October. Most sites along Fanno Creek are moderately impaired. In 1998, the most persistent impairment occurred near Scholls Ferry Road.

High stream temperature is a significant contributor to low dissolved oxygen within the watershed. During TMDL modeling, ODEQ (2000) determined that oxygen demand imposed by organic material was a potentially substantial contributor to low D.O. levels in Fanno Creek. (This included organic material contained in sediment, as well as that suspended or dissolved in the water column.) Decomposition of algae was also considered to have locally important effects on dissolved oxygen. Although other urban streams were not modeled, the same factors were considered to contribute to low D.O. levels in these streams.

ODEQ did not perform D.O. modeling on any rural streams within the Lower Tualatin watershed. However, they modeled D.O. demand on Gales Creek, which they considered to be applicable to Chicken Creek. They found that, other than temperature, oxygen demand from organic material in sediment was the only significant contributor to low dissolved oxygen.

5.1.4.7 Biological communities

Impairment of biological communities is an extensive problem within the Fanno Creek system. Fish surveys conducted in 1994 and 2000 found low species richness and a low number of intolerant species, indicating that populations are diminished in number and diversity from reference conditions. Similarly, macroinvertebrate surveys characterize these streams as low in species diversity, with populations comprised of pollution-tolerant species.

Conversely, macroinvertebrate populations in upper Chicken Creek had characteristics that rated among the best in the Tualatin subbasin. These included a high number of intolerant species, such as stoneflies, mayflies, and caddisflies, as well as high overall species diversity (Cole 2000). This demonstrates that portions of the watershed still retain the ability to support diverse ecological populations.

5.1.4.8 Effects of water quality on recreation

Most major streams within the watershed are considered be impaired for water contact recreation because of high bacteria levels. Diminished water quality also has indirect impacts on recreation. Poor water quality is one of the factors contributing to diminished salmonid populations, which in turn reduces cold water fishing opportunities. Conversely, relatively warm surface water temperature in the Tualatin River has generated warm water fishing opportunities.

Strategies to improve recreation opportunities are similar to those given to obtain other desirable water quality objectives. Implemention of water quality strategies to reduce nutrient loads, sediments, and bacterial inputs will create conditions more desirable for stream-related recreational activities.

5.1.4.9 Prohibited conditions

Due to the lack of systematic surveys for prohibited conditions within the watershed, it is not possible to identify the magnitude and frequency of conditions prohibited under the Tualatin River Subbasin Agricultural Water Quality Management Area Plan (OAR 603-095). Subsequent to identification, prohibited conditions can be addressed through voluntary actions promoted by the Washington County Soil and Water Conservation District and the Natural Resources Conservation Service. In the Tualatin subbasin, these activities have been an effective pathway for addressing water quality issues.

In urban portions of the watershed, laws apply that describe urban prohibited conditions. Clean Water Services is the Designated Management Agency for handling these conditions, and administers a set of programs to meet requirements of the Clean Water Act.

5.1.5 Aquatic species and habitat issues

5.1.5.1 Fisheries

Winter steelhead trout and cutthroat trout make up the major focus for habitat and water quality issues in the Lower Tualatin watershed. In addition to their intrinsic value, these species are sensitive to changes in habitat and water quality, thus functioning as indicator species of the condition of the stream ecosystem. Thus, measures taken to benefit salmonid populations are likely to benefit all aquatic resources. Although cutthroat trout populations in the Tualatin subbasin are not considered to be threatened, their range within the Lower Tualatin watershed is limited. Additionally, much of their rearing habitat is contained within the most urbanized and severely impacted streams within the watershed. These include Fanno Creek and Cedar Creek. Action should be taken on these streams to improve habitat for cutthroat trout.

Declining steelhead trout trends in the upper Willamette ESU, of which the Lower Tualatin watershed is a part, has led to the listing of these fish as Threatened under the federal Endangered Species Act. Although population information is limited, the reduced amount and quality of available habitat suggest a steelhead trout population that is reduced from historical numbers. For steelhead trout, habitat quality (including water quality) and quantity are limiting factors. Habitat quality is not considered to be comparable to that existing in the Gales Creek, Upper Tualatin-Scoggins, and Dairy-McKay watersheds. Nevertheless, suitable habitat for steelhead spawning is considered by ODFW to exist on two stream reaches: Fanno Creek below the Columbia Tributary and Chicken Creek below Edy Road and Krueger Road (ODFW 1999). The Chicken Creek reach should be considered a high priority area for habitat restoration. Steelhead spawning on Fanno Creek is not well documented; therefore, additional survey work would be useful on this stream. Fanno Creek poses a considerable challenge to restoration as significant degradation of water quality and habitat are found along many portions of this stream system.

Poor riparian conditions in most of the watershed have a negative effect on instream salmonid habitat. Most riparian areas lack large-diameter trees. Riparian forests along most tributaries largely provide a shading function, but in many areas they are unlikely to provide appreciable amounts of large woody debris during the near future. For most of the watershed, this indicates that habitat conditions similar to those existing during the reference period will not be produced naturally during the next 50 years. If riparian forests were replanted, and allowed to develop mature timber stands, they would eventually regain their ability to provide large woody debris to the stream system. However, management for this objective is likely to conflict with economic objectives within this watershed.

Lamprey species are susceptible to many of the same habitat concerns as salmonids. Increases in water temperature have provided conditions detrimental to lamprey populations. Additionally, Pacific lamprey in their larval stages make extensive use of fine substrate portions of the watershed. Thus, high water temperatures in the tributaries and the Tualatin River are likely to have substantial detrimental impacts to lamprey populations.

Although there is evidence that some culverts impede passage, insufficient data exists to determine the degree to which migration by anadromous fish has been impeded by human-placed structures. Although roads and culverts likely provide impediments to migration, an ODOT culvert survey found that all surveyed culverts on county roads within the watershed provided sufficient passage for anadromous fish. However, this survey was not comprehensive and additional culvert survey would be necessary to determine the true impacts of culverts upon aquatic life.

Migration may be inhibited by low water due to diversions. As upstream migration occurs prior to the irrigation season and enhanced instream water rights are in effect during migratory periods, migratory delay due to diversion may be minor. However, there are likely numerous unscreened diversions in the watershed, potentially providing a hazard to fish migrating and rearing in the valley channels.

The potential for potamodromous migration by cutthroat trout should also be taken into account. Although cutthroat trout are found above migratory barriers, studies have found that the likelihood of existence of a cutthroat trout population increased with length of stream above the barrier (Cramer 1997). Large numbers of stream crossings or other migratory barriers may diminish the viability of cutthroat trout populations.

5.1.5.2 Wetlands: Management impacts

The extent and functionality of wetlands have been greatly changed from reference conditions. Under reference conditions, most wetlands were shallow, seasonally flooded lakes, ponds, marshes and swamps in the Tualatin Plain. Drainage projects in the late 1800s and the early 1900s have severely diminished the extent of wetlands from pre-settlement levels. The remaining wetlands in the Tualatin Plain are greatly diminished in size, and wetland area within the watershed has been reduced by an estimated 5400 acres, or 83%. (This excludes wetlands too small to be included in the NWI.) Although these wetland areas provide aquatic habitat for many species, they almost certainly provide less aquatic vegetation and habitat for amphibian species than did historical wetlands of the Tualatin Plain. The remnant riparian forests are the least modified wetland type. Marshes have typically been collected into impoundments with little wildlife value. Although winter ponding of traditional wetland areas still occurs, the period of inundation is greatly reduced from natural conditions, and these areas are generally no longer considered to be regulatory wetlands.

The habitat functionality of many of the remaining wetlands has been degraded. This degradation is evidenced by the encroachment of non-native noxious species upon the wetland habitats. Reed canarygrass (*Phalaris arundinacea*) is nearly ubiquitous in wetlands. Purple loosestrife (*Lythrum salicaria*), an ODA schedule B noxious weed, is also a common invader of wetland habitats. Programs to restore native plant species would help to improve the ability of wetlands to provide habitat for native animal species.

Based on the assessments in the Beaverton Local Wetland Inventory (LWI), it appears that the ability of wetlands to support wildlife and aquatic life have been severely compromised by the changes that have taken place. However, functions related to hydrologic storage appear to have been retained by remaining wetlands, although the smaller wetland extent has resulted in diminished storage capacity. Prospects for wetland restoration vary depending upon wetland location, degree of degradation, and the type of surrounding land use.

Many efforts to restore wetland habitats have taken place within the watershed. These are often sponsored by Designated Management Agencies (DMAs) under the Clean Water Act, and are frequently performed with the intent of taking wetland ponds off-line. Additionally, numerous small wetland restoration activities have taken place, usually in parks or as mitigation projects within the Urban Growth Boundary (UGB). Given willing landowners, there may be potential for wetland restoration outside the UGB. Agencies and organizations such as NRCS and Ducks Unlimited work with landowners to restore and enhance wetlands. However, certain obstacles exist. The cost of local permits for wetland projects is often high. Additionally, these projects often require a high degree of maintenance if natural plant communities and wildlife support are desired functions.

5.1.5.3 Riparian habitat: Management impacts

Non-wetland riparian habitat is also diminished in extent and quality from reference conditions. During reference conditions, most valley streams had wide riparian forests. Subsequent land use practices have greatly reduced the width of these forests. Currently, a thin riparian buffer strip runs along many streams. Although such a buffer is of value, it has resulted in a tenuous, thin strip of riparian habitat surrounded by habitat adverse to many riparian species. Thus, the current scenario represents a massive loss of riparian habitat relative to reference conditions.

Along many stream reaches, riparian habitat has been fragmented or obliterated entirely. This is particularly the case along many urban streams, where streams have been extensively channelized, piped, and encroached upon. In agricultural areas, many smaller streams have been ditched, resulting in a loss of riparian habitat. Frequently, the riparian vegetation along these ditched streams is composed of exotics such as reed canarygrass.

Although future changes to land management rules are unclear, it seems certain that they will tend to emphasize more retention of woody vegetation on streams considered important to steelhead trout.

5.1.5.4 Impacts of wetland and riparian changes upon species

Loss of habitat has undoubtedly reduced the abundance of wetland and riparian dependent species in the Lower Tualatin watershed. However, few to no population surveys have been performed to verify this conclusion.

Although population status of many amphibian and aquatic species is unknown, it is assumed that they have declined with declining habitat. It is hoped that stabilization of habitat amounts will result in a stabilization of populations.

