GREATER OREGON CITY WATERSHED ASSESSMENT

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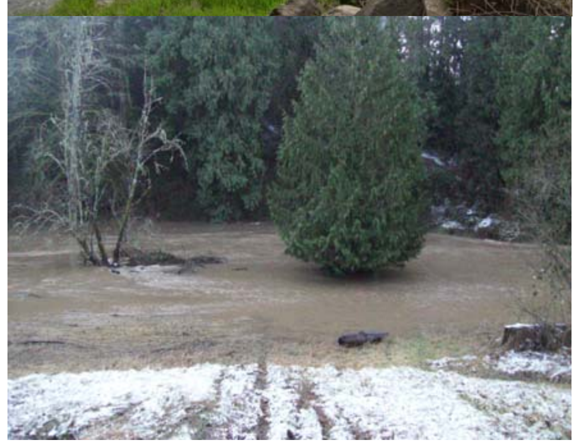

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Acronyms and Abbreviations

cfs	cubic feet per second
dbh	diameter at breast height
DPS	Distinct Population Segment
ESA	federal Endangered Species Act
ESU	Evolutionarily Significant Unit
GOCWC	Greater Oregon City Watershed Council
LiDAR	Light Detection and Ranging
NSPECT	Nonpoint-Source Pollution and Erosion Comparison Tool
NWI	National Wetland Inventory
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
OWRD	Oregon Water Resources Department
PAHs	polyaromatic hydrocarbons
RUSLE	Revised Universal Soil Loss Equation
TDS	Total Dissolved Solids
TMDL	total maximum daily load
TSS	Total suspended solids
UGB	urban growth boundary
USGS	U.S. Geological Survey

Introduction and Purpose

> **Abernethy Green**
>
> Originally called Green Point, Indians gathered here for over 3,000 years to fish at Willamette Falls.
>
> George Abernethy arrived here June 2, 1840, with the "Great Reinforcement" of Jason Lee's Willamette Mission. He took 640 acres just north of Oregon City, including a neck of land that extended to the Willamette River. This area became known as Abernethy green. George and Anna (Pope) Abernethy built their house at the mouth of Abernethy Creek next to the Methodist Mission where the first laws of Oregon were drafted.
>
> Oregon Trail emigrants started arriving on rafts from Fort Vancouver in 1843. They put in at Abernethy's house and climbed up to Abernethy green. Arriving in late fall or early winter, most of them opted to winter over in encampments at Abernethy green. During their stay here they would scout out their piece of the Willamette Valley, file their claim at the Government Land Office and resupply in Oregon City at places like Pettygrove's Red Store or Governor Abernethy's Mercantile.
>
> Beginning in 1846 two-thirds of Oregon Trail emigrants took Sam Barlow's Mount Hood Toll Road which ended right here at Abernethy Green. During peak years of the Oregon Trail migrations, Abernethy Green would be filled with covered wagons and neighbors Hiram Straight, Hugh Burns, Daniel Tompkins, and Jacob Hunsaker took the overflow. In 1851 Hunsaker's wife took in an emigrant family with mountain fever, and she lost a son and daughter to the disease. A rose from May John McLoughlin still grows on their grave.
>
> A devastating flood in 1861 destroyed everything nearby. George Abernethy was financially ruined and left for Portland. By this time improvements along the Oregon Trail had cut travel time almost in half and emigrants no longer needed to winter over. Abernethy Green ceased being the encampment at the end of the Oregon Trail.
>
> —Text of the marker at the end of the Oregon Trail, Oregon City, Oregon

The rich history of the Oregon City area has been influenced by its strategic location near Willamette Falls. Because of the economic importance of the Willamette River and its fish runs, there is extensive information on the river, its fish populations, and habitats. However, very little information is available on the status of fish species or habitats for the stream network that drains the area immediately below and above the falls: Abernethy and Beaver creeks and a group of small tributaries that begin in Oregon City and drain directly into the Willamette River. These streams are the focus of this watershed assessment.

The purpose of the watershed assessment is to provide the Greater Oregon City Watershed Council (GOCWC) with information on the natural processes, current management practices, and land uses that influence stream habitat, fish populations, and water quality in the watershed assessment area. The assessment provides the foundation for the *Greater Oregon City Watershed Council Restoration Action Plan*. This plan provides the GOCWC with a framework and a roadmap for implementing voluntary watershed restoration projects and landowner education.

The assessment's approach follows the general framework described in the Oregon Watershed Enhancement Board's *Watershed Assessment Manual* (Watershed Professionals Network 1999). The assessment is primarily based on existing information from watershed residents, stream habitat studies, field data collection efforts, government reports, aerial photography, and other data sources.

A unique feature of this assessment is the use of Light Detection and Ranging (LiDAR) data to characterize streamside riparian vegetation. LiDAR provides detailed and comprehensive information for assessing riparian vegetation characteristics and shade over stream channels.

Watershed Assessment Area

The watershed assessment area encompasses the stream network for three subwatersheds: Abernethy Creek, Beaver Creek, and Willamette River (Figure 1).

Abernethy Creek enters the Willamette River at river mile 25.3 and is tidally influenced at its confluence with the river. Lower Columbia River anadromous (i.e., residing in the ocean as adults and returning to rivers and streams to spawn) runs of coho salmon and steelhead trout are present in the Abernethy Creek subwatershed.

Beaver Creek, of which Parrott Creek is a large tributary, enters the river above Willamette Falls at river mile 31.4; this system is not tidally influenced. Because Beaver Creek is above the falls, which historically blocked some fish runs, this stream is part of the upper Willamette River system. The Beaver Creek subwatershed contains resident cutthroat trout and lamprey and may now be accessible to Upper Willamette River steelhead.

The Willamette River subwatershed consists of small tributaries that begin within Oregon City and flow over steep-sided bluffs directly into the river. These small streams are very high gradient and do not contain fish with the exception of lower channel habitats within the Willamette River floodplain. Fish occupy the lower floodplain portions of these small streams during high-flow periods.

The watershed assessment area is within the Willamette River Basin in western Oregon. Abernethy and Beaver creeks begin at elevations of about 1200 feet above mean sea level and flow generally in a northwesterly direction to join the Willamette River. Because the entire watershed assessment area is within the low elevation portions of the Willamette Valley, there are no mountainous areas to capture winter snowpack. Consequently, most precipitation comes from rainfall. The largest quantities of rainfall occur between October and November; very little precipitation occurs during the summer and early fall, when stream flows are at their lowest.

The watershed assessment area encompasses 44,353 acres (Table 1). The Abernethy Creek and Beaver Creek subwatersheds are similar in size (21,573 and 20,083 acres, respectively); the Willamette subwatershed is the smallest (2,697 acres). The headwaters of Abernethy and Beaver creeks are largely in unincorporated Clackamas County. Approximately 17% of the watershed assessment area is within the Oregon City urban growth boundary (UGB). A significant portion of the Abernethy subwatershed, primarily the lower stream channel, is within the UGB (16%). A somewhat smaller portion of the Beaver Creek subwatershed is within the UGB (13%), primarily small streams that originate in Oregon City and flow north into Beaver Creek. Most of the Willamette River subwatershed is within the UGB (59%).

Figure 1. Watershed Assessment Area Base Map

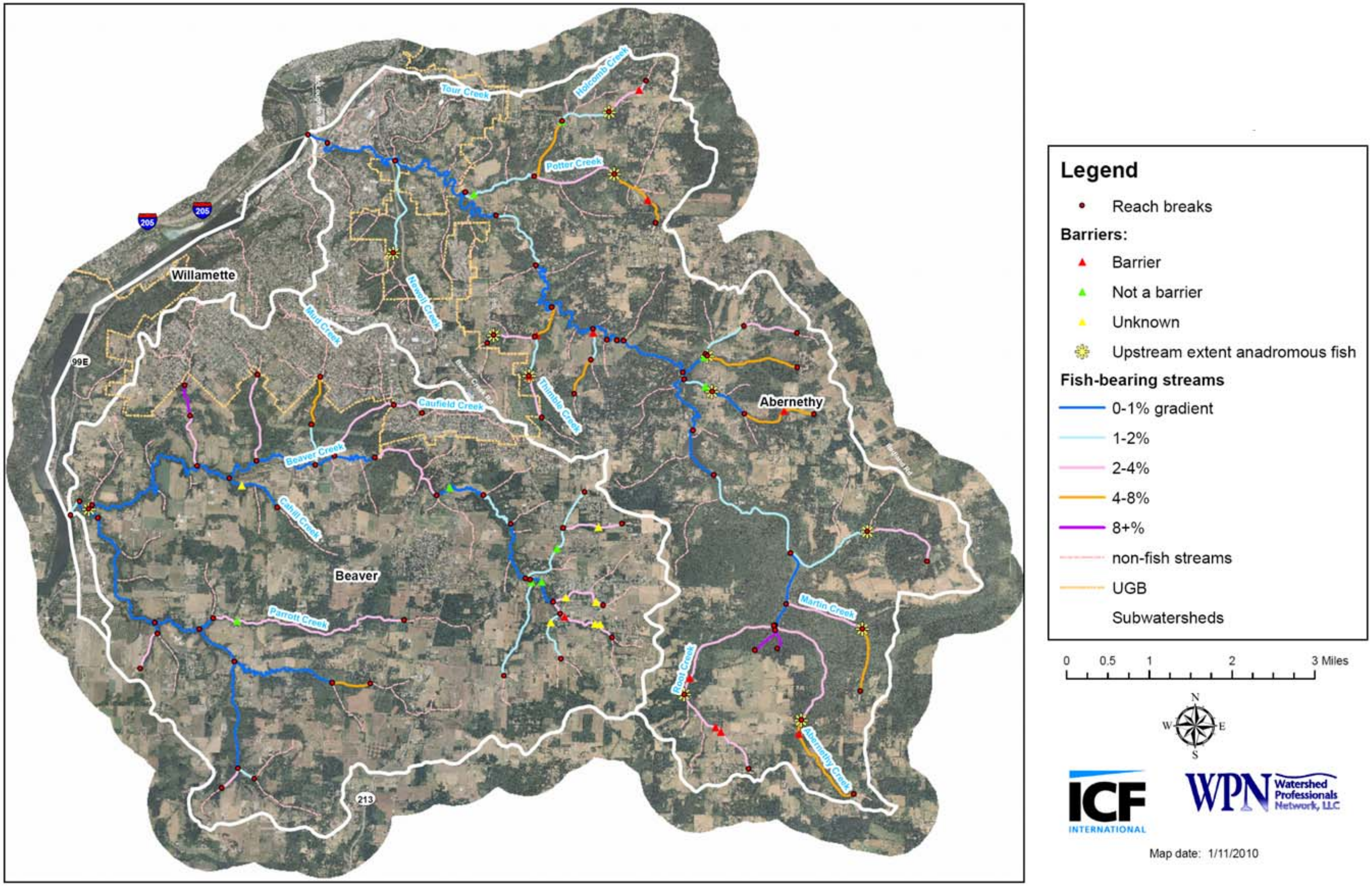


Table 1. Greater Oregon City Watershed Assessment Subwatershed Acreages and Proportions within the Oregon City Urban Growth Boundary

Subwatershed	Total Area Acres (Square Miles)	Oregon City UGB Acres (Square Miles)	Percentage within UGB
Abernethy	21,573 (33.71)	3,471 (5.42)	16%
Beaver	20,083 (31.38)	2,562 (4.00)	13%
Willamette	2,697 (4.21)	1,596 (2.49)	59%
Total	44,353 (69.30)	7,629 (11.92)	17%

UGB = urban growth boundary

The Abernethy Creek, Beaver Creek, and Willamette River subwatersheds have been dramatically altered over the years as a result of urbanization, agriculture, and other land uses. The presettlement historical vegetation of the watershed assessment area consisted of oak woodlands, prairie, and old-growth Douglas-fir forests in the uplands (Metro 2009a). The areas along the streams (i.e., riparian areas) were occupied by a mix of deciduous-coniferous forests and wetlands. The riparian area vegetation included red alder, big-leaf maple, western red cedar, and Douglas-fir, with an understory of fern, snowberry, and salmonberry. The area along the Willamette River between Abernethy and Beaver creeks consists of upland bluffs and steep cliffs, the historical (and current) habitat for many of the area's unique and culturally significant plant species, including Delphinium leucophaeum and camas. Historically, the upland bluffs contained abundant upland oak woodlands and prairie habitats (Metro 2009b).

The watershed assessment base map (Figure 1) serves as the foundation for the watershed assessment and for restoration action planning. The base map illustrates the following elements:

- land cover, vegetation types, and land uses displayed on high resolution aerial photography (2005);
- watershed assessment area and subwatershed boundaries;
- Oregon City UGB;
- stream channels with markers for the upper extent of anadromous, resident, and non-fish-bearing channels;
- location and type of fish passage barriers;
- stream reaches, including areas of uniform channel gradient (steepness) and habitat, or fish passage barriers; and
- stream gradient classifications.

Because the streams in the Willamette River subwatershed do not contain fish (with the exception of a small area in the river's floodplain), the stream channel network and reaches are not displayed on the base map.

This map is also a resource for GOCWC's planning and community outreach. Due to the limitations of print, the base map in this report (Figure 1) does not provide the detail of the digital version. The digital version is available from the GOCWC.

Land Use and Land Cover

The major land cover types and land uses in the watershed assessment area are shown in Figure 2. Agricultural and rural residential land uses account for 46% of the watershed assessment area; forest cover accounts for 33% (Table 2). The distribution of land cover types varies in the subwatersheds: the largest percentage of land in Abernethy Creek subwatershed is in forest cover (44%); the largest percentage in Beaver Creek subwatershed is under agricultural and rural residential land uses (55%); and the largest percentage in Willamette River subwatershed is urban land cover (28%).