5.2 Terrestrial

5.2.1 Vegetation issues

5.2.1.1 Post-settlement effects on landscape characteristics

Due to settlement, the pattern of vegetation has changed extensively from reference conditions. The reference landscape consisted of massive expanses of late-successional forest interspersed with occasional patches of early- and mid-successional vegetation where stand-replacement fires had occurred. In the valleys, there were also patchy prairies where frequent flooding occurred. Following European settlement, the vegetation pattern was changed to the current highly fragmented landscape. The Portland Hills are largely covered by small residential parcels. The remaining forest stands are a mosaic of many small patches of early and mid-successional forest, interspersed with very few small patches of late-successional forest. The largest remaining stands of these forests lie within the Cedar Creek and Tualatin Mouth subwatersheds. Additionally, the forested headwaters of Sylvan Creek lie adjacent to Forest Park, thus providing a large forested tract. The valleys and many hills within the watershed have been mostly transformed to agriculture and urban uses, although a narrow forested riparian corridor lies along the Tualatin River and some tributaries.

5.2.1.2 Potential vegetation management strategies

Given current ownership and landscape patterns, management of the watershed for large blocks of late-successional forest is unlikely. Opportunities exist, however, to manage these forests to provide small preserves and migratory corridors for species that do not require large habitat blocks. Some of these opportunities lie on lands managed by USFWS, CWS, Metro, and similar agencies. On private lands, potential to provide habitat for these species will depend upon the management emphases of the landowners. Partnership opportunities with these landowners may be available on a case-by-case basis.

Federal, state, and private lands all provide habitat for riparian-dependent species. Assuming current management practices, the width of riparian buffer strips on private land is likely to remain narrow, and only minimal habitat will be afforded. Some of these stands will develop mature structural characteristics, providing habitat for riparian species that prefer late-successional habitats or habitat features associated with late-successional habitats.

5.2.1.3 Noxious and exotic plants

Ecosystems in the Lower Tualatin watershed appear to be losing native species richness due to the invasion of exotic and noxious plants. Himalayan blackberry, Scotch broom, English ivy and reed canarygrass all provide major impacts within the watershed's foothills and valleys. In some cases, exotic weeds on these lands can adversely impact federal lands.

5.2.1.3.1 Potential strategies for control of noxious and exotic plants

The fragmented ownership pattern and differing management goals within the watershed make it difficult to have a coordinated program to promote and preserve native plant populations, and limit the spread of exotic plants and noxious weeds. Himalayan blackberry and Scotch broom are two aggressive exotic plant species that are favored by soil disturbing activities. Where these plants are controlled through herbicide application, herbicides must be carefully chosen to avoid loss of native plant diversity. There are potentially additional detrimental impacts when herbicides are applied near aquatic systems. Additionally, exotic plants tend to be more aggressive than natives and invade treated areas sooner than many native plants, therefore often requiring multiple herbicide treatments to be effective. Native shrub species that are commonly greatly reduced by the invasion of exotic plants include elderberry, cascara, thimbleberry and salmonberry. Loss of these species has the potential to impact the distribution or abundance of wildlife species such as band-tailed pigeon, Swainson’s and varied thrushes and black-tailed deer.

Success of eradication efforts will vary. Due to the widespread distribution and persistent nature of Scotch broom and Himalayan blackberry, it may be necessary to prioritize areas for abatement efforts, rather than attempting complete eradication within the watershed.

5.2.2 Species and habitat issues

5.2.2.1 Factors affecting the distribution of sensitive species

Several factors have impacted the numbers and distribution of sensitive species within the watersheds. These include the introduction of non-native species, as well as habitat conversion and fragmentation.

The introduction of non-native species has diminished species diversity both through competition and predation. These include such species as the nutria, which reproduces quickly and competes with native mammals, the opossum, and the bullfrog. The latter, in particular, has been implicated in the loss of native amphibians throughout the western portion of the United States and it is likely that bullfrogs have done likewise in the Tualatin subbasin.

The majority of the watershed is currently under intensive land use, whether urban or agricultural. The remainder is a fragmented assemblage of conifers, clearings, houses and prairies. This vegetation pattern makes it difficult for any sensitive species to remain in the watershed, aside from those that only need small stands of a particular habitat type to survive.

Many sensitive species are dependent upon late-successional habitat or specific features associated with late-successional habitat. Such habitat will continue to be limited in the watershed. Depending upon management policies, opportunities may exist to develop such habitat in lands adjacent to Forest Park (which is, itself, outside of the watershed).

The amount of snags and down woody debris available for species dependent on these habitat elements is low throughout the watershed. During field surveys, some ash snags were observed adjacent to the Tualatin River. However, snag density is far lower than would be considered optimal for species dependent on snag habitat. Large down wood is also scarce throughout the watershed and limited to local occurrences in small timber stands. (No surveys were conducted to find locations of down wood). Because of the lack of large trees over most of the watershed, recruitment potential is expected to remain poor. Most recruitment potential is in very small, scattered stands of mature timber along the Tualatin River and in canyons of the foothills. Active management efforts to increase levels of snags and down wood would benefit many species, including primary cavity nesters such as woodpeckers and secondary cavity nesters such as bats, flying squirrels and saw whet owls.

Due to loss of habitat, the populations of many species of concern have diminished. The spotted owl, for example, has been eradicated from the watershed due to lack of habitat. Populations of the pileated woodpecker have been reduced.

Prospects for a uniform habitat management strategy among landowners in the watershed are very unlikely. The fragmented ownership pattern restricts creation of such a strategy for sensitive species.

5.3 Social

5.3.1 Issues related to human uses

5.3.1.1 Agriculture

The amount of farmland is expected to decrease within the watershed. In its comprehensive plan, Washington County recognized the importance of agriculture to the quality of life in the region and designated Exclusive Farm Use (EFU) zones. Most lands presently in agriculture fall within this zoning, or under the mixed Agriculture-Forestry (AF) designation.

Agricultural operations impact watershed resources, often creating conflicts with other beneficial uses within the watershed. Irrigation is the greatest single use of surface water resources. Operations also can contribute to water quality problems, creating potential conflicts with fishery and recreational resources. With improved practices, negative impacts and conflicts are being reduced. Many of these improvements have been achieved with the assistance of the Farm Service Agency (FSA), the Natural Resources Conservation Service (NRCS), and the Washington County Soil and Water Conservation District (SWCD). Through implementation of farm conservation plans and other programs, farmers in conjunction with these agencies have been able to reduce soil loss, water consumption, and inputs of sediments, nutrients, and other pollutants to streams. Since many farms in the watershed operate without fully utilizing these services, further opportunities for improvement exist within the watershed. However, these agencies and programs lack the funding to fully meet the demand in a timely fashion.

Although total agricultural production is a substantial portion of the watershed economy, the results of the 1997 agricultural census indicate that many farms operate on a slim profit margin. This should be taken into account when implementing new programs to address conflicts with other beneficial uses in the watershed.

5.3.1.2 Timber

Timber harvest is a relatively small-scale land use within the watershed and is primarily dispersed among small woodlands. Owners of these woodlands often combine timber growing with other objectives on these lands. Although timber lands within the watershed are very productive, the market for timber from these lands does not appear likely to improve in the near future. It is likely that small woodland owners will need to develop new strategies for marketing their products. These could include finding "niche" markets for specialty products and the formation of cooperatives to market or mill their products. However, it is likely that the value of forest land within the watershed will continue to inflate along with other lands in the Portland metropolitan area, but for reasons unrelated to timber production (Tom Nygren, personal communication 2000).

5.3.1.3 Rural residential and urban uses

Increasing population is probably the greatest change creating a demand on watershed resources. As population grows, demands for housing space, recreation, and workspace increase, as well as demands on water and contributions of wastewater. Population trends in Washington County indicate that these demands and pressures will continue to persist into the next century. These pressures will continue to be severe in the Lower Tualatin watershed, especially in the portions of the watershed draining to Rock and Butternut creeks. Much of this growth will occur near streams, increasing potential hazards to stream resources. With this growth, there is an enhanced potential for problems related to accelerated erosion and faulty septic systems.

5.3.1.4 Recreation

Developed parks are distributed through urban portions of the watershed. Many of these areas are designed to multiple recreational and educational objectives, including environmental education. There appear to be considerable opportunities for expanding these opportunities while providing for environmental needs. Half of the wetlands identified in the Beaverton Local Wetland Inventory, for example, were considered to support educational and/or recreational objectives, while providing other functions associated with wetlands.

With continued population growth, there is expected to be a demand for increased parklands in this area. In anticipation of this prospect, Metro's Greenspaces Technical Advisory Committee seeks to identify potential acquisitions that will satisfy both ecological and community objectives. With the limited land base available within the UGB, such multiple-objective management will become increasingly important. As with other realms of human activity, care must be taken to preserve the resource while providing for recreation.

5.3.2 Cultural resources

Numerous artifacts of cultural importance have been found at locations throughout the watershed. Although care should be taken when conducting activities that might disturb areas of cultural importance, no specific cultural resources issues were identified.

5.3.3 Road-related issues

Roads can be beneficial because they facilitate access for utilization of resources, urban transport, fire suppression, and recreation. However, they also have potentially negative effects. Roads frequently conflict with water quality objectives by contributing sediment to streams. Exposed road surfaces are often readily erodible, while sidecasts and cutslopes are often susceptible to landsliding. Sediments are readily delivered to streams by near-stream roads and at stream crossings.

Stream crossings potentially create migratory hazards to anadromous fish. Additionally, insufficiently sized culverts may lead to road washouts, contributing to sedimentation problems.

Road surfacing led to a need for rock pits. Current quarries are concentrated in the Rock Creek (South) subwatershed. Although relatively few in number, basalt quarries are distributed over many portions of the Lower Tualatin watershed. These sites, along with historic quarries, may pose sediment risks to nearby streams. They also may create a safety hazard due to their depth and/or sheer wall faces.

5.4 Data Gaps

During preparation of this watershed analysis, several data gaps were identified. Data collection in these areas will provide potential benefits to management, planning, and restoration efforts.

Erosion Processes

- Magnitude, location, and causes of mass wasting in the Chehalem Mountains. A comprehensive landslide inventory based on aerial photography and field visits would enhance our knowledge in this area, as well as determining present and potential sediment sources.
- Magnitude and location of sheet, rill, gully, and bank erosion. This watershed analysis identified stream reaches and subwatersheds where such erosion was observed or would be likely. Site-specific field surveys and quantitative modeling would enhance our knowledge of these processes in the watershed.
- Magnitude of erosion reduction effected by implementation of specific BMPs and relative effectiveness of these BMPs.

Hydrology and Water Quantity

- Adequacy of current instream water rights to protect aquatic life and other instream beneficial uses. This report identified existing instream water rights, but did not attempt to determine whether these rights provided adequate protection for aquatic resources. More intensive field study would be necessary to answer this question.
- The best locations for potential purchases of instream water rights.
- Survey of well failures and study of the interaction between these wells and the hydrology in neighboring streams.
- The extent of illegal water diversions.

Stream Channel

- Field verification of OWEB channel types. Field study would also provide insights on characteristics not visible from maps and photography, and would aid in restoration planning.
- Ongoing changes in channel characteristics. Field study aimed at detection of current channel migration, widening, and entrenchment would aid in planning efforts.

Water Quality

- Location of inadequate septic systems in the watershed.
- Sources of bacterial inputs in subwatersheds contributing to Chicken and Fanno creeks.
- Sources of nutrient inputs in subwatersheds contributing to all creeks.

Aquatic Species and Habitats

- Distribution of anadromous fish habitat. A better understanding of the quantity and quality of habitat for anadromous salmonids and other species of interest would be gained from a comprehensive habitat survey. This is particularly important in the Fanno Creek system, where disagreement exists about the value of the stream to winter steelhead trout.
- Amount and distribution of salmonid spawning. Redd counts and spawning surveys would be beneficial to determine actual usage patterns by salmonids. This is particularly important in the Fanno Creek system. Verification of steelhead spawning would help to determine the value of restoration activities in Fanno Creek.
- Population and distribution of amphibian species. Comprehensive amphibian population surveys would help determine the distribution of sensitive species and the potential impacts of habitat loss and exotic species upon native amphibians.
- Population and distribution of special status and special attention species dependent on riparian and wetland habitats.
- Present extent, types, functions and condition of specific wetlands in rural areas. Additional information could be gained if the NWI delineation were refined using current aerial photographs and field research. Field study would also help to determine the condition of specific wetlands and locate priority sites for restoration.

Vegetation

- Amounts and distribution of sensitive botanical species. These include bryophytes, lichens, and fungi, as well as vascular plants. Comprehensive botanical surveys would facilitate planning efforts for these species.
- The composition of native plant species in a "natural" herbaceous community. Ralph Cook, THPRD, has noted that little is known about the composition of the "natural" herbaceous community in the northern Willamette Valley prior to European settlement.
- Methods by which native plant communities might be sustainably restored. Ralph Cook, THPRD, has noted the high maintenance demands necessary to maintain a "natural" landscape. More research in this area might yield lower costs in the long run.

Terrestrial Species and Habitats

- Distribution of sensitive species. Population surveys would contribute to management efforts for these species.

Human Uses

- Potential mitigation sites and funding sources for mitigation of rock pit sites.
- Size and condition of smaller culverts in the watershed. Washington County conducts culvert inventories, but presently concentrates its efforts on culverts exceeding 36 inch diameter.
- Historically, railroads and logging roads were built on sites throughout the watershed. Many of these “legacy roads” may continue to provide erosion and/or sedimentation hazards. However, determination of the locations of these roads, as well as potential mitigation opportunities, was beyond the scope of this report.

Chapter 6: Recommendations

Watershed needs and opportunities are most effectively addressed by a consistent, cooperative effort between landowners and government agencies. In keeping with that principle the following recommendations are intended as general guidelines for cooperative efforts that can be undertaken to achieve watershed objectives. These recommendations are not intended to mandate what state and private landholders should do with their own land, but instead to identify potential opportunities for improvement of conditions within the Lower Tualatin watershed. Opportunities will be available through cooperation with private landowners to create partnerships to implement these recommendations. As the nexus of many different interests, the Tualatin River Watershed Council can play a vital role in facilitating these partnerships.

These recommendations were designed with this concept in mind. Three groups have been identified. The actual implementation of these recommendations and objectives is performed by a large and varied group of individuals, grassroots organizations, and corporations. They organize educational activities, donate material, contribute labor and expertise, and manage their lands to achieve desirable watershed objectives. Although the people in this group represent diverse interests, they work toward similar beneficial objectives, and here they are described collectively as **partners**. Another group, that of governmental **agencies**, has specific duties to achieve watershed objectives. Although they are also important partners in the watershed restoration efforts, when performing their official duties they will be referred to as agencies. Finally, the **Tualatin River Watershed Council** acts as facilitator to promote implementation of these recommendations. In this role, the council acts to coordinate efforts between partners to achieve beneficial watershed objectives.

Success of many programs delineated within these recommendations is contingent upon funding. There are several sources of expertise and funding for projects on private lands that could be used for the opportunities identified below. State, federal, and local agencies have funding for willing landowners. For example, the Oregon Department of Fish and Wildlife and state Restoration and Enhancement funds are available for restoration of riparian and stream habitat. The Natural Resources Conservation Service and the Washington County Soil and Water Conservation District have access to federal funds for improvement, particularly of agriculturally related problems in the lower watershed. The U.S. Fish and Wildlife Service, through its Partners for Fish and Wildlife program, also funds wildlife habitat restoration and improvement projects for wetland, riparian, and instream areas on non-federal lands. This availability of funding should encourage private landowners to join in the effort to improve the Lower Tualatin watershed ecosystem. Furthermore, the Tualatin River Watershed Council and various agencies should pursue additional funding to address the identified needs within the watershed.

Through the watershed analysis process, several stream reaches and wetland areas were identified as priorities for preservation and restoration activities (Table 6-1). These priorities were generally based on the degree of degradation and the potential to restore specific beneficial uses (e.g., potential for salmonids to utilize improved habitat). Areas with relatively good habitat were earmarked for preservation.

Table 6-1. Priority sites for preservation, restoration, and monitoring activities.

Reach/subwatershed	Type of activity	Rationale
Fanno Creek.	• Sediment reduction • Nutrient Reduction • Bacteria reduction • Riparian reforestation • Habitat survey • Instream habitat restoration	• Potential steelhead spawning habitat. • High levels of sedimentation • High nutrient levels • High bacteria levels • High temperature throughout reach • Riparian cover and shading very poor • Degraded fish habitat
Chicken Creek: Downstream of Krueger Road.	• Habitat survey • Sediment control • Nutrient reduction • Bacteria reduction • Riparian restoration	• Steelhead spawning habitat. • Many nearstream roads • High bacteria levels • Relatively complete riparian forest
Ash Creek	• Nutrient control • Bacteria control • Temperature control • Riparian reforestation • Wetland enhancement	• Poor water quality • Limited riparian forest cover • Tributary to steelhead rearing habitat • Limited wildlife benefit in wetlands • Wetland heating of surface waters
Summer Creek	• Nutrient control • Bacteria control • Temperature Control • Riparian reforestation • Wetland enhancement	• Poor water quality • Limited riparian forest cover • Tributary to steelhead rearing habitat • Limited wildlife benefit in wetlands • Wetland heating of surface waters
Rock Creek (South)	• Riparian reforestation • Temperature control • Wetland enhancement • Bacteria monitoring/control	• Very limited riparian forest cover • Important wetland wildlife habitat • Spawning habitat for cutthroat trout
Tualatin River-King City	• Wetland enhancement	• Important wetland wildlife habitat

6.1 General recommendations

6.1.1 Aquatic

6.1.1.1 Erosion issues

Issue #1: Soil disturbing activities on steep and unstable lands lead to increased hazards for surface erosion, mass wasting, and sediment delivery. Stream crossings facilitate sediment delivery.

Solution Strategy: Erosion control efforts in the foothills of the Lower Tualatin watershed are best concentrated in areas of steep slope and subbasins with high densities of roads and stream crossings. These include rapidly urbanizing lands in the Portland Hills. Many of these lands lie under jurisdictional authorities that have programs to minimize the impacts of soil-disturbing activities. A coordinated effort between these entities to implement and monitor effectiveness of these programs would advance erosion control efforts.

Specific Recommendations.

- The Tualatin River Watershed Council should work with construction industry stakeholders to facilitate distribution of educational pamphlets describing appropriate BMPs and erosion control programs.
- If feasible, cuts and fills should be avoided on unstable lands. Where these are necessary, they should be designed in such a way as not to increase instability.
- Drainage-related erosion will be reduced if land owning partners and agencies with road maintenance authority maintain or improve road drainage by cleaning culverts, replacing decaying culverts, and installing downspouts on culverts that have outfalls at a substantial distance above the hillslope. Any culverts that are installed should be designed to withstand the 100-year flood event and to provide fish passage (See section 6.1.1.5).
- In order to reduce erosion and sediment contribution to streams, landowning partners and agencies with road maintenance authority should maintain a vegetative cover on road and drainage ditches. These should be designed in consultation with neighboring landowners to avoid undesirable effects, such as the spread of weeds. Land owning partners and agencies with road maintenance authority can reduce sediment contribution to streams by implementing the following practices where high densities of roads and stream crossings exist: Survey roads for areas with high risk of landslides or erosion from cutslopes, fillslopes, and road treads. Minimize such hazards. Locate culverts or drainage dips to avoid excess accumulations of water in ditches or on road surfaces. Minimize connectivity between drainage ditches and streams to minimize sediment delivery potential. These recommendations are particularly applicable to the following subwatersheds: **Tualatin Mouth, Upper Fanno Creek.**

Issue #2: Sheet, rill, and gully erosion from fields and streambank erosion is widespread in the valleys and adjacent foothills. The greatest problem from surface erosion occurs when soil is inadequately vegetated or otherwise protected from the energy of rainfall. Bank erosion is greatest in areas of impaired riparian vegetation. Where riparian vegetation is lacking, accelerated sediment delivery to streams also occurs.

Road drainage ditches provide channels that facilitate transport of eroded sediments and associated pollutants from fields, and delivery of these substances to streams.

Systematic methodologies to assess the effectiveness of Voluntary Water Quality Farm Plans and urban and agricultural Best Management Practices (both individually and in combination) are lacking.

Solution Strategy: Effective erosion control on agricultural lands will emphasize riparian restoration, residue management, cross-slope farming, rotations with sod-building crops, cover crops, filter strips and grassed waterways. The former objective is most efficiently achieved through voluntary efforts spearheaded by NRCS and SWCD. These agencies have a long history of working together with farmers to reduce soil loss. Additionally, these agencies are able to offer economic incentives and cost-sharing programs to implement Best Management Practices. When developing conservation plans, erosion predictions should be based on the most erodible slopes rather than average slopes in a field. Implementation of a systematic methodology and database to keep track of specific components of Water Quality Management Plans would assist agency sources in refining future prescriptions.