A large portion of the watershed assessment area (9%) is covered with impervious surfaces (i.e., pavement, buildings, roofs, and other surfaces that do not absorb rainfall). The amount and distribution of impervious surfaces has significant implications for watershed health. Unless steps are taken to control runoff, rainfall on these areas does not infiltrate into the ground and rapidly runs off as stormwater into streams, negatively affecting stream flows, water quality, and fish populations, and stream habitat. The Willamette subwatershed, which has the highest proportion of area within Oregon City, has the most impervious surfaces (22%). In addition, individual streams (e.g., Newell Creek, which has headwaters within Oregon City) can have a much greater proportion of the drainage area in impervious surfaces.

Waite et al. (2008) assessed the impacts of urbanization on streams in the Willamette Valley. The authors found that increases in impervious surfaces resulting from urbanization affect the flow regime in ways that can reduce the quality of stream habitats, increase sedimentation rates, and increase fluctuation in frequency and magnitude of runoff from rain storms (i.e., storm flows). An impervious surface area of 5% of the watershed appears to be a threshold for negative effects on streams and fish populations (Waite et al. 2008).

U.S. Geological Survey (USGS) data (2004)on percent impervious surfaces for the Oregon City area were used to evaluate the percent impervious surface for the contributing watershed area upstream of the midpoint of each stream reach (Homer et al. 2004) (Figure 3). For the purposes of this assessment, reaches were classified as follows by percent impervious surface in contributing area:

- 5% or less—good
- 5–10%—fair
- greater than 10%—poor

Based on these classifications, reaches in the Abernethy Creek subwatershed were the least affected overall by impervious surfaces, with approximately 75% of the reach length classified as good, 20% as fair, and only 5% as poor (Figure 4). Approximately 45% of the reach length in Beaver Creek was classified as good, 20% as fair, and 35% as poor (Figure 4).

Figure 2. Land Use and Land Cover in the Watershed Assessment Area

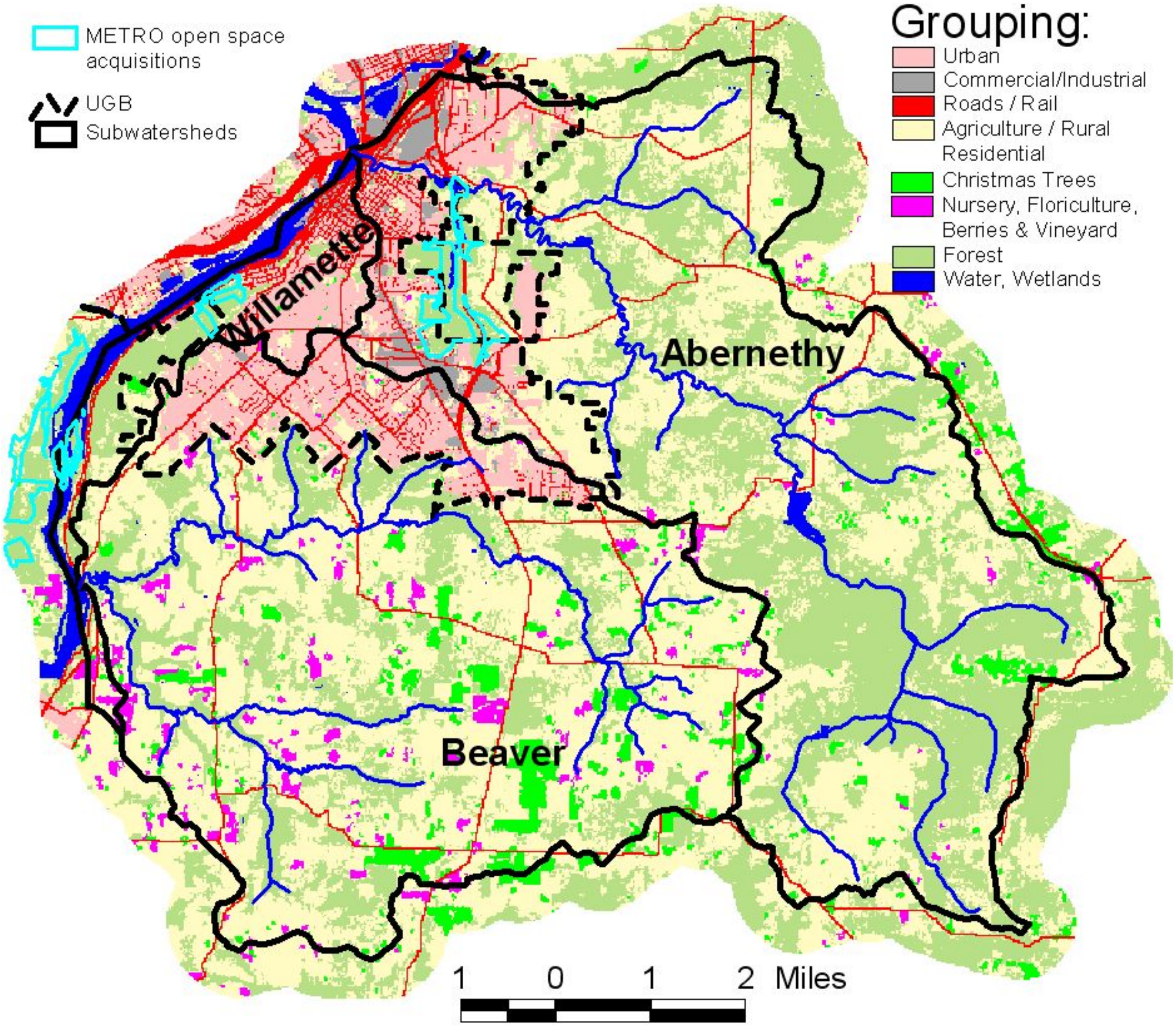
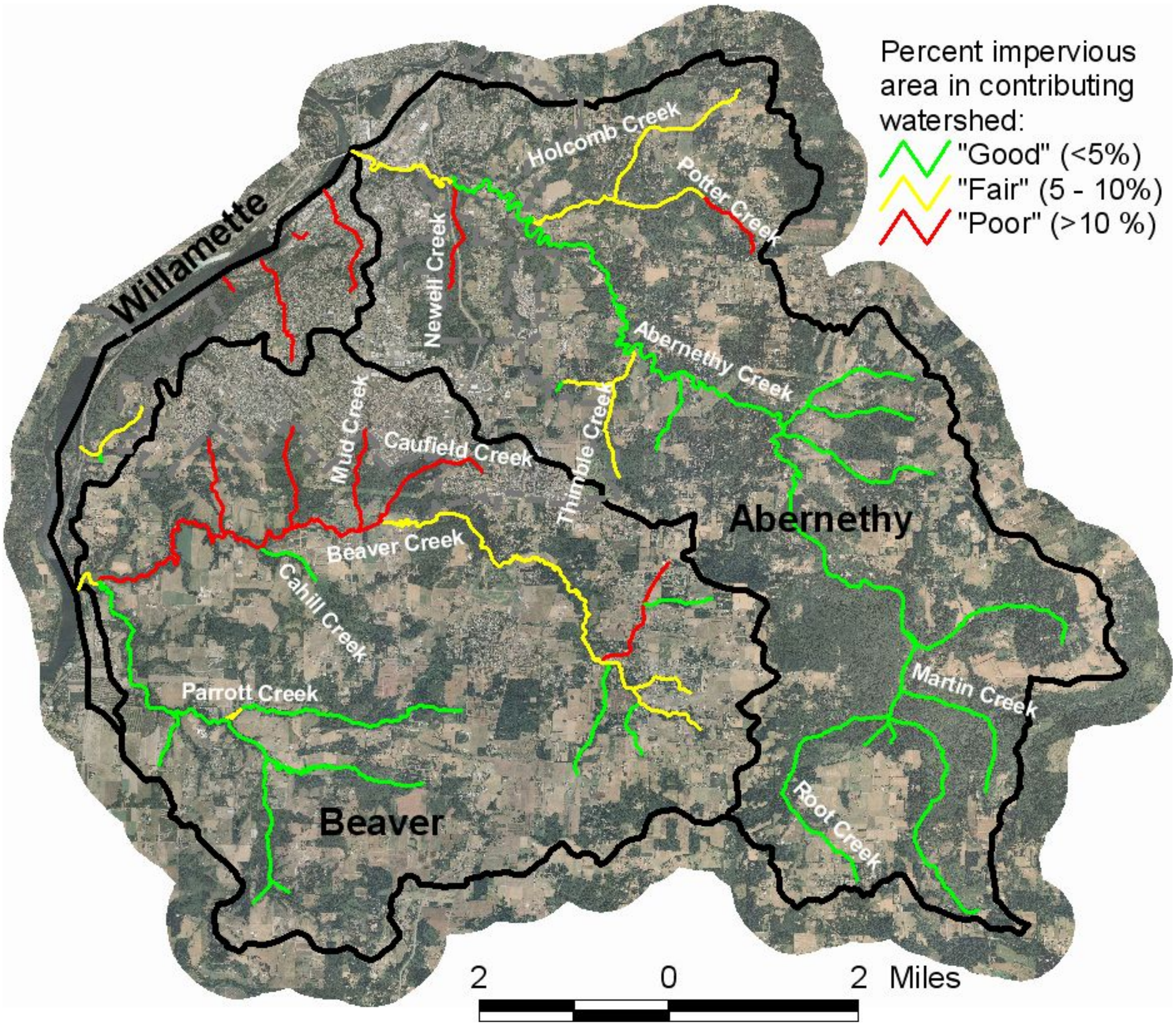


Table 2. Watershed Assessment Area Land Uses and Land Cover Types

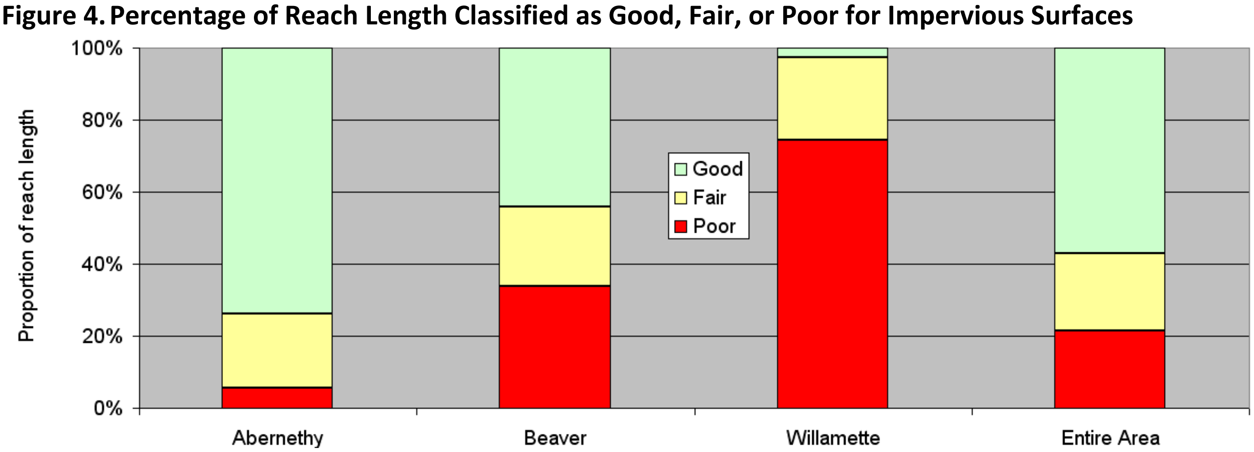
Land Use/Land Cover Group	Percent Cover by Subwatershed: Willamette River	Abernethy Creek	Beaver Creek (includes Parrott)	Entire Assessment Area
Urban	28%	6%	8%	8%
Commercial and industrial	2%	2%	0%	1%
Agriculture and rural residential	14%	42%	55%	46%
Roads and rail	15%	4%	3%	4%
Water and wetlands	12%	0%	0%	1%
Forest	26%	44%	23%	33%
Nursery, floriculture, berries, and vineyards	2%	0%	3%	2%
Christmas trees	1%	2%	6%	4%
Watershed Land Use Summary				
Subwatershed area (square miles)	4.21	33.71	31.38	69.30
Metro open space acquisitions (acres)	112	387	—	499
Mean percent impervious area	22%	7%	9%	9%

Figure 3. Percent Impervious Surface for the Contributing Watershed Area Upstream of the Midpoint of Each Stream Reach



Source: Homer et al. 2004

Figure 4. Percentage of Reach Length Classified as Good, Fair, or Poor for Impervious Surfaces



Natural Areas

The regional government, Metro, has made a large investment in protecting natural areas throughout the Portland area (Metro 2009a). Metro purchases land from willing landowners and sets it aside for watershed protection, wildlife, and recreation. The following three areas in the Abernethy Creek and Willamette River subwatersheds are now protected by Metro:

- **Newell Creek Canyon—300 acres in the Abernethy Creek subwatershed.** The presence of native fish and the relatively large size of the undeveloped land bordering the stream make the canyon biologically notable. The goal for this area is to protect undeveloped lands along lower Newell Creek for future restoration (especially threatened habitat for native steelhead and cutthroat populations) and wildlife connectivity. This acquisition is part of a larger strategy to protect natural corridors and uplands along the mainstem of Abernethy Creek and its major tributaries (particularly Holcomb and Potter Creeks) to protect water quality and wildlife habitat.
- **Upper Abernethy Creek headwaters stream—107 acres in the Abernethy Creek subwatershed.** This acquisition includes a relatively large, intact forested area adjacent to two small streams, which protects water quality and fish habitat. (This area is not shown on Figure 2 or other figures; it is adjacent to Tributary C, on the digital version of the base map).
- **Willamette Narrows and Canemah Bluff—112 acres in the Willamette River subwatershed.** This acquisition forms the Willamette River corridor in the vicinity of Oregon City and protects unique rock outcrops and rare plant communities (oak woodlands and prairies).

These areas have some of the highest quality habitat in the watershed assessment area, and offer opportunities for the GOCWC to coordinate restoration actions with Metro and adjoining landowners.

Geology

The watershed assessment area contains four hydrogeologic units. These units are shown in Figure 5 and described below in order of oldest to youngest (McFarland and Morgan 1996 as summarized by Snyder 2008).

Unconsolidated sedimentary aquifer. This unit consists primarily of Quaternary deposits from the Missoula Floods at the end of the last ice age (12,700–15,300 years ago), along with areas of alluvial deposits along channels and floodplains of the present-day (Holocene) drainage system (Gannett and Caldwell 1998). The Missoula Floods were caused by periodic failure of ice dams at the outlet of glacial Lake Missoula in western Montana. These glacier-outburst floods carried material that was deposited as layers of silt, sand, gravel, cobbles, and boulders in the Portland Basin as a result of loss in transport power as floodwaters emerged from the narrow Columbia River Gorge. This unit consists of highly permeable coarse deposits, and is the most permeable of the aquifers in the Portland Basin.

Soil textures in this unit are predominantly silt loams (Natural Resources Conservation Service 2009). The predominant hydrologic soils class for this area is type "C," indicating a slow infiltration rate, even when thoroughly wetted. In the Oregon City area the unconsolidated sedimentary aquifer is found along the Willamette River corridor and in the lower elevation areas of Beaver and Parrott Creeks. This unit is not present in the Abernethy Creek subwatershed.

Troutdale gravel aquifer. This unit is made up primarily (approximately 90%) of Boring Lavas, with additional areas (approximately 10%) of terrace deposits (i.e., deeply weathered sand, gravel, and silt of older alluvial surfaces, including fans), both from the Pleistocene and Pliocene (Gannett and Caldwell 1998). This unit has a relatively high permeability. Perched groundwater in this unit is associated with the Boring Lavas, although these perched groundwater bodies are discontinuous and irregularly distributed (McFarland and Morgan 1996).

The Troutdale gravel aquifer unit is the most common unit in the in watershed assessment area (60%) (Figure 5). The unit occurs at the highest elevations and is intersected by many of the tributary and headwater streams. It is one of the most important aquifers in the region; many public-supply, industrial, and domestic wells derive their water from this source.

Soil textures are predominantly silty clay loam and silt loam (Natural Resources Conservation Service 2009). Hydrologic Soil Group rating is predominantly "B," indicating moderate infiltration rates, moderately well-drained to well-drained soils.

Troutdale sandstone aquifer. This unit is comprised of continental sedimentary rocks from the Pliocene and upper Miocene (Gannett and Caldwell 1998). The rocks include sand, gravel, sandstone, conglomerate, siltstone, and mudstone that were transported from the Cascade Range and Columbia River basin. The unit is found primarily in the subsurface; in the watershed assessment area it occurs primarily where the principal tributaries have incised into the overlying Troutdale gravel aquifer (Figure 5). Overall it comprises approximately 30% of watershed assessment area. It is an important water-bearing unit north of the watershed assessment area to the west of the mouth of the Columbia River Gorge, but its importance diminishes moving south.

Soil textures in the unit are predominantly silt loams and silty clay loams (Natural Resources Conservation Service 2009). Hydrologic Soil Group rating is predominantly type "C," indicating slow infiltration rates and the impeded downward movement of water.

Older rocks. This unit is made up of Columbia River Basalts from the Miocene epoch (Gannett and Caldwell 1998). It occurs only along the Willamette River, and comprises only 2% of the watershed assessment area (Figure 5). The older rocks underlie the basin fill sediments described above. The Columbia River Basalt Group is used in the vicinity of the watershed assessment area as an aquifer where it is not overlain by thick sedimentary rock aquifers.

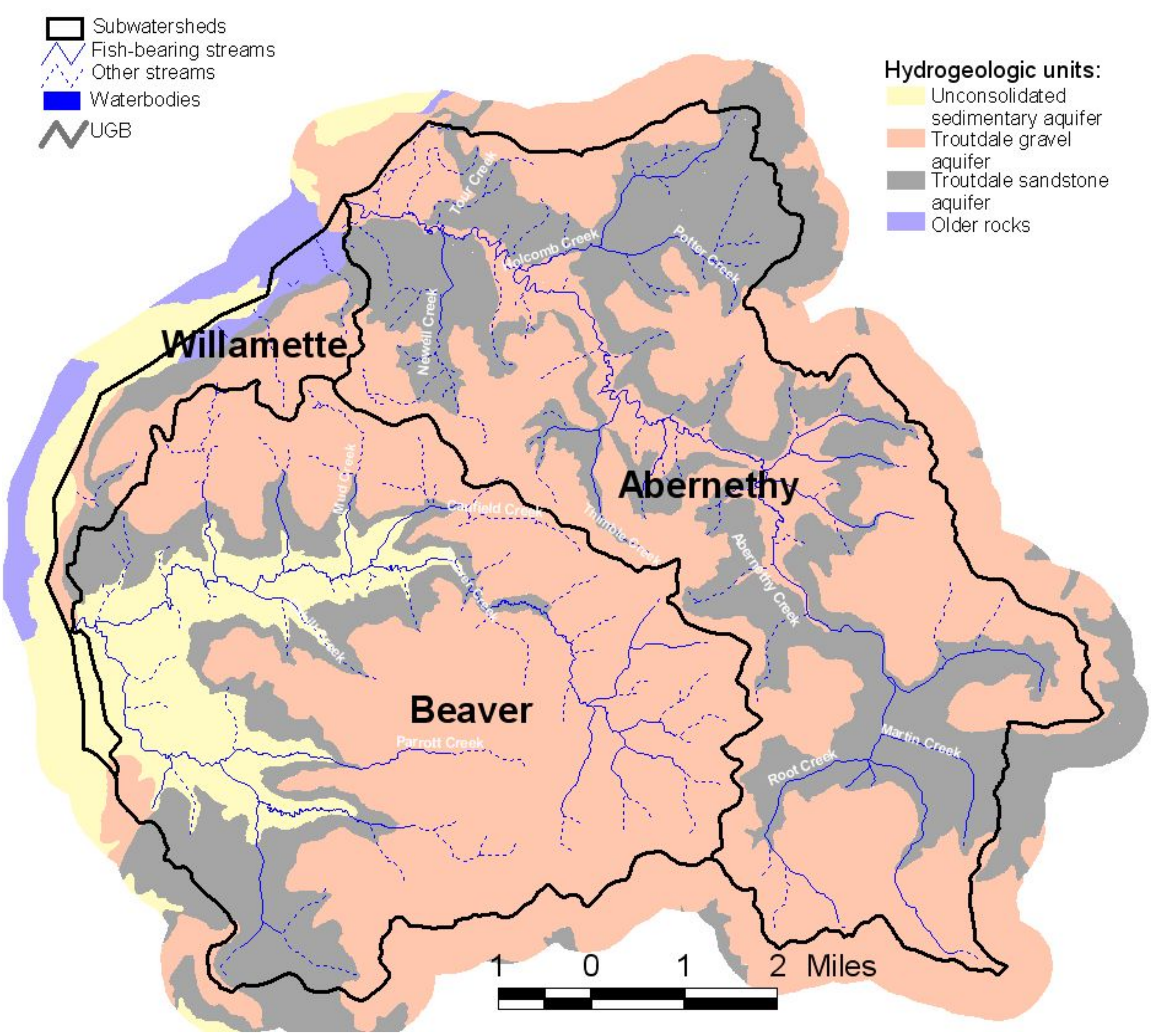
Soil textures in this unit are predominantly silt loam, very stony silt loam, and gravelly loam (Natural Resources Conservation Service 2009). Hydrologic Soil Group ratings are predominantly types "D" and "C," indicating very slow infiltration rates for these shallow soils over nearly impervious material.

The geologic setting has implications for water quality, fish habitat, and prioritizing steps to improve the health of the watershed, including the following:

- Soil textures throughout the watershed assessment area are very fine, contributing to the overall fine-grained nature of sediments in the area. Slow infiltration rates associated with these soils exacerbate the impacts of high-magnitude rainfall events by favoring rapid surface runoff over infiltration into ground and slower runoff into streams.
- The types of soils in the watershed assessment area result in a sediment-rich environment with high levels of background sedimentation in streams.

- Stream channel substrate throughout the watershed assessment area is expected to be relatively fine-grained (e.g., sands and silts), based on the types of soils in the watershed assessment area. The best spawning gravels are probably derived from the Boring Lavas (i.e., the Troutdale gravel aquifer unit; Figure 5). Areas underlain by older rocks (i.e., Columbia River Basalts) would be expected to have relatively good spawning-sized substrate; however, these areas make up only a tiny portion of the watershed analysis area.
- The depth to groundwater (measured in feet below land surface) in the vicinity of streams is generally low throughout the watershed analysis area, approximately 40 feet on average (Snyder 2008). In the unconsolidated sedimentary aquifer, the depth to groundwater is very low in the vicinity of streams (approximately 10 feet). Consequently, groundwater recharge should be relatively rapid, resulting in rapid stream response to storm events. Furthermore, wetlands and wet riparian areas would be expected to be prevalent in areas where depth to groundwater is very low.

Figure 5. Hydrogeologic Units in the Watershed Assessment Area



Introduction

This section describes and quantifies the riparian and wetland conditions in the watershed assessment area compared to historical conditions. The assessment focuses on riparian vegetation composition, stream shading levels, and invasive plant species.

Riparian areas are areas that lie between a stream, or other waterbody, and the adjacent upland and that contain distinctive vegetation. Riparian areas include wetlands and those portions of floodplains and valley bottoms that support riparian vegetation. Vegetation that is growing on or near the banks of water bodies is usually more dependent on water than vegetation that is found further upslope. Historically, riparian vegetation in the watershed assessment area included red alder, big-leaf maple, western red cedar, and Douglas-fir, with an understory of fern, snowberry, and salmonberry (Metro 2009a).

The key product of the riparian vegetation assessment is a detailed map of riparian vegetation for the stream reaches throughout the watershed assessment area. Riparian areas are shown for fish-bearing streams in the Abernethy Creek and Beaver Creek subwatersheds; riparian vegetation for the Willamette River subwatershed was not mapped, because its small streams do not contain fish.

Riparian Area Assessment

Riparian vegetation was assessed based on LiDAR (2006–2008) data, which provide fine-scale measures of bare earth and the heights of other objects (e.g., trees, shrubs, buildings). From these two elevation sources (ground and tree heights, for example), absolute vegetation heights were calculated relative to the ground surface. A “canopy height map” was created, based on these measurements, and use to classify the vegetation as shrubs or trees. Shading over the stream channel was calculated as “effective shade,” which is a function of vegetation height, stream channel aspect (north or south), and local hill slopes and other topography. For mapping purposes, a riparian area is defined as a 200-foot-wide area (100 feet on each side of the stream’s center). The detailed riparian area maps are available from the GOCWC.

The assessment identified riparian areas in 4% of both the Abernethy Creek and Beaver Creek subwatersheds (Table 3). Although the area covered by riparian vegetation is relatively small, it is disproportionately important because it fulfills several critical functions that promote healthy streams and fish populations—stream shade; food sources (i.e., leaves); and large wood in the stream channel that creates pools, cover, and other high quality fish habitat elements.

Table 3. Acres and Percentage of Subwatersheds in Riparian Areas (100 feet on each side of the stream channel)

Subwatershed[1]	Total acres in riparian area	% Subwatershed area within the riparian area
Abernethy	911	4%
Beaver	768	4%
Total	1,679	4%

1 Riparian areas were not mapped for the Willamette River subwatershed.

The riparian areas were classified by vegetation types and land uses (Table 4). The classifications reflect the effects on the stream system or potential threats, such as invasive weeds, that could affect the quality of riparian vegetation. Forested areas, for example, play key roles in shading the stream, providing bank stability, and providing logs and large wood create pools and cover for fish. Figure 6 shows an example of the riparian area classification map for lower Abernethy Creek. The complete set of the riparian area classification maps for the watershed assessment area are available from the GOCWC.