Specific Recommendations:

- NRCS, SWCD and other agencies should continue to promote implementation of Best Management Practices by agricultural interests. NRCS and SWCD should determine locations in the watershed where BMPs are least often used, and focus efforts on these areas. Together with the Tualatin River Watershed Council and the Farm Bureau, NRCS and SWCD should determine outreach measures to improve landowner interest in implementation of BMPs. These entities should actively seek funding to provide expanded assistance toward these objectives. They should pursue greater funding for cost-share programs and incentives to retain greater widths of riparian vegetation. Local governmental agencies should request a greater role in promoting programs such as the Conservation Reserve Enhancement Program (CREP), so that these programs best meet local needs.
- Public agencies responsible for road maintenance should maintain a vegetated lining in road ditches. Similarly, land owning partners will benefit from reduced erosion if they incorporate a vegetated design in drainage ditches on their property. Ditches should be designed in consultation with neighboring landowners so they do not have an adverse effect on their operations.
- When designing conservation plans, NRCS and SWCD should keep a database of practices implemented in each plan, and enhance monitoring of farms under such plans to determine the effectiveness of various prescriptions. As part of this effort, they should design a standardized format for the database so that information collected by different agencies can be easily interchanged. Although these recommendations are applicable to all agricultural subwatersheds, priority should be given to those with high proportions of highly erodible lands. These include the **Chicken Creek and Cedar Creek** subwatersheds.
- Clean Water Services and other urban agencies should continue (and expand) efforts to encourage impervious surface reduction. (See Issue #5.)
- The Tualatin River Watershed Council and its partners should continue to coordinate efforts to restore and enhance riparian vegetation. As part of this effort, the Council should continue to coordinate programs with community groups to plant riparian vegetation. In urban areas, the Council should assist CWS and SOLV with their restoration projects. In rural areas, the Council, together with NRCS and SWCD, should assist landowners with restoration efforts. From an erosion standpoint, the areas of highest priority for revegetation include **Upper Fanno Creek, Ash Creek, Rock Creek (South), Hedges Creek, and Summer Creek**. The natural vegetation type should be taken into account when conducting revegetation efforts at a site.
- The Tualatin River Watershed Council and its partners should encourage policies to protect existing riparian vegetation. As part of this effort, they should advertise currently existing incentives and cost-share programs to remove riparian lands from agricultural production. Where these programs provide inadequate incentive for riparian restoration, the Tualatin River Watershed Council and its partners should work with the federal and state government to provide additional incentives.
- The Tualatin River Watershed Council, together with NRCS and SWCD, should work with Washington County to improve the process associated with permits for wetland restoration so these types of projects are encouraged.
- The NRCS and SWCD should continue efforts to work with rural landowners to address conditions prohibited by the Tualatin River Subbasin Agricultural Water Quality Management Area Plan (OAR 603-95). Contingent upon available funding, they should expand planning efforts within priority subwatersheds.

6.1.1.2 Hydrology and water quantity issues

Issue #3: Wetlands and floodplains are diminished from historical levels. This has resulted in loss of hydrologic function of the Tualatin River.

Solution Strategy: The most effective policy given current constraints is to protect existing floodplain and wetland resources, and to prevent encroachment of activities that are incompatible with floodplain and wetland function. Where incompatible uses do not exist, there may be opportunity to restore the functionality of degraded wetlands. Additionally, there may be partnership opportunities with landowners to create or re-establish wetlands where they do not currently exist.

Specific Recommendations:

- The Tualatin River Watershed Council, partners and NRCS and SWCD should sponsor a study to determine priority sites for preservation or restoration of historic floodplain and wetland function. For each site, appropriate protection, restoration, or enhancement strategies should be identified. Information gained in this study should be systematically maintained in a database, where it can be referenced for future funding opportunities.
- Where willing landowners are available, partners and appropriate agencies should acquire property or habitat conservation easements to protect or expand existing wetlands. They should also evaluate opportunities for land acquisition with which to create new wetlands. If wetland creation appears to be a viable option, they should obtain land for this purpose.
- TRWC, partners and appropriate agencies should look for opportunities to remove dikes and historic channel controls.
- The Tualatin River Watershed Council should promote research projects designed to improve the effectiveness of wetland restoration. These include projects to determine the structure of native herbaceous wetland communities under reference conditions, as well as projects to determine ways to establish viable native herbaceous wetland communities.
- Agencies and partners should conduct post-project monitoring to determine the success of wetland restoration efforts.

Issue #4: Over much of the year, surface flow may be insufficient to support all beneficial uses at some locations. Current instream water rights may be inadequate to protect resources.

Solution Strategy: Water conservation is a necessary part of any strategy designed to optimize water supply for all beneficial uses. As irrigation is currently the largest use of surface water during summer, conservation efforts would benefit greatly if agriculture employs technological solutions to minimize waste during irrigation. Part of this effort could effectively be promoted through the use of incentives.

During formulation of its action plan, the TRWC recommended the acquisition of additional water rights to supplement current instream water rights. The Watermaster, OWRD District 18, has determined that all Water Availability Basins within the watershed are a high priority for the acquisition of instream water rights. If the decision is made to acquire supplementary instream water rights, consideration should be given to the OWRD instream leasing program. Several considerations should go into any decision to acquire instream water rights. Seniority, of course, is a prime consideration. However, location of these water rights is also important. Acquisitions in Chicken Creek (and, perhaps, Fanno Creek) would be most directly beneficial to steelhead trout. At other locations, enhanced flow will help to improve water quality and could benefit resident cutthroat trout. However, they are unlikely to provide direct benefit to steelhead trout except during migration periods. Other native fish species, such as lampreys, would benefit from resulting improvements in water quality.

Specific Recommendations:

- TRWC, partners, and agencies should encourage irrigation water management, including the use of technological soil moisture sensing devices and the conversion of sprinkler to drip systems on appropriate crops.
- TRWC, partners, and agencies should conduct a study to determine the adequacy of current instream water rights to provide adequate conditions for fish and other aquatic life. This analysis should focus on tributaries where augmented flows are not currently available. If current instream water rights are found to be inadequate, locations of greatest need for supplementary water rights should be noted. Priority for water rights acquisition should be given to the most senior rights available at these locations. When acquiring water rights, strong consideration should be given to use of the OWRD instream leasing program.
-

Issue #5: Urban portions of the watershed are extensively covered by asphalt, concrete, and other impervious surfaces. This has increased winter peak flows and decreased groundwater recharge. Additionally, the altered hydrology has had secondary effects on channel structure, erosion, and fish habitat.

Solution Strategy: Impervious cover reduction will be essential to addressing hydrologic alteration within urban areas. Although some opportunity may exist to preserve currently undeveloped areas for groundwater recharge, pressures for infill will reduce these opportunities. In new developments, it will be important to innovate designs and practices that allow water to infiltrate and percolate to groundwater. Additionally, strategies need to be found to retrofit older developments to increase groundwater recharge and reduce surface runoff.

Specific Recommendations:

- Clean Water Services and other urban agencies should continue (and expand) efforts to encourage effective impervious surface reduction. These will include public education, as well as implementation of project designs that use pervious materials. Alternatives to reduce impervious area in currently existing developments should also be explored.
-

6.1.1.3 Stream channel issues

Issue #6: Most stream channels are severely deficient in large wood. This has limited the development of pools, which provide essential habitat for fish and other aquatic life. In most subwatersheds, little potential exists for recruitment of large wood to streams.

Solution Strategy: Intensive land use within the watershed limits the potential for recruitment of large woody debris. The best remaining potential exists in streams contributing to Cedar Creek and the Tualatin Mouth subwatersheds. Additionally, large ash trees adjacent to the Tualatin River provide large wood to the channel, although not at historical levels. Where attempts are made to restore this function, long-term development of large woody debris recruitment potential should be supplemented by short-term tactics. Potential elements of this strategy include re-introduction of conifers to hardwood stands, thinning within riparian zones to promote development of tree mass, and artificial placement of instream structures. Location of these restoration activities will depend on management objectives. Channel structure throughout the watershed would benefit from placement of large wood. The greatest direct benefit to salmonids would likely result from wood placement in Chicken Creek. Depending upon the degree of salmonid utilization of Fanno Creek, placement of LWD may be of benefit on that stream, as well.

Specific Recommendations:

- The TRWC and its partners, in coordination with ODFW, should facilitate a stream habitat assessment on **Fanno Creek and Chicken Creek**. As part of this assessment, the feasibility of wood placement should be determined. These efforts can supplement other survey efforts conducted by CWS (such as the Watersheds 2000 project) and TRWC to determine the potential effectiveness of habitat restoration.
- As an interim measure, partners performing stream restoration should place large wood in channels, and construct instream structures to create pools in degraded habitat with high fisheries potential. Restoration projects should include substantial post-project monitoring to determine the effectiveness of restoration techniques. Channel structure throughout the watershed would benefit from this recommendation. Sub-basins where placement of large wood would have the greatest benefit for salmonids are listed in the aquatic species and habitat section (Section 5.1.5).
- Where feasible, landholding partners should manage riparian areas to develop late-successional characteristics so that they can eventually develop large wood for potential delivery to streams. This can include re-introduction of conifers to hardwood stands and some thinning within riparian zones.

6.1.1.4 Water quality issues

Issue #7: In many portions of the watershed, sediments are delivered to streams at levels well above reference conditions. These sediments often carry adsorbed pollutants.

Solution Strategy: Strategies to combat sedimentation are described under the erosion section (Section 6.1.1.1).

Specific Recommendations:

- The Tualatin River Watershed Council should work with the appropriate management agencies to facilitate use of sediment-reduction BMPs. This will include distribution of educational material related to these BMPs.
- NRCS and SWCD should continue efforts to expand implementation of agricultural Best Management Practices to reduce sediment discharge to streams (see under Erosion).
- Agencies, partners, and TRWC should work together to restore riparian buffers (see under Erosion).
- Landowning partners and agencies with road maintenance responsibility should minimize connectivity of road drainage ditches to stream channels (see under Erosion). Where necessary, they should build a sediment settling system to detain runoff prior to stream entry.

Issue #8: High levels of bacteria and ammonia have adversely impacted streams within the watershed. In some cases, inputs of these constituents have caused streams to be listed under section 303(d) of the Clean Water Act.

Solution Strategy: The management strategy for problems related to bacteria and ammonia nitrogen should focus on keeping animal and human waste away from aquatic systems. Successful nitrogen management also relies on effective fertilizer management.