Table 4. Riparian Area Classification Types

Riparian Area Classification	Plant Species/Functional Groups	Benefits to the Stream/Disturbance Mechanisms/Notes
Forested	Douglas-fir, western red cedar, black cottonwood, big leaf maple, landscape tree species (mostly >30 feet in height)	Stream shading, bank stability, input of leaves and other materials, wildlife habitat, large wood inputs
Small Trees/ Hardwoods	Species listed above, with dominance of hardwoods (e.g., cottonwood, red alder, willow, dogwood, ash) and young conifers (10–30 feet in height)	Factors listed above, with long-term large wood recruitment from young conifers
Tall Shrubs	Native hardwoods (i.e., very small trees and tall shrub forms), often with mature Himalayan blackberry (~5–10 feet in height)	Stream shading and areas for invasive species spread (e.g., blackberry)
Shrubs/Grass	Mostly blackberry and herbaceous weeds, with potentials for native meadow species; domestic irrigated fields also included	Invasive/nonnative plant species
Land Use	Fields, roads, impervious surfaces and other features of low heights and high reflectance	Areas with high erosion potential, invasive species colonization, low shade
Water bodies	Surface water observed that is larger than the stream channel (e.g., lakes, ponds, impoundments, wetlands)	Water storage sites, reservoirs; potential sites for water heating (impoundments) or cooling (wetlands)
Unclassified/ Transitional	Areas that did not have high confidence in classification; includes buildings, structures, and transitional zones between vegetation types	Data gaps

Figure 6. Riparian Area Classification Map for Lower Abernethy Creek (Reach 2)

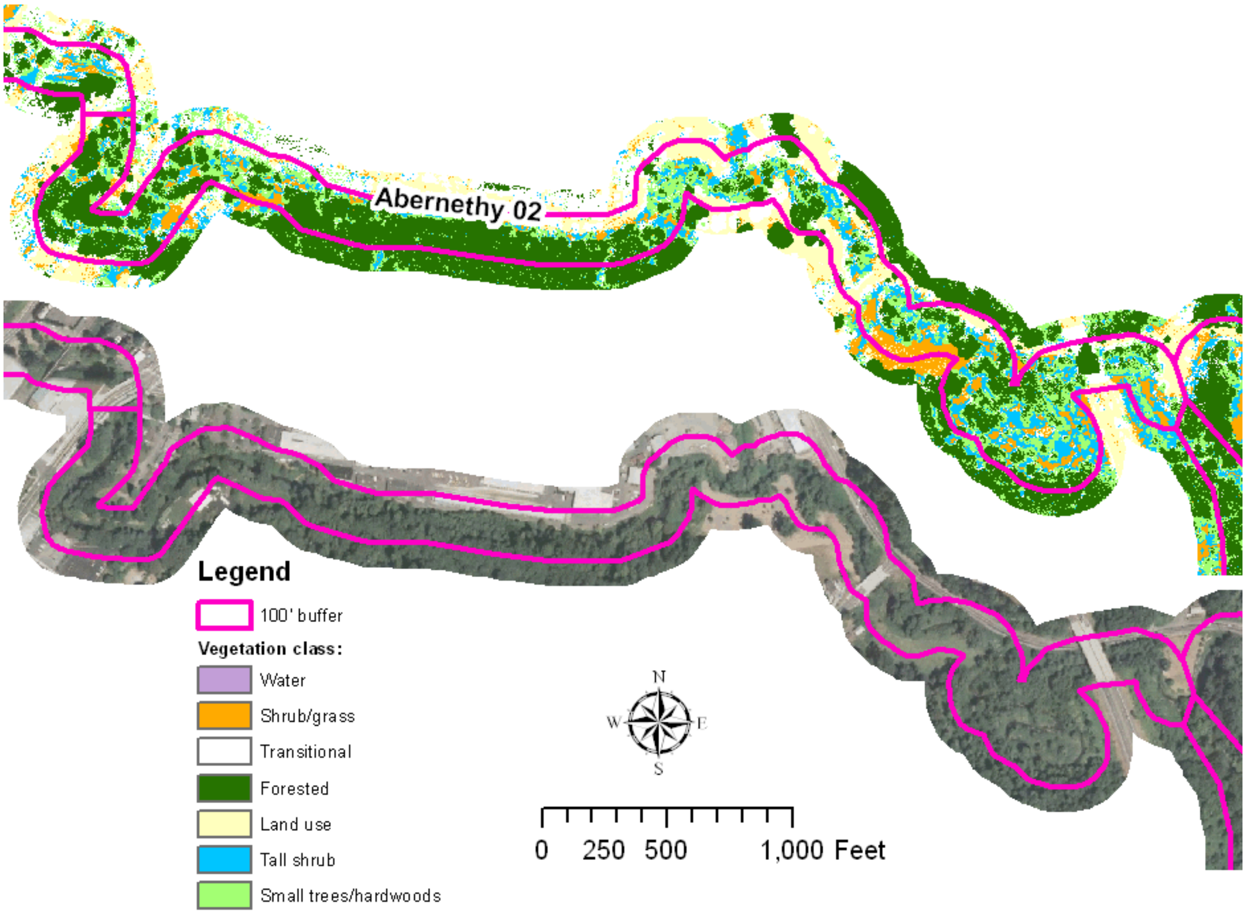
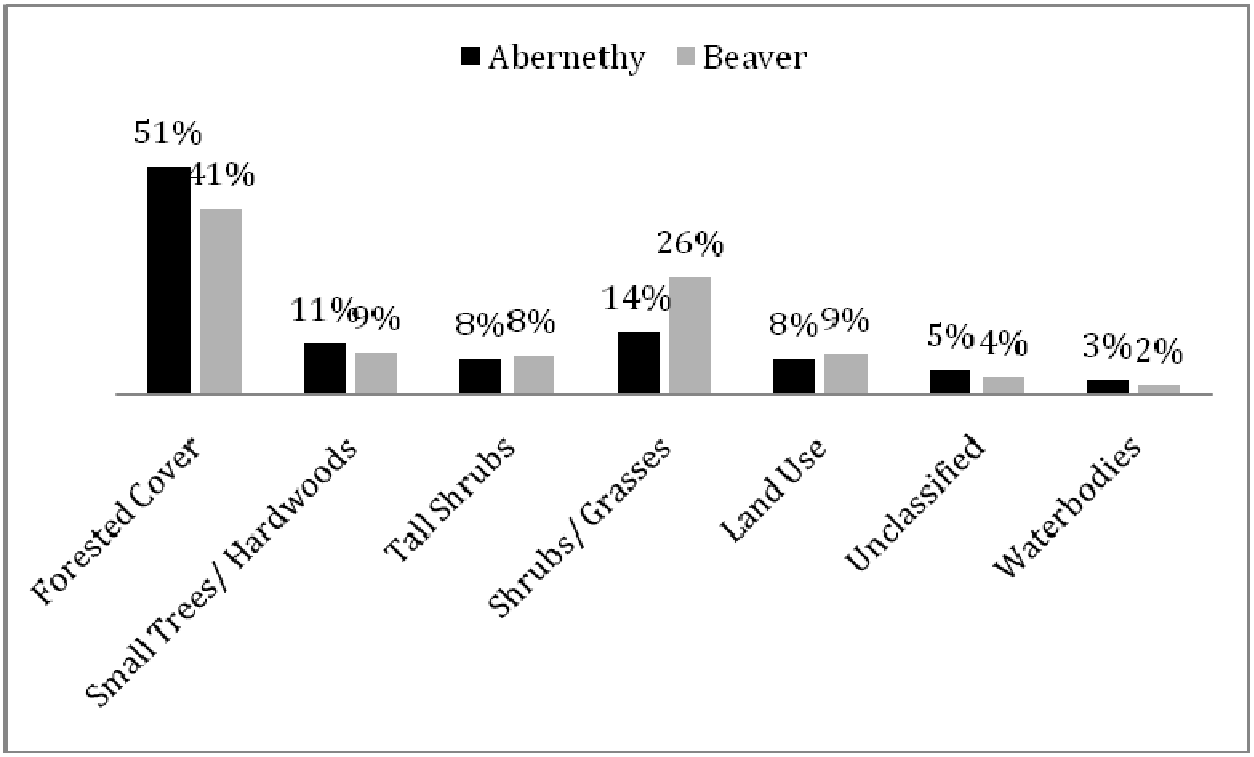


Figure 7 shows the percentage of the riparian area covered by each of the classification types. Forested vegetation is the most common riparian area classification: 51% of the Abernethy Creek subwatershed and 41% of the Beaver Creek subwatershed are in forested riparian areas. With the exception of shrubs and grass cover, the distribution of the other riparian area types is roughly equivalent for the two subwatersheds. The Beaver Creek subwatershed has a much larger proportion (26%) of the riparian area covered in shrubs and grasses. The larger proportion of riparian area shrubs and grasses is probably due to the dominance of agricultural land uses in the Beaver Creek subwatershed.

Figure 7. Percentage of Abernethy Creek and Beaver Creek Subwatershed Riparian Areas Covered by Each of the Classification Types



Invasive Plant Species

Invasive plants are nonnative species whose introduction does environmental harm to watershed health. The five most common invasive plants found in the Portland area include English ivy, Himalayan blackberry, Scot's broom, reed canarygrass, and Japanese knotweed. Invasive plants are most likely to enter areas that have been disturbed by human land uses such as homes, agricultural areas, or roads. Riparian areas can be colonized by all of the five most common invasive plants, but Himalayan blackberry, reed canarygrass, and Japanese knotweed are the most common species found along streams in the watershed assessment area. These invasive plants displace trees and other native vegetation that are important for stream habitat and water quality.

The riparian area maps show areas that may be colonized by invasive plants; however, ground surveys would be required to confirm their presence. Riparian areas classified as tall shrubs or shrubs and grasses have a high probability of being dominated by invasive weeds. The Beaver Creek subwatershed has the highest proportion of these types of riparian areas (Figure 7).

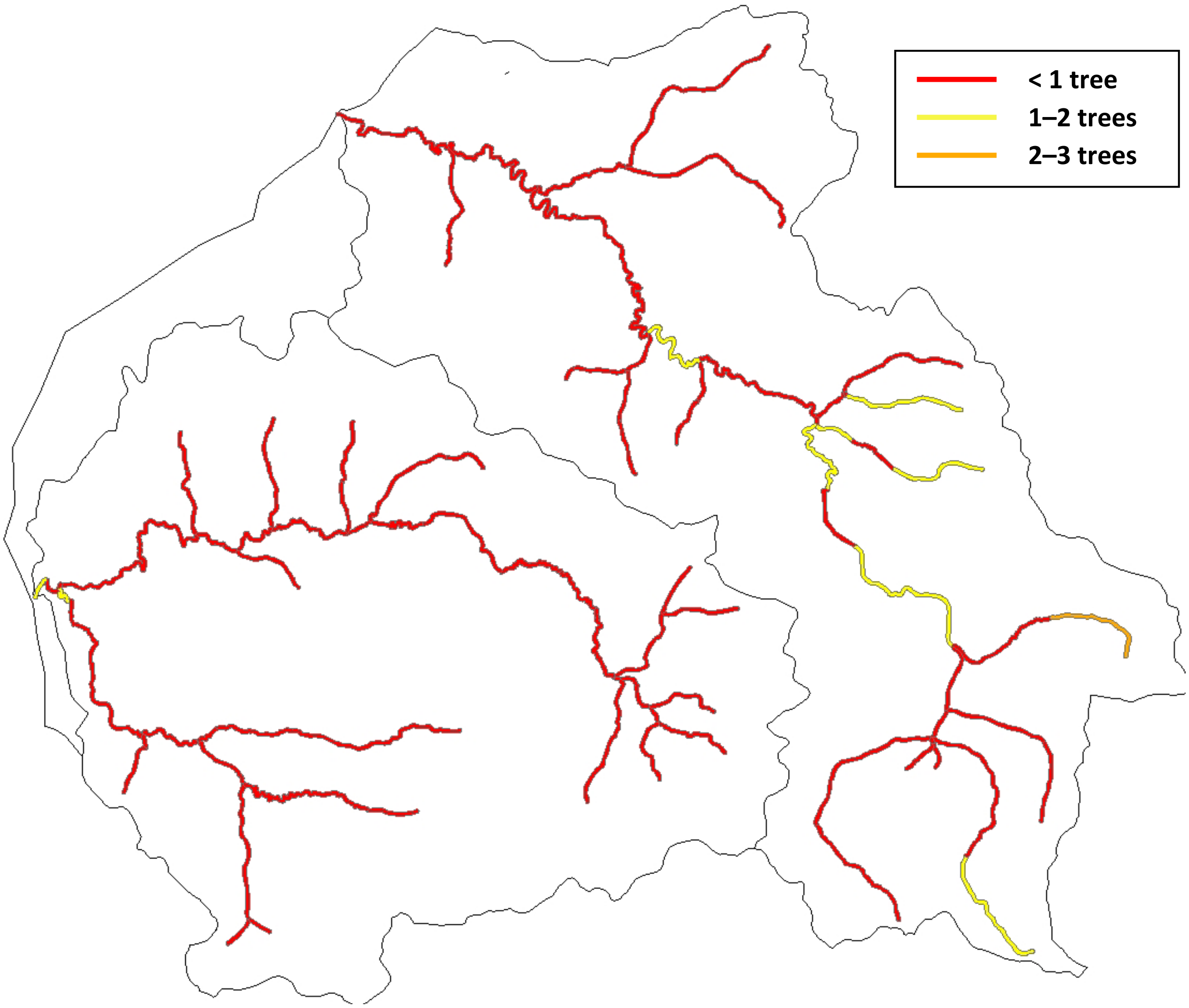
A comprehensive ground inventory of invasive plants has not been completed for the watershed assessment area, but there are scattered observations. All five of the most common invasive plant species were present in an inventory of the Newell Creek canyon, and were particularly prevalent along forest edge areas and highway corridors (John Inskeep Environmental Learning Center No Date). Based on field reconnaissance conducted as part of the watershed assessment, Japanese knotweed was observed in riparian areas along Abernethy Creek tributary streams, including Holcomb Creek. This very aggressive species propagates to downstream points through broken rhizomes or other plant tissue and the potential area of infestation includes all reaches downstream of an established patch. For this reason, the riparian areas throughout the assessment area are considered to have an “extreme” potential threat rating for the presence of Japanese knotweed.

Forested Riparian Areas and Contributions of Large Wood

Forested riparian areas with large trees are important for stream habitat because, over time, these areas can provide large wood to the stream channel, which creates pools and cover for fish. Large trees greater than 20 inches in diameter at breast height (dbh) provide stable large wood in streams. An estimate of riparian areas containing these large trees was made using the LiDAR tree height coverage and measurements of tree crowns. This estimate provides a general estimate of the potential large wood contributions of riparian areas. Field measurements of trees would increase the level of accuracy.

The riparian areas of Abernethy Creek and Beaver Creek subwatersheds contain very few large trees. Each of the riparian areas contains fewer than two trees greater than 20 inches dbh (Figure 8). Given the limited number of large trees in the riparian areas, few opportunities exist for large trees to fall and provide the amount of large wood to stream channels necessary for high quality fish habitat.

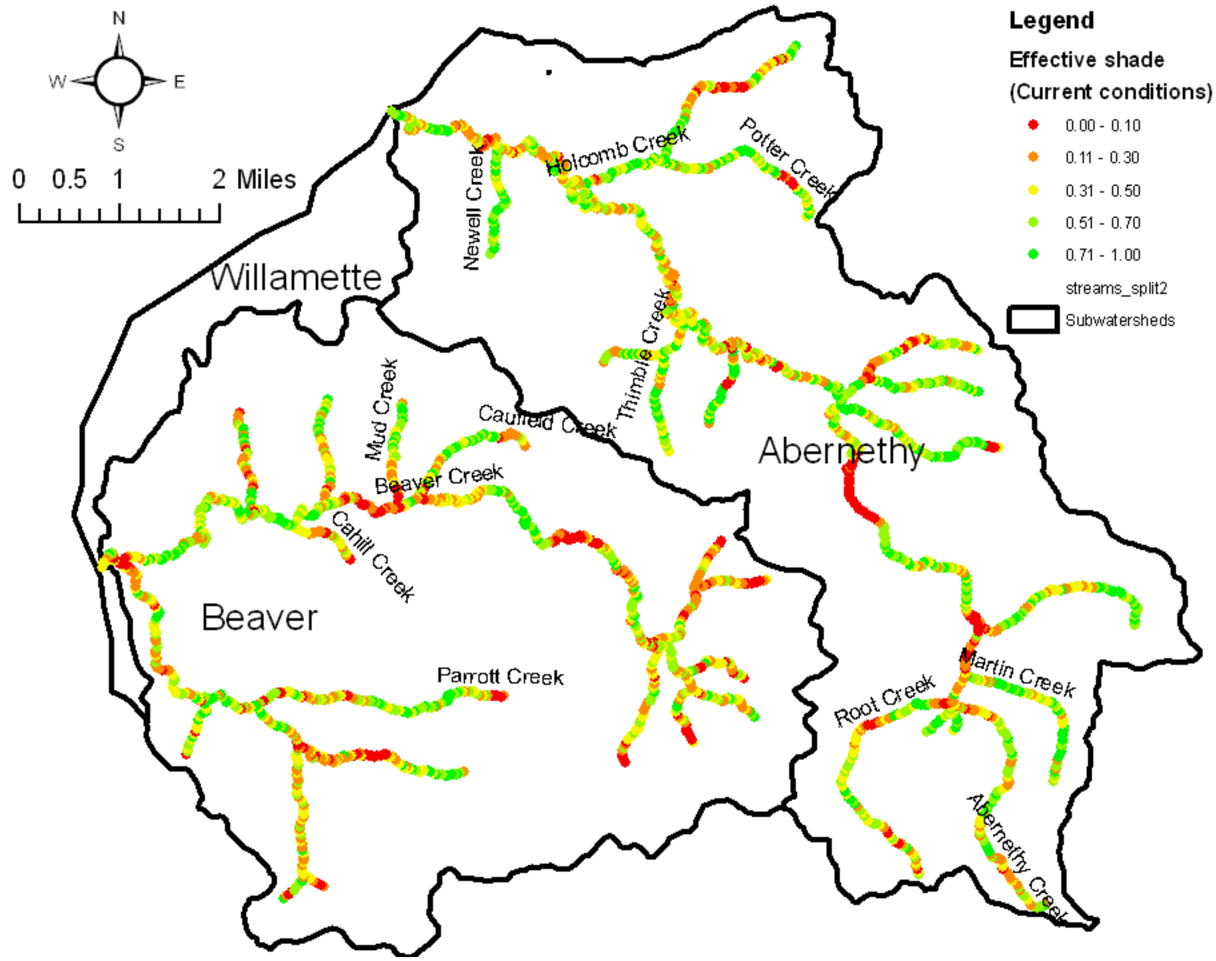
Figure 8. Number of Riparian Area Trees Greater Than 20 Inches dbh per 1,000 Feet of Riparian Area



Stream Shade

The riparian vegetation canopy provides shade over the stream, which maintains cool water for fish and other aquatic species. Effective shade in the Abernethy Creek and Beaver Creek subwatersheds was measured as a combination of three factors: vegetation height, stream aspect (north, south, east, or west flowing channels), and neighboring topography (e.g., hillslopes). For the most part, there is adequate shade over the watershed assessment area stream channels (Figure 9). Average effective shade is 47% for Abernethy Creek subwatershed and 41% for Beaver Creek subwatershed. The large area with no shade along upper Abernethy Creek is due to the open water created by Beaver Lake Estates reservoir.

Figure 9. Shade over Abernethy Creek and Beaver Creek Subwatershed Stream Channels. The large section with minimal shade on upper Abernethy Creek is Beaver Lake



Wetland Habitat Loss

Wetlands provide a number of important functions that contribute to watershed health, including habitat for wildlife species and areas along stream margins where fish can find cover during flood events. Wetlands can reduce the magnitude of flooding by absorbing water created by storms and slowly releasing it back into the stream system.

No information on the likely extent of wetland loss was available for the watershed assessment area. One approach to estimating possible wetland loss is by comparing present-day wetlands to the area classified as having hydric soils. Hydric soils are soils that are, or have been, saturated, flooded, or have had standing water long enough during the growing season to develop anaerobic (i.e., without oxygen) conditions in the upper part of the soil layer. Areas with hydric soils that do not currently support wetlands may have supported them in the past. The Natural Resources Conservation Service (2009) soil survey of the Clackamas area identifies hydric soils within several soil series. Not all of the area within these mapping units contains hydric soils, and not all of the hydric soils necessarily supported wetlands historically. However, this information provides us with an approximation of the extent that may have been occupied by wetlands historically.

Current wetland locations are available from the National Wetland Inventory (NWI) produced by the U.S. Fish and Wildlife Service (2009). The area currently occupied by wetlands and the area of hydric soils in the watershed assessment area are shown in Figure 10. The watershed assessment area has approximately 1,500 acres of hydric soils and 250 acres of wetlands (Figure 11), suggesting that wetlands may currently occupy only one-sixth of the area that they occupied historically. The proportion of estimated wetland loss appears to be similar among the subwatersheds (Figure 11).

Figure 10. Current Wetland Locations and Soil Mapping Units That Contain Hydric Soils in the Watershed Assessment Area

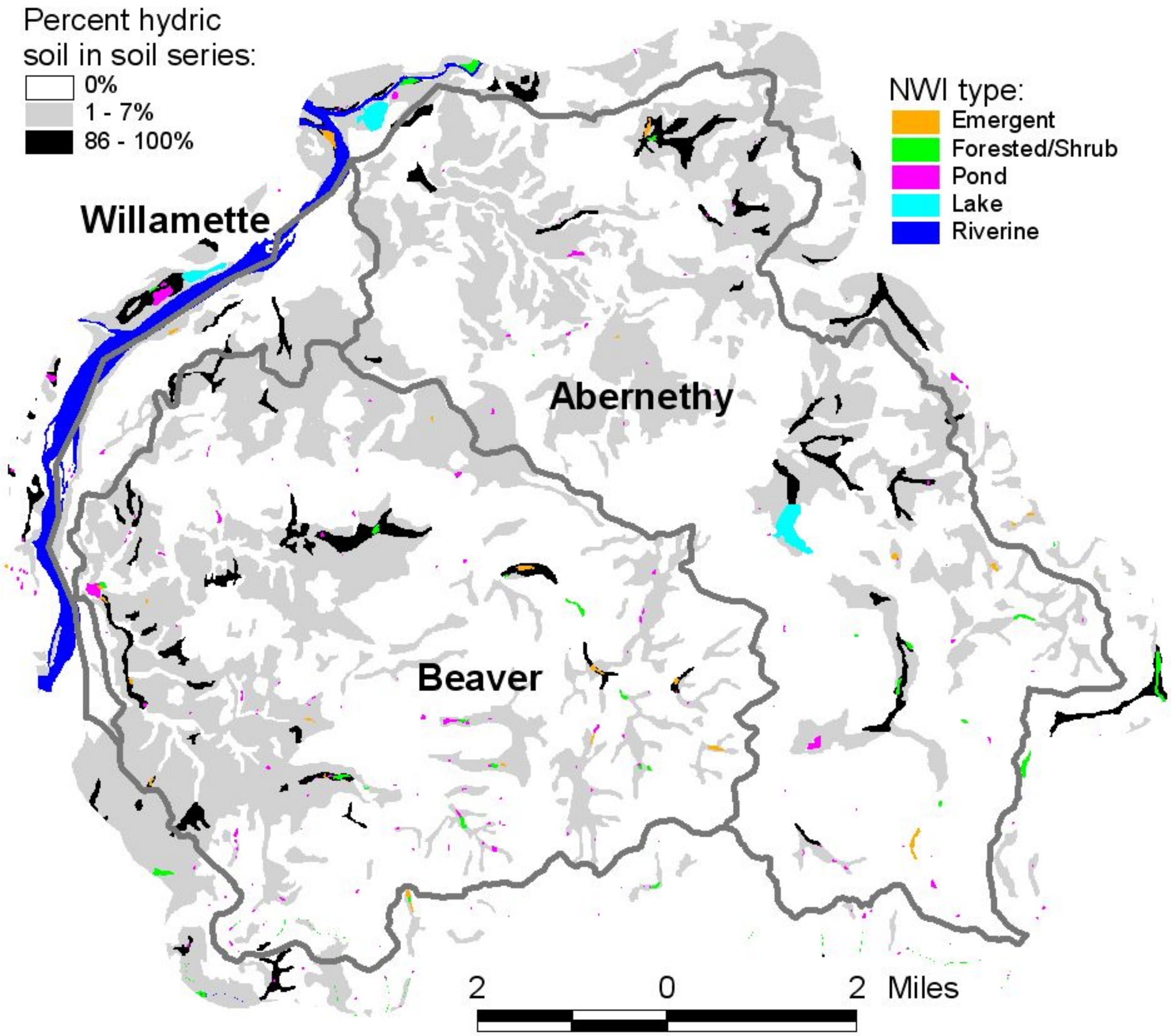
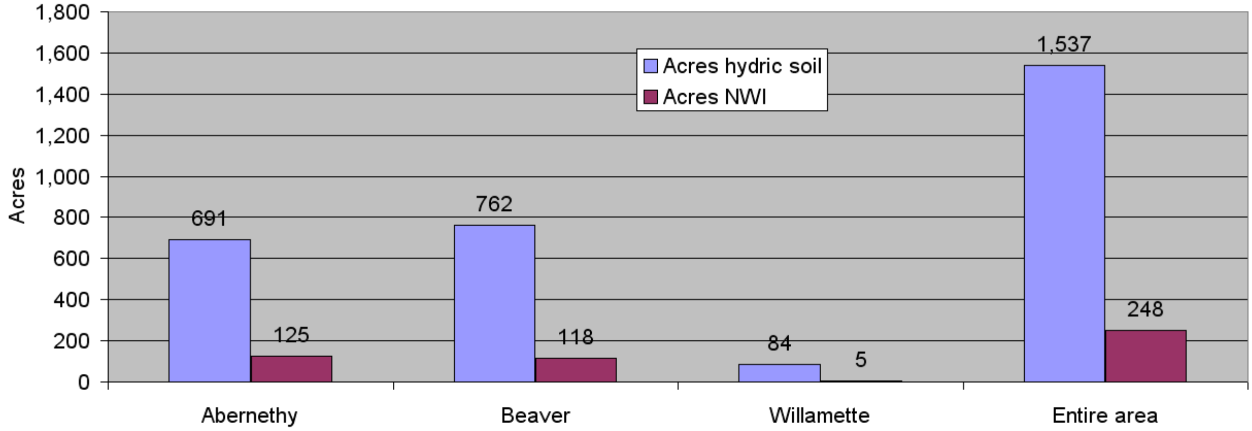


Figure 11. Current Wetland Locations and Soil Mapping Units That Contain Hydric Soils in the Watershed Assessment Area



Introduction

This section focuses on the causes and effects of streamflows at both extremes: low flows and high flows (floods). Human activities, such as agriculture, withdraw water from streams, which can reduce flows during the critical summer and early fall periods when flows are naturally low. Floods, depending on the perspective, can be beneficial or destructive. Floods benefit streams through the force of water and routing of materials through the system, including moving logs and gravels, scouring pools, and creating spawning areas. On the other hand, floods can destroy property and endanger human lives.

This section summarizes what is known about streamflow patterns and about human influences on these patterns in the watershed assessment area. Key issues examined are the flood history of the watershed, how land uses and storage affect high and low flows, and the nature of water withdrawal activities. Land use impacts on streamflows are addressed using techniques that USGS has applied in similar adjacent watersheds, and are based primarily on the percent impervious surface in the drainage areas of the primary streams as described under "Watershed Overview."

Streamflow Patterns

Few records exist on streamflow patterns for the watershed assessment area. The locations of available streamflow data from the five gages in the watershed assessment area are shown in Figure 12. These streamflow gages were operated for 1 year (1936) by the Oregon Water Resources Department (OWRD). The records from these gages are of too short in duration to be of much value in characterizing streamflow conditions; however, they provide a historic snapshot of how watershed response varies among the drainages. Mean daily streamflows, normalized for drainage area, are shown in Figure 13. In general, watershed response over this 1-year period of record is consistent across drainage area and watershed location. Flood recession in the Holcomb Creek watershed appears to be faster than in other areas, possibly due to the predominance of Troutdale Sandstone in the contributing area (Figure 5).