Specific Recommendations:

- The Tualatin River Watershed Council should coordinate with the appropriate management agencies to develop runoff management strategies in urban areas.
- Agencies should intensify efforts to identify and improve faulty septic systems near streams. These efforts should include an educational program on the maintenance of septic systems. In order to facilitate improvement of these systems, homeowners should be offered incentives such as cost-share opportunities.
- Agencies and animal-owning partners should intensify efforts to keep sources of animal waste from entering streams. NRCS and SWCD should continue efforts to identify sources of animal waste to aquatic systems and to work with land owners to eliminate these sources. Together, they should implement appropriate measures, potentially including livestock exclusion, vegetation buffers, and proper storage and application of waste. NRCS and SWCD should continue efforts to publicize available cost-share programs to implement these measures. In order to remove streams from the 303(d) list, these efforts are applicable to most rural subwatersheds, particularly **Chicken Creek and Tualatin Mouth**. Additionally, pet waste has been identified as a potentially important bacteria source in urban subwatersheds.
- Agencies and partners should work together to improve fertilizer management for urban, agricultural, and forestry applications. NRCS and SWCD, other appropriate agencies, and educational institutions should seek funding to continue studies to determine optimal fertilizer and manure application systems. As funding becomes available, they should conduct these studies expeditiously. They should distribute findings of these studies to applicable agency personnel and private agriculture, forestry, and landscaping businesses. Additionally, they should update publicly accessible literature to include the most current findings and create a distribution system to ensure that the literature makes its way to applicable personnel.
- NRCS and SWCD should continue to work with landowners to implement agricultural BMPs that reduce nutrient laden runoff to streams.

Issue #9: Phosphorus levels in portions of the watershed exceed established TMDLs.

Solution Strategy: Monitoring data indicate that instream phosphorus concentrations are well above those attributable to natural sources. Persistent effort will be essential to reducing instream phosphorus below current levels. Measures taken to minimize sediment delivery to streams, as well as effective nutrient and animal waste management will limit inputs of adsorbed phosphorus. Reductions in readily decomposable organic matter will reduce anaerobic streambed conditions that release phosphorus from sediments.

Specific Recommendations:

- TRWC should coordinate with Metro and other appropriate management agencies to maximize implementation of BMPs related to reduction of nutrients and sediment in urban areas. This will include distribution of educational material and grassroots recruitment of private property owners.
- NRCS and SWCD should continue implementation of rural BMPs and educational programs, especially with respect to nutrient management, animal waste management, livestock grazing, and erosion control.
- Partners and agencies should implement measures to reduce inputs of sediment, manure, grass clippings and other non-woody organic matter to streams.
- Agencies and partners should avoid practices that resuspend stream bottom sediments.
- ODEQ or another agency source should conduct a study to investigate the role of inadequate septic systems in contributing to phosphorus loads. In stream reaches where inadequate septic systems are found to be a significant contributor of phosphorus, the source should be identified, and a cost-share program should be implemented to upgrade the septic system to adequate standards.

Issue #10: Most streams have summer temperatures detrimental to salmonids and other aquatic life preferring cool water conditions.

<u>Solution Strategy</u>: Strategies for temperature moderation should focus on protection and restoration of the riparian canopy. Some stream reaches would also receive local reduction of water temperature through leasing of additional instream water rights.

Specific Recommendations:

- The Tualatin River Watershed Council, partners, and agencies should work together to implement programs to restore canopy cover through revegetation of the riparian zone with appropriate species. (See under Erosion).
- The Tualatin River Watershed Council and its partners should explore leasing options for additional instream water rights (See under Hydrology/Water quantity)

---

*Issue #11: Summer dissolved oxygen levels in many streams are below optimal levels for salmonid rearing. This is particularly important on **Fanno Creek and Chicken Creek**, which are considered to provide habitat for steelhead trout.*

<u>Solution Strategy</u>: Strategies to improve dissolved oxygen levels throughout the watershed should emphasize thermal moderation. Additionally, ODEQ has found that dissolved oxygen levels in urban streams will receive a potentially substantial benefit if inputs of nutrients and organic material are reduced.

Specific Recommendations:

- The Tualatin River Watershed Council should work with appropriate management agencies to reduce fertilizer runoff, animal wastes, faulty septic systems, and organic debris from all sources.
- NRCS and SWCD should work with land and animal owners to implement measures for management of waste and organic debris.

---

*Issue #12: Sedimentation appears to be impairing biological function in the watershed. Biological sampling indicates that high impairment exists in subwatersheds contributing to **Fanno Creek**. Sediment-related impairment is also expected to be present in other subwatersheds.*

Solution Strategy: Sediment reduction strategies are indicated. Although the problem is only partially related to human management, that part can be addressed by implementing measures to address erosion and mass wasting caused by human activities. (See erosion section)

Specific Recommendations:

- Agencies, the Tualatin River Watershed Council, and concerned partners should work together to implement measures recommended to address erosion issues.
- Where erosion is occurring, concerned parties should consider the construction of sediment control structures, vegetated buffer strips and/or wetlands to prevent sediment delivery to stream systems or, alternatively, to remove sediments from streams. This is particularly important in subwatersheds contributing to Fanno Creek, where there is a substantial length of nearstream roads.

6.1.1.5 Aquatic species and habitat issues

Issue #13: Salmonid populations are declining. Degradation of habitat and water quality has contributed to this decline.

Solution Strategy: Attempts to restore salmonid populations should focus on habitat preservation and restoration. These efforts should concentrate on **Chicken Creek**, where much of the Lower Tualatin watershed's existing salmonid spawning and rearing habitat is located. Pending the results of future surveys, **Fanno Creek** may also be a high priority site for habitat restoration. Cutthroat trout would also benefit from restoration efforts on these streams, as well as **Cedar Creek and Rock Creek (South)**.

Habitat restoration can provide an important role in the watershed. However, restoration should not substitute for preservation of currently suitable habitats. Compared to watersheds further west in the Tualatin River subbasin, the Lower Tualatin watershed has relatively little high quality salmonid habitat. Preservation opportunities will be available on a spotty basis, rather than for extensive stream reaches.

Instream restoration strategies should focus on restoring channel structure, roughness elements, and habitat diversity. Additionally, reduction of nutrient and sediment inputs will be part of any successful habitat restoration activity. Channelization and lack of large woody debris (LWD) are important factors impacting channel structure (Ward 1995). Current LWD recruitment potential is poor. LWD placement is a viable short-term option, but should not replace riparian protection and other measures that will provide for long-term recruitment potential. Other measures, such as restoration of stream canopy and improvement of water quality, coincide with objectives of other modules. If efforts are taken to address concerns related to erosion, hydrology, water quality, and stream channel characteristics, benefits to fish will accrue.

Specific Recommendations:

- TRWC, partners, and agencies should work together to preserve existing salmonid spawning and rearing habitat. They should conduct surveys to determine the location and condition of such habitat. During these surveys, appropriate restoration sites should be noted. For optimal results, surveys for steelhead trout habitat should be concentrated on **Fanno Creek and on Chicken Creek below Kruger Road**. Additional habitat surveys for resident cutthroat trout may be valuable on longer reaches of these streams, as well as **Cedar Creek and Rock Creek (South)**.
- TRWC, partners, and agencies should work together to restore instream habitats for salmonids. Such restoration may include placement of large woody debris and/or instream channel structures. Restoration projects should be accompanied by monitoring to determine the most effective techniques. Portions of **Chicken Creek and Fanno Creek** are potential sites for restoration.
- TRWC, partners, and agencies should work together to restore riparian vegetation. Partners should plant appropriate native tree species where the natural riparian canopy has been removed. Where non-native shrub and herb species such as Himalayan blackberry and reed canarygrass have invaded riparian habitats, partners should replace these species with

appropriate native trees and shrubs. This recommendation applies throughout the watershed. Areas where riparian restoration would provide the greatest potential benefit for fisheries include **Fanno Creek**.

- Landowning partners and appropriate agencies should conduct culvert surveys to locate obstructions to fish migration. They should replace culverts and other stream crossing structures that do not provide adequate passage.
- Conservation organizations, other partners, or agencies should acquire land or conservation easements in crucial riparian habitats. Agencies should promote incentives for private land owners to implement BMPs designed to protect aquatic habitat. The TRWC, partners, and agencies should strive to form cooperative fisheries enhancement projects across ownership boundaries that maximize habitat improvement.

Issue #14: Reductions in wetland area have led to depletion of habitat for wetland and riparian species. This has adversely impacted populations of these species, especially amphibians.

Solution Strategy (Wetlands): The most effective policy given current constraints is to protect existing wetland resources, and to prevent encroachment of activities that are incompatible with wetland function. As financing becomes available, procurement of additional lands and conservation easements will also assist in providing wetland habitat. Where incompatible uses do not already exist, there may be opportunity to restore the functionality of degraded wetlands. For example, eradication of reed canarygrass and restoration with native vegetation may enhance the habitat values of these wetlands. Additionally, opportunities may exist to enhance habitat values within storage ponds. Many of these ponds already provide open water habitat for waterfowl. Emergent species could be planted along pond margins to increase habitat values for amphibians and other species dependent on shallow water habitat. However, this approach may cause conflicts with other interests using the ponds.

Solution Strategy (Riparian habitats): Strategies for riparian dependent species should emphasize increasing the amount of suitable riparian habitat. Programs are currently underway to meet this objective. One such program is the Conservation Reserve Enhancement Program (CREP). Administered by the NRCS, this program provides financial incentives for farmers to establish buffer strips along streams. Currently, no farmers in the Tualatin subbasin have enrolled land in the CREP program because program incentives are insufficient to attract their interest. If incentives were increased, it is hoped that this and similar programs would increase the amount and quality of habitat available to riparian dependent species.

Specific Recommendations:

- The TRWC should coordinate with the Tualatin Hills Parks and Recreation District, Pacific University, Portland State University, and other partners and agencies to perform population surveys to determine the extent of amphibian species, as well as other riparian and wetland-dependent species.
- The TRWC, partners, and agencies should evaluate and implement programs to restore wetland functionality. These are discussed in Section 6.1.1.2. Opportunities for wetland enhancement exist at in most subwatersheds, including **Rock Creek (S), Tualatin-Fanno Confluence, and Hedges Creek**.
- The TRWC, NRCS, and SWCD, should work with permitting authorities to improve the process associated with permits for wetland projects.
- Conservation organizations, other partners, or agencies should acquire habitat conservation easements in riparian areas.
- The SWCD and NRCS should develop a mechanism for other partners to provide funding to supplement CREP incentives in order to encourage farmers to begin restoring riparian areas.

6.1.2 Terrestrial

6.1.2.1 Vegetation issues

Issue #15: Management practices have resulted in a change in vegetational characteristics. The amount of vegetation in late-successional stages has been severely reduced from reference levels. Hardwoods have invaded areas formerly dominated by conifers.

Solution Strategy: Intensive land use within the watershed limits potential opportunities to manage for late-successional stand characteristics. Some potential may exist in subwatersheds draining to **Cedar and Chicken** creeks, as well as small patches in the **Tualatin Mouth** subwatershed. The ability to develop late-successional habitat characteristics will depend on the management emphases of different landowners. Often, restoration of conifers to hardwood areas is in the management interests of both federal and private landowners.