Figure 12. Stream Gages in the Watershed Assessment Area (Operated January–Mid-December 1936)

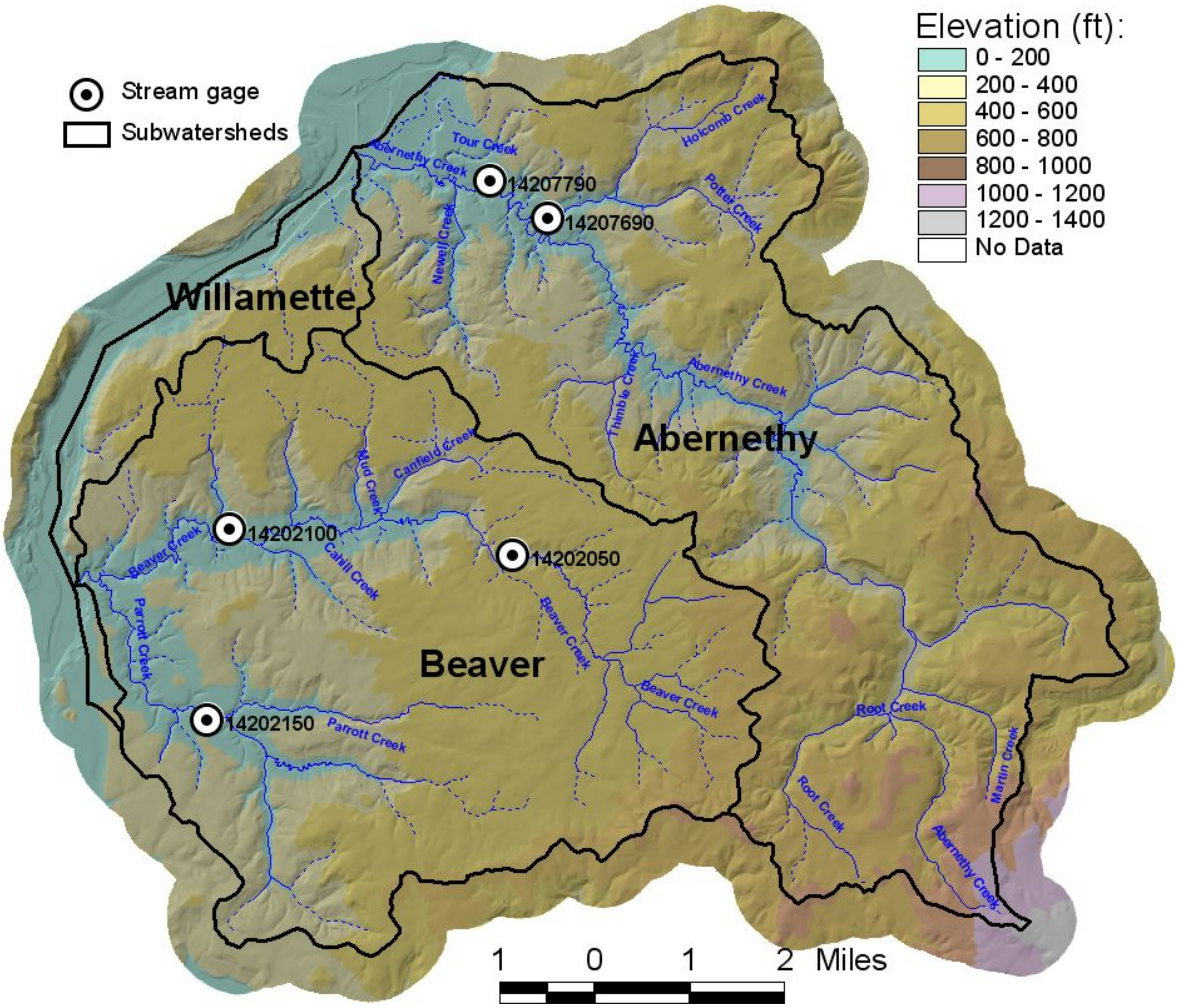
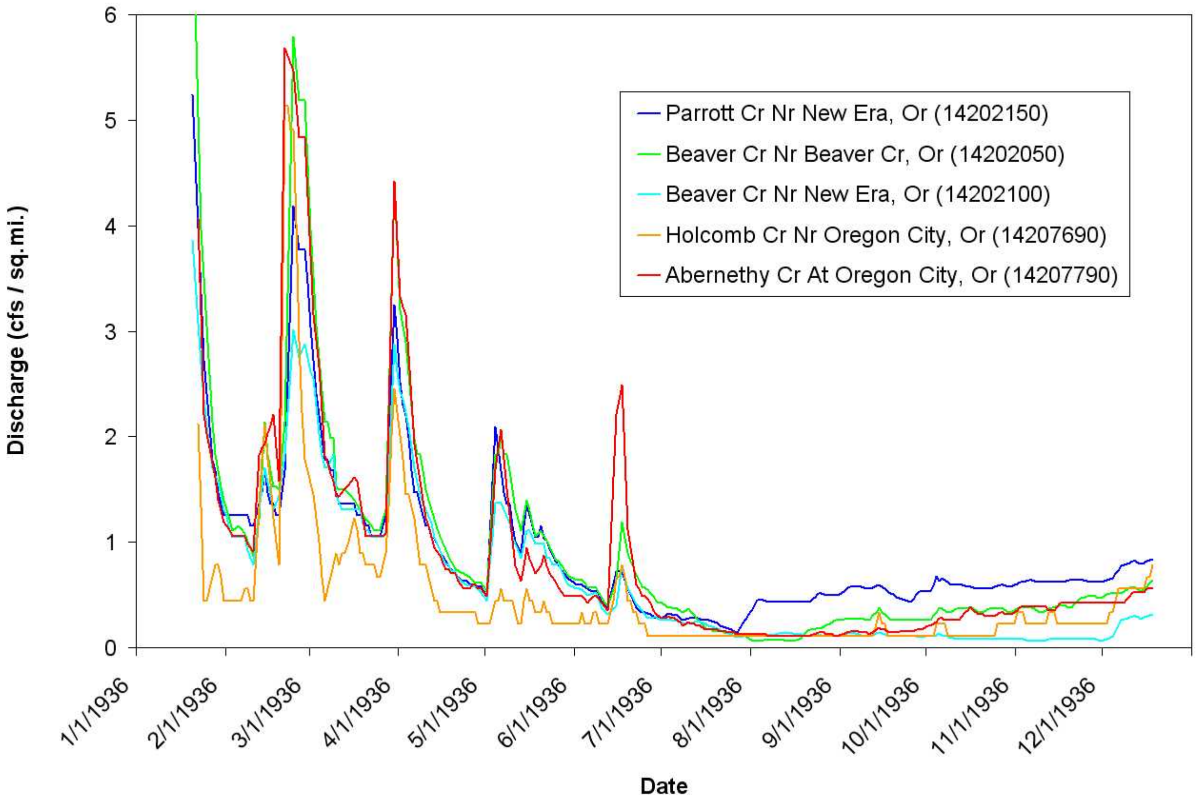


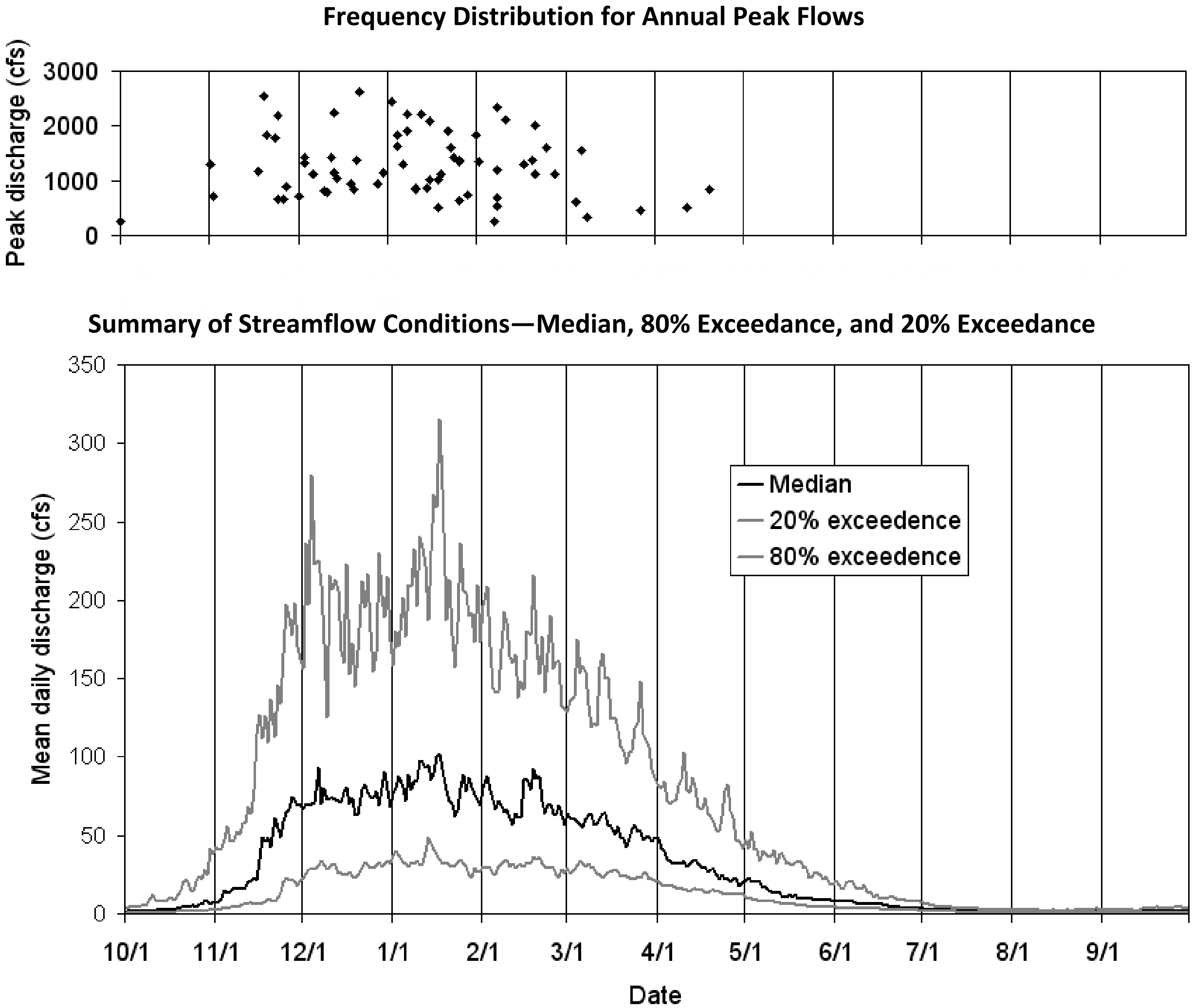
Figure 13. Mean Daily Discharge Normalized by Drainage Area



The longest-term active gage in the vicinity of the watershed assessment area is the Johnson Creek gage at Sycamore, which drains an area of similar size, precipitation, geology and relief. Figure 14 shows the median, 80%, and 20% exceedance[1] flows at the Johnson Creek gage. Mean daily streamflow is highest during the winter months, with the highest values generally occurring in January. Annual peak-flow events occur primarily from December through February, and are most prevalent during January. Summertime streamflows are generally quite low, and are at their lowest in August. Lower Abernethy and Beaver creeks should display the same streamflow patterns.

[1] The median (i.e., 50% exceedance) streamflow is the streamflow that occurs at least 50% of the time in a given month. The 80% exceedance streamflow is exceeded 80% of the time, and can be thought of as the streamflow that occurs in a particularly dry month. Conversely, the 20% exceedance streamflow is exceeded only 20% of the time, and can be thought of as the streamflow that occurs in a particularly wet month.

Figure 14. Flows at Johnson Creek Stream Gage



Flood History

The primary mechanisms for generating floods in the Willamette Basin are rainfall, snowmelt, and rain-on-snow events. Rain-on-snow events are wintertime conditions when relatively warm wind and rain combine to produce rapid snowmelt. These events typically occur at higher elevations. Because watershed assessment area is below 2,300 feet elevation (Watershed Professionals Network 1999), the dominant peak-flow generating processes are estimated as rainfall. Although rain-on-snow events are less likely at lower elevations such as those in the watershed assessment area, they can still occur.

No long-term data on annual floods are available for the watershed assessment area. Data on annual floods from the Johnson Creek at Sycamore gage were used to illustrate recent flood history in the area. The magnitudes of the annual flood events are presented as a time series in Figure 15. Recurrence intervals, also shown in Figure 15, were calculated for the period of record using techniques described by the Interagency Advisory Committee on Water Data (1982). The two largest floods recorded at the Johnson Creek gage were on December 22, 1964 (2,620 cubic feet per second [cfs]), and November 19, 1996 (2,550 cfs). Significantly, the most recent event on January 2, 2009, was the third largest on record (2,430 cfs; Figure 16). All of these flood events were near or slightly below 25-year recurrence intervals; in other words, they have a one in four (25%) chance of occurring in any given year.