Specific Recommendations:

- Where feasible, landowners are encouraged to reestablish native conifers on sites where hardwoods have invaded.
- Large landowning partners are encouraged to manage currently mature stands of private forests to develop late-successional characteristics including stand complexity, snags, and down wood.

Issue #16: Native species richness within much of the watershed has been compromised by invasive exotic and noxious weeds.

Solution Strategy: Solutions for management of exotic weeds are best managed by partnerships between agencies and landowners. In the watershed, however, fragmented land ownership makes formation of weed abatement partnerships difficult. Cooperative efforts between the Tualatin River Watershed Council, Oregon Department of Agriculture, and Washington County would provide a major step in forming effective partnerships.

To prevent recolonization by weed species, planting and cultivation of desirable species should accompany weed eradication.

Specific Recommendations:

- TRWC should facilitate contact between the Farm Bureau, ODA, NRCS, SWCD, private industrial landholders, and other entities representing landholders to form partnerships to combat noxious weeds. TRWC should coordinate efforts by other groups with current efforts being conducted by the Oregon Department of Agriculture. If feasible, eradication efforts should emphasize non-chemical methods near aquatic systems. Non-chemical methods should also be considered for other areas.
- NRCS, SWCD, and other applicable agencies should advertise the availability of educational pamphlets encouraging eradication of noxious weeds. These pamphlets should be updated as necessary to address problems specific to the Tualatin Valley.
- TRWC, ODA, SWCD, and concerned partners should form a committee to determine which plants have the capability to become noxious weeds within the Tualatin Basin. The committee should work with the appropriate agencies, nurseries, and consumer groups to restrict the ability of these plants to become naturalized within the basin.

6.1.2.2 Terrestrial species and habitat issues

Issue #17: Many plant and animal species in the watershed are sensitive to management-induced habitat changes. Habitat for many of these species has been reduced from former levels.

Solution Strategy: Proper management strategies for sensitive species will vary by the species. O'Neil et al. (2001) identify habitat needs of many species.

Knowledge of species distribution is an important prerequisite for successful management for sensitive species. In order to gain this knowledge, systematic surveys should be conducted where habitats are suitable for these species.

Specific Recommendations:

- TRWC and its partners should act as facilitators to formulate uniform habitat management policies.
- TRWC and its partners should support research into ways to facilitate sustainable native plant communities.
- Government policy makers should consider providing incentives for landowners to manage forests for recruitment of snags and down wood.
- TRWC should seek funding and facilitate partnerships to conduct systematic surveys for sensitive species.
- TRWC and its partners should encourage use of LWD from construction sites for habitat improvement.

6.1.3 Social

6.1.3.1 Issues related to human uses

Issue #18: Timber, agricultural, domestic, industrial, and wildlife interests often come into conflict for limited resources. As population increases, this competition will intensify.

Solution Strategy: A cooperative approach between various interests is necessary to resolve competing watershed demands. The Tualatin River Watershed Council plays a major role in facilitating this cooperation.

Specific Recommendations:

- In order to achieve Oregon's environmental policy objectives, the Oregon Watershed Enhancement Board should continue funding for the Tualatin River Watershed Council.
- Resource interest groups should be encouraged and supported in efforts to develop educational, landowner assistance, and technical expertise initiatives to foster sustainable resource management in the Tualatin subbasin.

6.1.3.1.1 Recreation

Issue #19: Nearstream recreational activities can lead to disturbance of the riparian zone. Support activities associated with recreational facilities can contribute pollutants to streams.

Solution Strategy: Measures should be taken to minimize the effects of recreational activities upon streams. These include regulation of stream access, maintenance of vegetated buffer strips between streams and activities detrimental to the aquatic system, and monitoring to determine the location, nature, and magnitude of recreation-associated impacts on streams.

Specific Recommendations:

- TRWC, agencies, and partners should work together to conduct a survey to determine specific sites of impacts due to recreational access to streams. Determine whether recreational benefits outweigh impacts at these sites. Where continued access is considered beneficial, consider improving the streambank or otherwise constructing facilities to minimize impacts.
- Agencies should monitor parks to ensure that they do not contribute appreciable inputs of fertilizers, pesticides, and herbicides to stream systems. Managers of these facilities should be encouraged to develop conservation plans.

6.1.3.1.2 Road-related issues

Issue #20: Roads are significant contributors to problems related to erosion, water quality, stream channels, and aquatic life (see respective sections).

Solution Strategy: A diversified strategy is necessary to deal with road-related problems. This strategy will consist of a combination of measures to restrict road-related impacts upon streams.

Specific Recommendations:

- Landowning partners should avoid building new roads on steep terrain. Where feasible, roads in these areas should be decommissioned. (See Section 6.1.1.1).
- Surveys should be conducted to locate "legacy roads" and abandoned railroad grades that may be posing problems to watershed resources. Additionally, funding should be sought to reduce impacts from these roads.

Bibliography

Agee, J.K., and M.H. Huff. 1987. Fuel succession in a western hemlock/Douglas-fir forest. Can. J. For. Res. 17:697-704.

Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Island Press. Covelo, CA.

Altman, B., C.M. Henson, and I.R. Waite. 1997. Summary of information on aquatic biota and their habitats in the Willamette Basin, Oregon, through 1995. USGS Water-Resources Investigations Report 97-4023. Portland, OR.

American Local History Network. 2001. Clackamas County History. Website: www.usgennet.org/alhnorus/ahorclak/.

Aroner, E. 1998. Tualatin River Basin tributary water quality status report, 1997. Report prepared for the Unified Sewerage Agency by WQHYDRO. Hillsboro, OR.

Aroner, E. 2000. Tualatin River Basin tributary water quality status report, 1999. Report prepared for the Unified Sewerage Agency by WQHYDRO. Hillsboro, OR.

Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. *In* W.R. Meehan (ed.), Influences of Forest and Rangeland Management. W.R. Meehan, ed. American Fisheries Society Special Publication 19:83-138. Bethesda, MD.

BLM (Bureau of Land Management). 1997. North Yamhill Watershed Analysis. BLM Salem District, Tillamook Resource Area. Tillamook, OR.

BLM (Bureau of Land Management). 1999. Western Oregon Digital Imagery Project (WODIP). GIS data available from BLM Oregon State Office.

Bonn, B.A. 1999. Selected elements and organic chemicals in bed sediment and fish tissue of the Tualatin River basin, Oregon. USGS Water-Resources Investigations Report 99-4107. Report prepared in cooperation with the Unified Sewerage Agency of Washington County. Portland, OR.

BOR (Bureau of Reclamation). 2001. Tualatin Fish Mitigation Program, Tualatin Project, Washington County, Oregon. Final Environmental Assessment and Finding of No Significant Impact. U.S. Bureau of Reclamation, Pacific Northwest Region, Lower Columbia Area Office. May, 2001. Portland, OR.

Bourke, P., and D. Debats. 1995. Washington County: Politics and community in antebellum America. Johns Hopkins University Press. Baltimore, MD.

Brown, B., R.B. Bury, D.M. Darda, L.V. Diller, C.R. Peterson, and R.M. Storm. 1995. Reptiles of Washington and Oregon. Seattle Audubon Society. Seattle, WA.

Brown and Caldwell. 1998. Fanno Creek Resource Management Plan. Prepared for the City of Portland, Bureau of Environmental Services.

Burns, S.F., W.J. Burns, D.H. James, and J.C. Hinkle. 1998. Landslides in the Portland, Oregon metropolitan area resulting from the storm of February 1996: Inventory map, database and evaluation. Report prepared as fulfillment of Metro contract 905828. Dept. of Geology, Portland State University. Portland, OR.

Busby, P.J., T.C. Wainwright, G.J. Bryant, L. Lierheimer, R.S. Waples, F.W. Wasknitz and I.V. Lagomarsino. 1996. Status review of West Coast steelhead from Washington, Idaho, Oregon and California. NOAA Technical Memorandum NMFS-NWFSC-27. National Marine Fisheries Service.

Cass, P.L. and R. Miner. 1993. The historical Tualatin River basin. Oregon Water Resources Research Institute, Oregon State University. Corvallis, OR.

Clean Water Services. 2000. Unpublished Watersheds 2000 data. Hillsboro, OR.

Close, D.A., M. Fitzpatrick, H. Li, B. Parker, D. Hatch, and G. James. 1995. Status Report of the Pacific Lamprey (*Lampetra tridentata*) in the Columbia River Basin. Report prepared for U.S. Dept. of Energy, Bonneville Power Administration. Project Number 94-026. Portland, OR.

Cole, M.B. 2000. Assessment of macroinvertebrate communities of the Tualatin River Basin. Report prepared for the Unified Sewerage Agency and the Tualatin River Watershed Council by ABR, Inc. Forest Grove, OR.

Cramer, S.P. and Associates. 1997. [Data based on analysis of ODFW fish population survey data for the Umpqua Basin]. Gresham, OR.

CSE (Center for Science Education, Portland State University). 2000. Nutria in the NW. Web page: http://hope.cse.pdx.edu/wetlands/nwnutria.dir/nnwEI.htm.

Csuti, B. A.J. Kimerling, T.A. O’Neil, M.M. Shaughnessy, E.P. Gaines, and M.M.P. Huso. 1997. Atlas of Oregon wildlife. Oregon State University Press. Corvallis, OR.

Ecotrust. 1998. Tualatin River Watershed Information System. A collection of GIS layers on CD-ROM. Available from Tualatin River Watershed Council. Hillsboro, OR.

EPA (U.S. Environmental Protection Agency). 1992. GIS data related to locations of Toxic Release Inventory (TRI) and National Pollutant Discharge Elimination System (NPDES) sites.

Fans of Fanno Creek. 2000. “Fish Stories”: The historical occurrence of salmonids in the Fanno Creek watershed. Report researched and written by J. Blowers. January 12, 2000. Portland, OR.

Farnell, J.E. 1978. Tualatin River navigability study. Division of State Lands. Salem, OR.

FEMAT (Forest Ecosystem Management Assessment Team). 1993. Forest ecosystem management: An ecological, economic, and social assessment. Report prepared July, 1993.

Franklin, J.F., and C.T. Dyrness. 1973. Natural vegetation of Oregon and Washington. USDA Forest Service General Technical Report PNW-8.

Franklin, J.F., F. Hall, W. Laudenslayer, C. Maser, J. Nunan, J. Poppino, C.J. Ralph, and T. Spies. 1986. Interim definitions for old-growth Douglas-fir and mixed conifer forests in the Pacific Northwest and California. USDA For. Serv. Res. Note PNW-447. Portland, OR.