Figure 15. Magnitude and Recurrence Interval for Annual Flood Events at Gage #14211500, Johnson Creek at Sycamore. Dashed lines signify the recurrence interval for the flood event (e.g., a 10-year event has a one in ten chance of occurring in any one year)

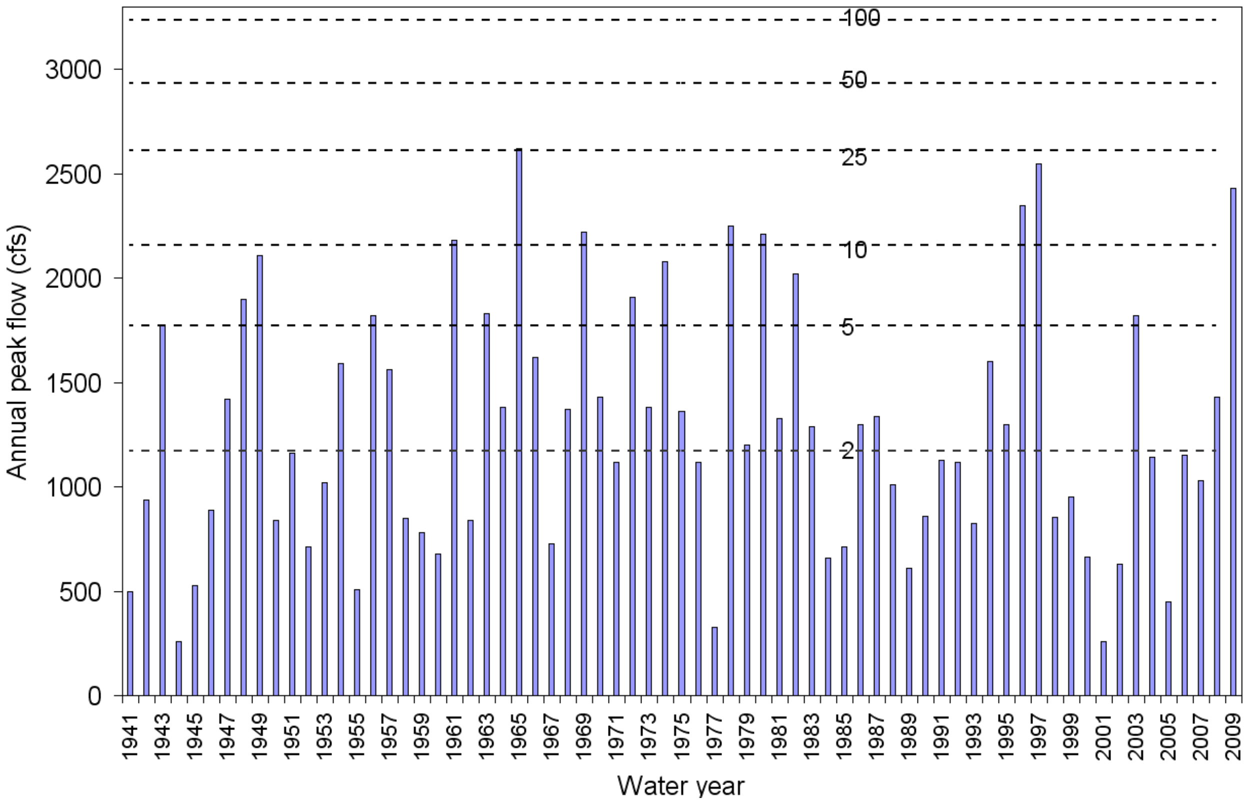


Figure 16. Beaver Creek during January 2, 2009, Flood

Photo courtesy of Ben Fritchie

Water Use

Data available from OWRD (Oregon Water Resources Department 2009a, 2009b) were used to identify locations and characteristics of water use for the watershed assessment area. Only those water rights whose current status is listed as "non-cancelled" were included in this assessment.

Water rights entitle a person or organization to use the public waters of the state in a beneficial way. Oregon's water laws are based on the principle of prior appropriation (Oregon Water Resources Department 2008). The first entity to obtain a water right on a stream is the last to be shut off in times of low streamflows. In times when water is in short supply, the water right holder with the oldest date of priority can demand the water specified in their water right regardless of the needs of junior users. The oldest water right in the watershed assessment area has a priority date of April 27, 1911, and the newest a priority date of June 4, 2008 (Oregon Water Resources Department 2009a).

Certain water uses do not require a water right (Oregon Water Resources Department 2008). Exempt uses of surface water include natural springs that do not flow off of the property from which they originate, stock watering, fire control, forest management, and the collection of rainwater. Exempt groundwater uses include stock watering, watering of less than 0.5 acre of lawn and garden, and domestic water uses of no more than 15,000 gallons per day.

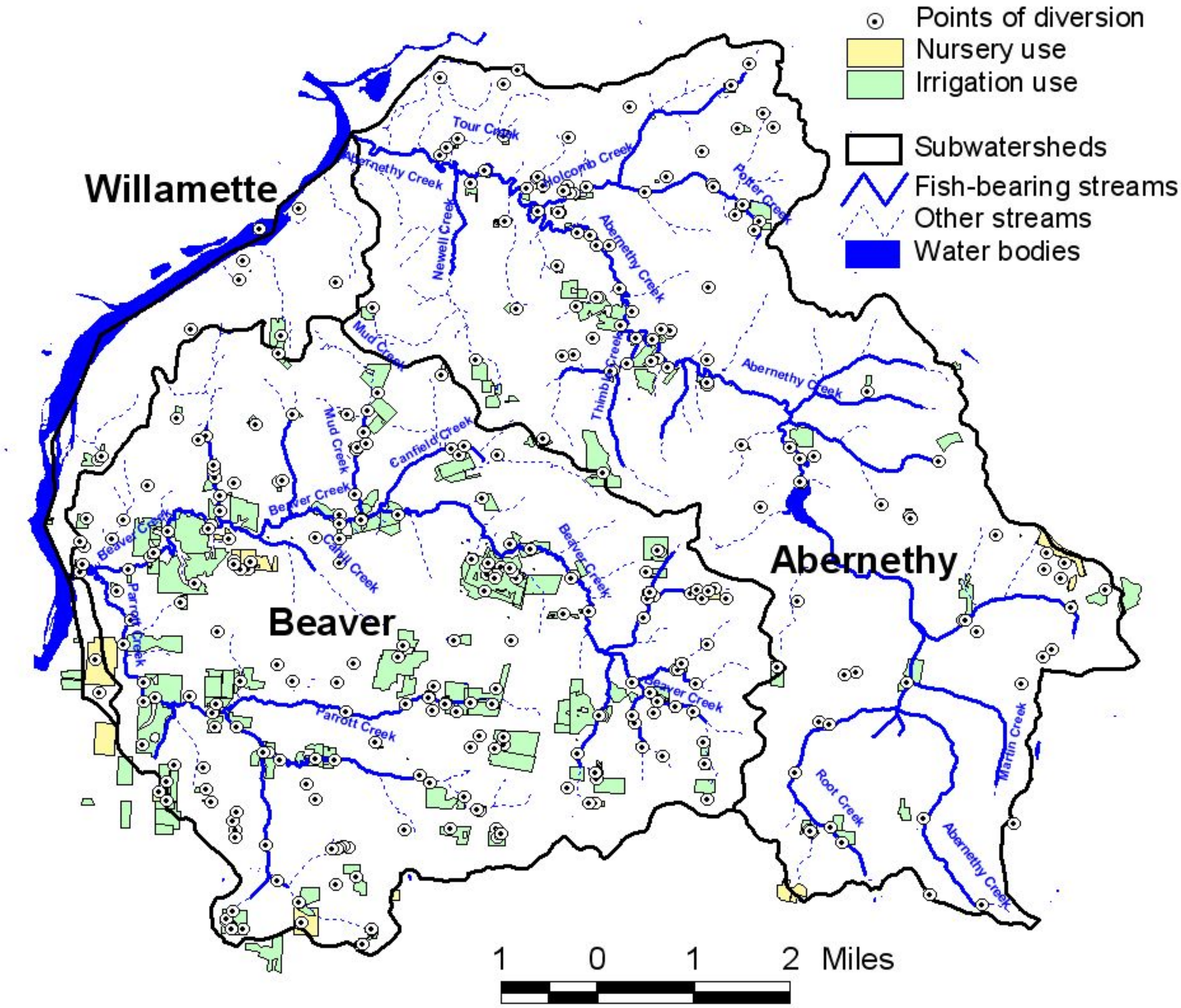
In Oregon, any entity wanting to use the waters of the state for a beneficial use has to go through an application and permit process administered by OWRD. Under this process an entity applies for a permit to use a certain amount of water, and then establishes that the water is being used for a beneficial use. Once the beneficial use is established, and a final proof survey is done to confirm the right, a certificate is issued.

OWRD also approves instream water rights for fish protection, minimizing the effects of pollution, or maintaining recreational uses (Oregon Water Resources Department 2008). Instream water rights set the flow levels that must be maintained in a stream reach on a monthly basis, have a priority date, and are regulated the same as other water rights. Instream water rights do not guarantee that a certain quantity of water will be present in the stream; under Oregon law, an instream water right cannot affect a use of water with a senior priority date (Oregon Water Resources Department 2008). No instream water rights were identified in the watershed assessment area (Oregon Water Resources Department 2009a).

Locations of Water Withdrawals

OWRD identifies approximately 700 points of diversion for water rights in the watershed assessment area (Oregon Water Resources Department 2009b). The approximate locations of these points of diversion are shown in Figure 17. Points of diversion for water rights are found in all three subwatersheds. Half (49%) of the points of diversion are from surface waters, one-quarter (25%) are from groundwater sources, and the remaining quarter (26%) are for storage.

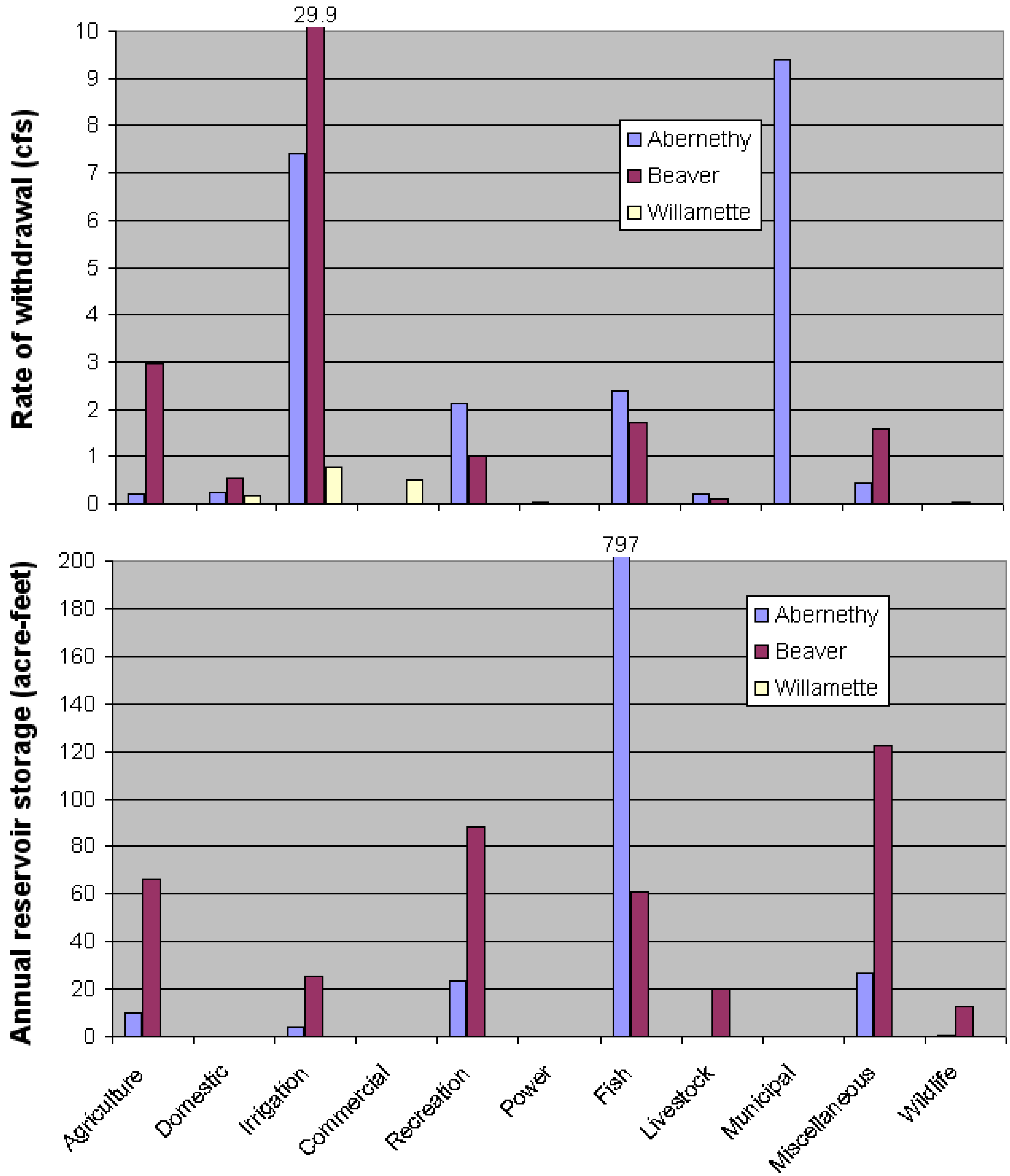
Figure 17. Points of Diversion for Water Rights and Irrigated Areas in the Watershed Assessment Area



Withdrawal Rates

Information on withdrawal rates associated with water rights in the watershed assessment area is available through OWRD (2009a). Rate of withdrawal given in the OWRD data is expressed as an instantaneous rate (i.e., cubic feet per second), except for reservoir storage, which is expressed as a total yearly volume (i.e., acre-feet). In addition, the withdrawal rate for many water rights changes by season (e.g., the allowable withdrawal rate may be lower in the summer months). Withdrawal rates are summarized in Figure 18. August 1 was chosen as the date of focus, because it falls within the period typical of the lowest flows in the watershed assessment area.