Fulton, A.E. 1995. Banks, a darn good little town. Washington County Historical Society. Beaverton, OR.

Goheen, D.J., and E.M. Goheen. 1988. Forest pest evaluation of the Ball Bearing Hill-High Heaven unit, Yamhill Resource Area, Salem District, Bureau of Land Management. USDA Forest Service, For. Pest Manage. R6-88-02. PNW Region, Portland, OR.

Hadfield, J.S. 1985. Laminated root rot, a guide for reducing and preventing losses in Oregon and Washington forests. USDA Forest Service., For. Pest Manage. PNW Region, Portland, OR.

Hadfield, J.S., D.J. Goheen, G.M. Filip, C.L. Schmitt, and R.D. Harvey. 1986. Root diseases in Oregon and Washington conifers. USDA Forest Service, For. Pest Manage. R6-FPM-250-86. PNW Region, Portland, OR.

Hart, D.H., and R.C. Newcomb. 1965. Geology and groundwater of the Tualatin Valley, Oregon. USGS Water Supply Paper #1697.

Hesse, M.P. 1994. Scholls Ferry Tales. Groner women's club. Available at the Washington County Historical Society. Hillsboro, OR.

Hughes, M.L, and K.A. Leader. 2000. Distribution of fish and crayfish, and measurement of available habitat in the Tualatin River basin. Report prepared by ODFW for Unified Sewerage Agency of Washington County. Hillsboro, OR.

Johnson, D.H., and T.A. O'Neil, managing editors. 2001. Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press. Corvallis, OR.

Kurahashi and Associates, Inc. 1997. Fanno Creek Watershed Management Plan. Prepared for the Unified Sewerage Agency of Washington County.

Laurel Ladies Social Club. 1977. Laurel. Available at the Washington County Historical Society. Hillsboro, OR.

Leader, K.A., and M.L. Hughes. 2001. Distribution and abundance of fish, and measurement of available habitat in the Tualatin River basin outside the urban growth boundary. Report prepared by ODFW for the Tualatin River Watershed Council. Hillsboro, OR.

Leonard, W.P., H.A. Brown, L.L.C. Jones, K.R. McAllister, and R.M. Storm. 1993. Amphibians of Washington and Oregon. Seattle Audubon Society. Seattle, WA.

MacWilliam, J., and V. Mapes. 1984. Traces of the Past. Prepared by Beaverton School District 48 Print Shop. Beaverton, Oregon. Available at Washington County Historical Society. Hillsboro, OR.

Martinazzi, L., and K.L. Nygaard. 1994. Tualatin…from the beginning. Tualatin Historical Society. Tualatin, OR.

Meehan, W.R. (ed.). 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. AFS special publication #19. American Fisheries Society. Bethesda, MD.

Metro. 1997. RLIS Lite GIS data. Portland, OR.

Metro. 2001. RLIS Lite GIS data. Portland, OR.

Morris, W.G. 1934. Forest fires in western Oregon and western Washington. Oreg. Hist. Q. 35(4):313-39.

Murtagh, T., V. Niles-Raethke, R. Rohrer, M. Gray, T. Rien, and J. Massey. 1992. Fish management plan, Tualatin River subbasin. Oregon Department of Fish and Wildlife. Clackamas, OR.

Nehlsen, W., J.E. Williams, and J.A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries: Bulletin of the American Fisheries Society. Vol. 16(2) March-April 1991.

Nelson, E.E., N.E. Martin, and R.E. Williams. 1981. Laminated root rot of conifers. USDA For. Serv. Fore. Disease and Insect Leaflet 159.

NRCS (Natural Resources Conservation Service). 1982. Soil Survey of Washington County, Oregon. Hillsboro, OR. (Agency named Soil Conservation Service at time of publication.

OCS (Oregon Climate Service). 1997. Precipitation intensity maps featuring 2-year 24-hour precipitation and 100 year 24-hour precipitation, Western Oregon. Web page: http://ocs.oce.orst.edu/.

OCS (Oregon Climate Service). 1998. Annual precipitation map for Oregon. Web page: http://ocs.oce.orst.edu/

ODEQ (Oregon Department of Environmental Quality), and USA (Unified Sewerage Agency). 1982. Tualatin River water quality, 1970-1979.

ODEQ (Oregon Department of Environmental Quality). 1998. Oregon 1998 Section 303(d) list of water quality limited waterbodies. Salem, OR.

ODEQ (Oregon Department of Environmental Quality). 2000. Tualatin subbasin total maximum daily load (TMDL). Draft prepared August, 2000. ODEQ Water Quality Division. Portland, OR.

ODFW (Oregon Department of Fish and Wildlife). 1999. GIS database showing winter steelhead distribution in the Tualatin subbasin.

Oliver, C.D., and B.C. Larson. 1990. Forest stand dynamics. McGraw-Hill, Inc., New York.

Orr, E.L., W.N. Orr, and E.M. Baldwin. 1992. Geology of Oregon, fourth edition. Kendall/Hunt Publishing Company. Dubuque, IA.

OSU (Oregon State University) Extension. 1999. Agricultural census of Oregon.

Oswego Heritage Council. 2001. [Pioneer family histories]. Website: http://home.europa.com/~heritage/

OWRD (Oregon Water Resources Department). 1997. Water rights in Oregon. Salem, OR.

OWRD (Oregon Water Resources Department). 1998. Water Rights Database (WRIS).

Pater, D.E., S.A. Bryce, T.D. Thorson, J. Kagan, C. Chappell, J.M. Omernik, S.H. Azavedo, and A.J. Woods. 1998. Ecoregions of western Washington and Oregon. US Environmental Protection Agency. Portland, OR.

Payne, M. 1979. Tigardville, Tigard. Lake Grove Printing Company. Lake Oswego, OR.

Preston, J.B. 1852. [Survey plats]. Includes plats for Township 1 South, Range 1 West; Township 1 South, Range 1 East; Township 2 South, Range 1 West; Township 2 South, Range 1 East; and Township 3 South, Range 1 West. Maps available from BLM state office. Portland, OR.

REO (Regional Ecosystem Office). 1995. Ecosystem analysis at the watershed scale: federal guide for watershed analysis. Version 2.2, revised August 1995. Portland, OR.

Risley, J.C. 1997. Relation of Tualatin River water temperature to natural and human-caused factors. U.S. Geological Survey Water Resources Investigations Report 97-4071.

Schlicker, H.G. 1967. Engineering geology of the Tualatin Valley Region, Oregon. Oregon State Department of Geology and Mineral Industries Bulletin #60. Portland, OR.

SD #1 (School District number 1, Washington County Oregon). 1951. West Union Centennial, 1851-1951. Printed by Hillsboro Argus. Hillsboro, OR.

Sedell, J.R., and K.J. Luchessa. 1982. Using the historical record as an aid to salmonid habitat enhancement. *In:* Armantrout, N.B. (ed.) Proceedings of a symposium on acquisition and utilization of aquatic habitat inventory information. Western Division, American Fisheries Society. Bethesda, MD.

Sherk, R. 1936. A history of Sherwood. BA thesis submitted for Pacific College. Forest Grove. Reviewed copy was archived at Oregon State Historical Society, Portland.

Sherwood [City of Sherwood]. 2001. Sherwood history. Webpage: http://www.ci.sherwood.or.us.

Shively, David D. 1993. Landscape change in the Tualatin basin following Euro-American settlement. Oregon Water Resources Research Institute, Oregon State University. Corvallis, OR.

Spies, T.A., J.F. Franklin, and T.B Thomas. 1998. Woody debris in Douglas-fir forests of western Oregon and Washington. Ecology 69:1689-1702.

SRI (Scientific Resources, Inc.), and Walker and Macy, Inc. 1990. Tualatin River Ecological Assessment. Appendix E3, Volume III. Wastewater Facilities Plan. Report Prepared for the

Unified Sewerage Agency of Washington County, and Tualatin Basin Consultants. Hillsboro, OR.

TAC (Tualatin Basin Technical Advisory Committee). 1997. Technical review of nonpoint sources of phosphorus and total maximum daily loads for tributaries of the Tualatin Basin. Report prepared by the nonpoint source subcommittee, May 1997. Hillsboro, OR.

Teensma, P.D.A., Rienstra, J.T., and M.A. Yeiter. 1991. Preliminary reconstruction and analysis of change in forest stand age classes of the Oregon Coast Range from 1850 to 1940. USDI Bur. Land Manage. Tech. Note T/N OR-9.

Thies, W.G. 1984. Laminated root rot: The quest for control. J. For. 82:345-356.

Thies, W.G., and R.N. Sturrock. 1995. Laminated root rot in western North America. USDA For. Serv. PNW Res. Sta. Gen. Tech. Rep. PNW-GTR-349. Portland, OR.

TRFMTC (Tualatin River Flow Management Technical Committee. 1999. Annual Report, 1998. Prepared by USA in cooperation with watermaster district #18. Hillsboro, OR.

TRFMTC (Tualatin River Flow Management Technical Committee. 2000. Annual Report, 1999. Prepared by USA in cooperation with watermaster district #18. Hillsboro, OR.

TRWC (Tualatin River Watershed Council). 1999. Tualatin River Watershed Action Plan. Hillsboro, OR.

U.S. Census Bureau. 1990. Data from the year 1990 census.

U.S. Census Bureau. 2000. Data from the year 2000 census.

USACE (U.S. Army Corps of Engineers). 1953. Tualatin River, Review of Survey Report. Portland, OR.

USACE (U.S. Army Corps of Engineers). 1974. Tualatin River Basin Flood Control Study: Transcript of Public Meeting. USACE Portland District. Portland, OR.

USDA and ODA. 2000. 1999-2000 Oregon Agriculture and Fisheries Statistics. V.G. Korn, ed. Salem, OR.

USDA and USDI (USDA Forest Service and USDI BLM). 1997. Northern Coast Range adaptive management guide. Report BLM/OR/WA/PL-97/008+1792. Tillamook, OR.

USFWS (United States Fish and Wildlife Service). 1980. National Wetlands Inventory.

USFWS (United States Fish and Wildlife Service). 1992. Environmental Assessment: Tualatin River National Wildlife Refuge. USDI U.S. Fish and Wildlife Service, Region 1. Portland, OR.

USGS (United States Geological Survey). Geologic Map of Oregon.

Verts, B.J., and L.N. Carraway. 1998. Land mammals of Oregon. University of California Press. Berkeley, CA.

Ward, D. (ed.). 1995. Distribution of crayfish and measurement of available habitat in the Tualatin River basin, final report of research. Report prepared by Oregon Department of Fish and Wildlife for Unified Sewerage Agency. Hillsboro, OR.

Washington Forest Practices Board. 1997. Standard methodology for conducting watershed analysis, version 4.0. Olympia, WA.

WCDLUT (Washington County Department of Land Use and Transportation). 2000. Bat friendly bridges. Updates (newsletter). Spring 2000. Hillsboro, OR.

West Linn Bicentennial Committee. 1976. Just yesterday, a brief story of West Linn, Oregon. West Linn, OR.

Wilson, D.C. 1997. Post middle-Miocene geologic history of the Tualatin Basin, Oregon, with hydrogeologic implications. PhD dissertation, PSU.

WMG (Water Managers Group of Washington County). 1998. Integrated water resource management strategy. Draft report dated October 1998. Prepared by Montgomery Watson.

Wolf, D.W. 1992. Land use and nonpoint source phosphorus pollution in the Tualatin Basin, Oregon: A literature review. Tualatin River Basin Water Resources Management Report Number 1. Published by Water Resources Research Institute and Oregon State University Extension Service. Corvallis, OR

WPN (Watershed Professionals Network). 1999. Draft Oregon watershed assessment manual. Draft dated January, 1999.

Appendix 1

TUALATIN RIVER
RIVER MILE INDEX
-211400300

Mile	**Description**	**Drainage Area** square miles	**Elevation** feet - 0.00 gage datum
0.00	Mouth of Tualatin River at Willamette River River Mile 28.5 (LB Willamette)	712	
0.20	Weiss Bridge- Petes Mtn Rd.		
1.60	Fields Creek (RB-02114003000010)		
1.69	State Hwy 212 Bridge (Fields Bridge)		
1.75	West Linn Stream Gage Station - LB (USGS #14207500)	706	85.61
2.40	Tate Creek (LB-02114003000020)		
3.45	Lake Oswego Corp. Diversion Dam		
4.25	Interstate 205 Bridge		
4.56	Wilson Creek (LB-02114003000080)		
5.34	Boat Launch -LB		
5.36	Shipley Creek (LB-02114003000100)		
5.38	Shipley Bridge- Stafford Rd. (NWS Wire Weight Gage)		
5.62	Pecan Creek (LB-02114003000120)		
6.02	Athey Creek (RB-02114003000123)		
6.70	Saum Creek (RB-02114003000130)		
6.70	Oswego Canal Diversion (LB; River Elevation Recording Gage #14206990, Headgate, and Canal Recording Gage #14207000)		
7.36	Boat Launch - LB (Dogwood Drive)		
7.67	Browns Ferry Park Canoe Launch - RB		
7.83	Clackamas/Washington Counties Line (Underground Cable Crossing Sign)		

TUALATIN RIVER
RIVER MILE INDEX
-211400300

Mile	Description	Drainage Area square miles	Elevation feet - 0.00 gage datum
8.18	Interstate 5 Bridge		
8.60	Boones Ferry Road Bridge		
8.64	Hedges Creek (RB-02114003000150)		
8.90	Tualatin Park Boat Launch (RB)		
8.91	Southern Pacific RR Bridge Tualatin River at Tualatin Elevation Recording Station (#14206970) - RB		
9.32	Fanno Creek (LB-02114003000180) (Index available)	26.8	
9.33	Durham Treatment Plant Outfall (LB)		
9.34	Oregon Electric RR Bridge		
9.80	Cook Park Boat Launch LB)		
11.50	US Hwy. 99W Bridge (Pacific Highway) Canoe Launch - LB (access from southeast of bridge)		
12.68	Overhead BPA Transmission Line; Vancouver-Eugene		
12.80	Rivermeade Boat Launch (Private) - LB		
15.20	Rock Creek-South (RB-02114003000250)	13.7	
15.50	Chicken Creek (RB-02114003000270)		
16.09	Chicken Creek Drainage Ditch (RB)		
16.22	Shamberg Bridge (Elsner Road) Rated Staff Gage for Stream Flow - RB		
21.12	Overhead BPA Transmission Line; Big Eddy-Keeler		
26.90	State Hwy. 210 bridge (Scholls)		
28.20	McFee Creek (RB-02114003000310)		
30.76	Unnamed Stream (LB-02114003000320) (Jacktown)		
31.62	Burris Creek (RB-02114003000330)		

TUALATIN RIVER
RIVER MILE INDEX
-211400300

Mile	Description	Drainage Area square miles	Elevation feet - 0.00 gage datum
31.92	Christensen Creek (RB-02114003000350)		
33.30	Harris Bridge (State Highway 208) Farmington Recording Stream Gage (#14206500) - LB	568	100.42
35.68	Butternut Creek (LB-02114003000380)		
37.38	Gordon Creek (LB-02114003000400)		
38.08	Rock Creek Treatment Plant Outfall (LB)		
38.09	Rock Creek (LB-02114003000420 Beaverton Creek (LB-02114003000420060)	74.6 36	
38.44	Rood Bridge Small Watercraft Launch - LB Rood Bridge Road Bridge Recording Stream Gage (#14206440) - LB		105.16
40.44	Davis Creek (RB-02114003000430)		
41.64	Minter Bridge Road Bridge		
43.88	Jackson Slough (LB) Jackson Bottom Wetlands Hillsboro Treatment Plant Effluent Outfall (LB)		
44.40	State Highway 219 Bridge Rated Staff Gage for Stream Flow - RB		
44.73	Dairy Creek (LB-02114003000480) - index available Mckay Creek (LB-02114003000480020) - index available East Fork Dairy Creek (02114003000480080) - index available West Fork Dairy Creek (02114003000480090) - index available	226 63.4	
51.54	Golf Course Road Bridge Golf Course Recording Stream Gage (#14204800) - RB		
53.74	LaFollett Road (Bridge removed)		
55.24	Forest Grove Treatment Plant Outfall Fern Hill Wetlands		
55.32	Fernhill Road Bridge		
56.10	Springhill Pump Plant Intake		

TUALATIN RIVER
RIVER MILE INDEX
-211400300

Mile	Description	Drainage Area square miles	Elevation feet - 0.00 gage datum
56.80	Gales Creek (LB-02114003000560) - index available	78.6	
57.38	Carpenter Creek (LB-02114003000580)		
57.84	Dilley Creek (LB-02114003000600)		
58.04	Johnson Creek (LB-02114003000602)		
58.82	Springhill Road Bridge Tualatin River at Dilley Stream Gage (LB) (USGS 14-2035.00)	125	147.57
59.02	O'Neil Creek (LB-02114003000620)		
60.00	Scoggins Creek (LB-02114003000640) - index available		
60.80	Wapato Creek (RB-02114003000670) Wapato Creek Improvement District Return Flow		
62.00	Wapato Improvement District Headgate (RB)		
62.24	Southern Pacific RR Bridge		
62.25	State Highway 47 Bridge (Gaston)		
62.30	Bates Road Bridge		
62.80	Black Jack Creek (LB-02114003000700)		
62.90	Overhead BPA Transmission Line; Forest Grove-McMinnville		
63.13	TVID Patten Valley Pump Station Outfall #1		
63.87	Tualatin River at Gaston Recording Stream Gage (14202500) - RB	48.5	
64.26	TVID Patten Valley Pump Station Outfall #2		
65.34	Williams Canyon (RB-02114003000730)		
65.90	Mt. Richmond Road Bridge		
67.30	Hering Creek (LB-02114003000760)		
67.83	South Road Bridge (Cherry Grove)		

TUALATIN RIVER
RIVER MILE INDEX
-211400300

Mile	Description	Drainage Area square miles	Elevation feet - 0.00 gage datum
68.44	Roaring Creek (RB-02114003000790)		
69.42	Little Lee Falls		
70.70	Raines Bridge- Tualatin River below Lee Falls Rated Staff Gage for Stream Flow (LB)		
71.07	Lee Falls		
73.28	Haines Falls		
73.30	City of Hillsboro Haines Falls Intake - LB		
74.00	Lee Creek (LB-02114003000860)		
74.05	Patten Creek (RB-02114003000870)		
75.70	Sunday Creek (LB-02114003000900)		
76.60	Maple Creek (LB-02114003000940)		
76.95	Ki-A-Cut Falls		
78.00	Barney Reservoir Aqueduct Outfall (RB)		
79.3+	Headwaters of Tualatin River		

FANNO CREEK
STREAM MILE INDEX
2114003000180

Mile	Description
0.00	Confluence with the Tualatin River (02114003000)
0.86	Oregon Electric RR Bridge
1.19	Durham Road Bridge USGS Gage #14206950
2.00	Ball Creek (LB - 02114003000180020)
2.12	Bonita Street Bridge Rated Staff Gage
3.28	SW Hall Blvd Bridge
3.95	SW Ash Avenue Bridge
4.28	SW Main St Bridge
4.30	State Hwy 99W Bridge
4.49	SW Grant Ave Bridge
5.07	SW Tiederman Ave. Bridge
5.08	Summer Creek (RB - 02114003000180070) Rated Staff Gage at Fowler School
5.32	SW Tigard Ave Bridge
5.53	SW North Dakota St Bridge
5.54	Ash Creek (LB - 02114003000180080) Rated Staff Gage at Greenburg Road

FANNO CREEK
STREAM MILE INDEX
2114003000180

Mile	Description
6.38	Scholls Ferry Road Bridge
7.30	Tuckerwood - Rated Staff Gage
7.66	SW Hall Blvd Bridge
8.40	SW Denny Rd Bridge
8.60	Oregon Electric RR Bridge
8.70	State Hwy 217 Bridge
9.42	Scholls Ferry Road Bridge Rated Staff Gage
9.66	SW 92nd Ave Bridge
9.90	SW Bohmann Parkway Bridge
10.16	SW 86th Ave Bridge
10.78	SW Nicol Road Bridge
11.76	Olson Road Bridge
11.96	Sylvan Creek (RB - 02114003000180190)
11.98	SW Beaverton-Hillsdale Hwy (State Hwy 10)
12.10	Washington-Multnomah Counties Line
12.58	SW 56th Ave Bridge USGS Gage
12.81	SW Shattuck Road Bridge

FANNO CREEK
STREAM MILE INDEX
2114003000180

Mile	Description
13.22	SW 45th Ave Bridge
13.23	Ivey Creek (RB- 02114003000180250)
13.32	SW 43rd Ave Bridge
13.38	SW 42nd Ave Bridge
13.48	SW 39th Ave Bridge
13.98	SW Beaverton-Hillsdale Hwy (State Hwy 10)
14.10	SW 30th Ave Bridge