Figure 18. Withdrawal Rates and Annual Reservoir Storage in the Watershed Assessment Area for August 1 of Any Given Year



The total instantaneous rate of withdrawal on August 1 is 22.4 cfs in the Abernethy Creek watershed, 37.9 cfs in the Beaver Creek subwatershed, and 1.4 cfs in the Willamette River subwatershed (Figure 18; top graph). The largest instantaneous water use in the Abernethy Creek subwatershed is for Municipal purposes (Figure 18; top graph), primarily because of a municipal well owned by the Clackamas Water District, which is located north of Abernethy Creek, downstream of Newell Creek (Figure 17). Irrigation and agriculture are primary uses of water withdrawals in the Abernethy Creek and Beaver Creek subwatersheds (Figure 18; top graph). Water withdrawal rates for irrigation are much higher in the Beaver Creek subwatershed than in the Abernethy Creek subwatershed, despite the subwatersheds' similar sizes.

The total annual volume of reservoir storage is 861 acre-feet in Abernethy Creek subwatershed, and 396 acre-feet in Beaver Creek subwatershed (Figure 18; bottom graph). There is no storage in the Willamette River subwatershed. The largest reservoir storage use in the Abernethy Creek subwatershed (Figure 18; bottom graph) is Terra Corporation's Beaver Lake, on upper Abernethy Creek, which is used for fish culture (Figure 17). In addition to fish culture, large users of water storage in the Abernethy Creek and Beaver Creek subwatersheds are for "miscellaneous," recreation, agriculture, and irrigation.

Effects of Water Withdrawals on Flow Regime

Two pieces of information are needed to estimate the net effects of water use on streamflows at any given location: an estimate of the natural streamflow volume and an estimate of the consumptive portion of all upstream water withdrawals. Unfortunately, no gage records are available for the watershed assessment area, so monthly streamflows cannot be estimated directly. OWRD estimates natural monthly streamflows at the outlets of "water availability basins" (WABs); however, the WAB that contains the watershed assessment area (the Lower Willamette River, from the Molalla River to the confluence with the Columbia River) is too large to allow for meaningful results. Similarly, the consumptive use values that have been calculated for the areas are too course in resolution to allow for a meaningful analysis of effects specific to Abernethy or Beaver creeks.

Assuming that the flows at the outlets of Abernethy and Beaver creeks are similar to what has been observed at the Johnson Creek gage and assuming that existing water rights are fully used, it is likely that water withdrawals in Abernethy and Beaver creeks would have a significant negative effect on streamflows during summer and early fall periods. However, further analysis is needed to understand the full effect of water withdrawals on streamflows and fish populations.

Surface Erosion and Stream Sediment

Introduction

Rainfall can erode soils, carrying fine particles of sediment into the stream system. Sediment is a natural part of stream habitat, forming part of the channel bottom, or substrate; however, increased sediment loads carried into stream channels can negatively affect fish habitat by filling channels and covering spawning gravels. Due to the underlying geology and soil types, the watershed assessment area has naturally high rates of soil erosion and associated sediment in streams. This assessment examines erosion above the natural background level.

The likely primary sources of sedimentation in the watershed assessment area are bank erosion and upland surface erosion. These sediment sources are evaluated using the impervious surface assessment described above, under "Watershed Overview," and through a modeling application of the Revised Universal Soil Loss Equation (RUSLE). Stormwater runoff from impervious surfaces affect bank erosion areas and magnitudes through increased peak flows that scour banks and create exposed areas of bare soils. Surface erosion associated with land uses (e.g., agriculture, forestry) is evaluated through the RUSLE.

Bank Erosion

Bank erosion is a natural process that occurs in all stream systems, largely in response to variable streamflow events and changes in the resistive strength of the bank material, often associated with streambank vegetation and associated root strength. Bank erosion rates in urban or urbanizing watersheds are likely to be elevated over background levels due to changes in the flood-flow regime. As discussed in the section above, the most likely mechanism for flow regime impacts in the watershed assessment area is the increase in impervious surfaces in the upstream contributing watershed. The area-weighted percent impervious value for the contributing watershed area upstream of the midpoint of each reach (Figure 3) represents the likely magnitude of bank erosion impacts. As discussed above, reaches having 5% or less impervious surface in the contributing area are classified as good, 5–10% as fair, and greater than 10% as poor. Based on these criteria, reaches in the Abernethy Creek subwatershed were the least affected overall, with approximately 75% of the reach length classified as good, 20% as fair, and only 5% as poor. Approximately 45% of the reach lengths in the Beaver Creek subwatershed were classified as good, 20% as fair, and 35% as poor. Areas with poor impervious surfaces likely have the highest levels of bank erosion.

Upland Surface Erosion

The Nonpoint-Source Pollution and Erosion Comparison Tool (NSPECT) was used to evaluate the potential impacts of upland land uses on surface erosion and sediment delivery (Eslinger et al. 2005). NSPECT uses the RUSLE to estimate average annual runoff and sediment load (Renard et al. 1997). The application of NSPECT requires map-based representations of 1) digital elevation model data to calculate surface flow direction and flow accumulation throughout a watershed 2) land cover data 3) soils data and 4) annual precipitation data.

Values for two soil parameters are needed to run NSPECT: soil erodibility ("k factor") and the hydrologic soil type (i.e., A, B, C, or D, depending on the soil's infiltration rates). Both of these values were available for soil series in the NRCS (2009) soil layers available for Clackamas County. Annual precipitation values from the time period 1971–2000 (PRISM Climate Group 2006) were used to characterize mean annual precipitation in the watershed assessment area.

Average annual sediment yield was calculated for two modeling scenarios: current land cover and historic land cover. Soil, elevation, and precipitation values were held constant between the two modeling scenarios. Average annual sediment yield was calculated at the midpoint of each stream reach under both scenarios, and the increase over background was calculated by dividing current yield by historic yield. The resultsare illustrated in Figure 19, as sediment increase over natural background levels, and summarized in Figure 20.

All stream reaches showed a modeled increase over background conditions. Increases were lowest in areas of relatively undisturbed forest (e.g., Martin Creek) and highly urbanized areas (e.g., the headwaters of Mud Creek). The greatest modeled increases in sediment yield are for the areas with extensive agricultural uses. The Beaver Creek subwatershed, which has the highest percentage of area in agricultural land uses, displays the highest sediment rate above background.

Figure 19. Sediment Increase over Background for the Watershed Assessment Area (Calculated at the Midpoint of Each Reach)

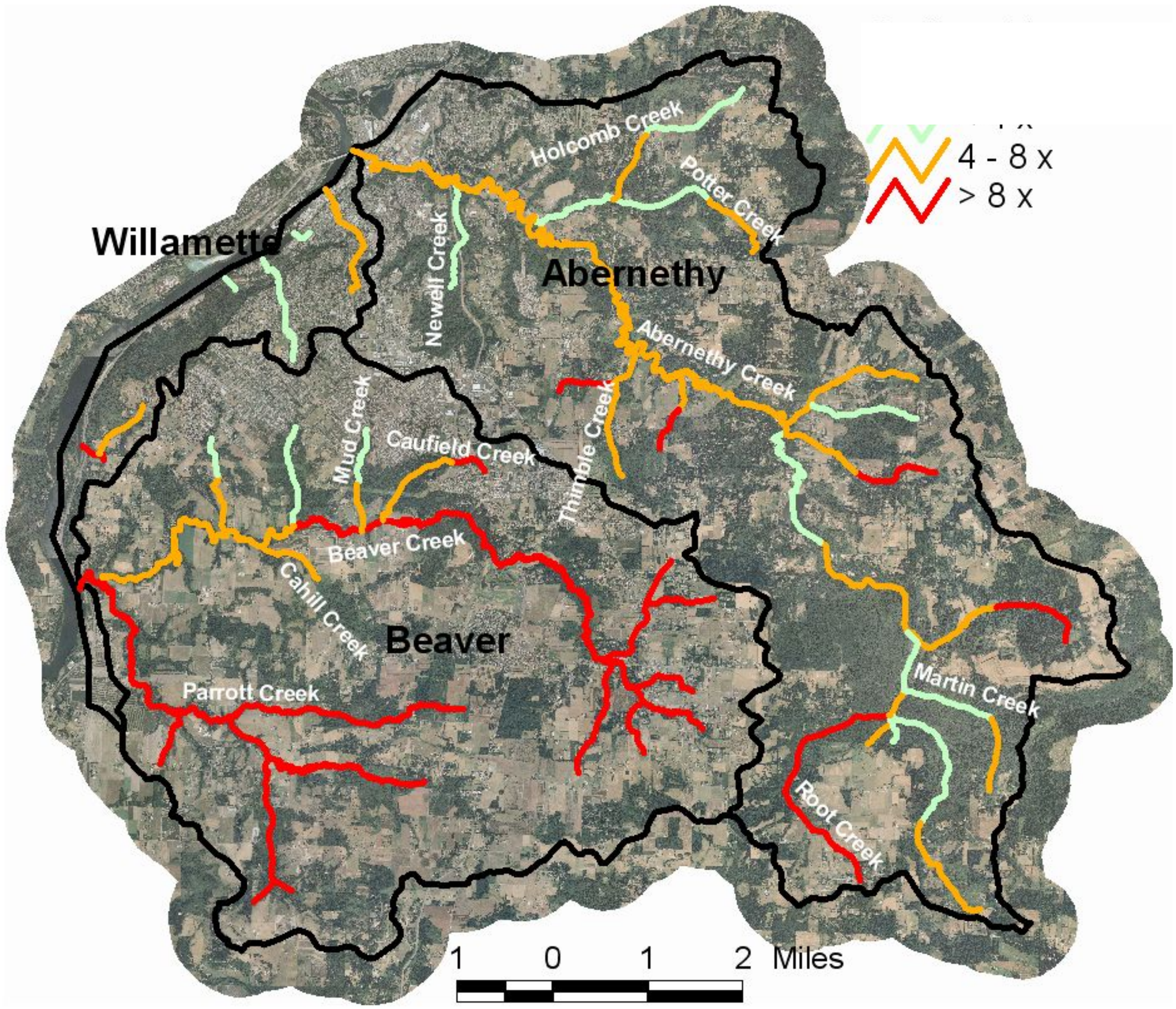
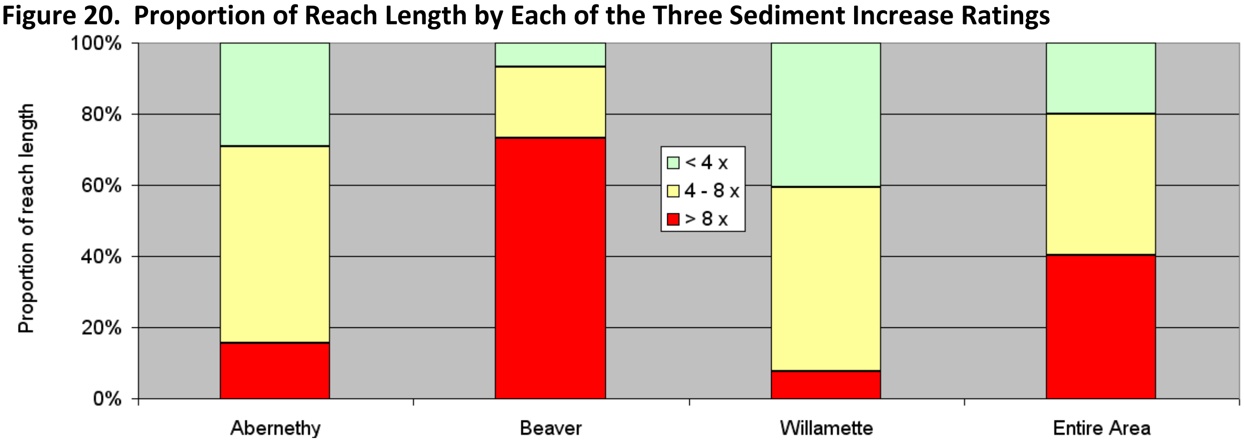


Figure 20. Proportion of Reach Length by Each of the Three Sediment Increase Ratings



Introduction

The Oregon Water Quality Standards (Oregon Administrative Rules [OAR] 340-041-0340, 2010) include the list of beneficial uses of the stream, the water quality criteria designated to protect those uses, and policies to implement the water quality standards. Since criteria applicable to streams are based on the protected beneficial uses it is important to identify the uses specific to each water body. Beneficial uses applicable to Willamette River Basin and Abernethy Creek and Beaver Creek subwatersheds are identified in the Oregon Water Quality Standards (Table 5). Water quality standards for temperature and other parameters applicable to salmon and trout rearing and migration are in effect for Abernethy Creek and Beaver Creek subwatersheds. Standards for salmon and steelhead spawning are applicable only to Abernethy Creek subwatershed.

Table 5. General Beneficial Uses Identified for All Willamette River Basin Tributaries and Specific to Abernethy Creek and Beaver Creek Subwatersheds (2010)

General Beneficial Use Designations	
Public Domestic Water Supply	Wildlife & Hunting
Private Domestic Water Supply	Fishing
Industrial Water Supply	Boating
Irrigation	Water Contact Recreation
Livestock Watering	Aesthetic Quality
Fish and Aquatic Life	
Beneficial Uses: Fish Use Designations for Abernethy Creek Subwatershed	
Salmon and trout rearing and migration	
Salmon and steelhead spawning use, October 15–June 15	
Beneficial Uses: Fish Use Designations for Beaver Creek Subwatershed	
Salmon and trout rearing and migration	
No spawning use	
Source: OAR 340-041-0340	

The federal Clean Water Act, Section 303(d), requires states to maintain a list of streams considered water quality limited, in other words, streams that do not meet particular water quality standards for the beneficial uses. If a 303(d) listing is warranted, a total maximum daily load (TMDL) plan is developed for the stream segment. The TMDL plan identifies the maximum pollutant load (e.g., water temperature) that can be supported and still meet water quality criteria. Pollutant loads, above the level that meet water quality criteria, must be reduced over time using pollution-control technology for point sources, such as wastewater treatment plants, and best management practices for non-point sources, such as agricultural land uses.

The approach to evaluating water quality issues in the watershed assessment area is based on an initial review of available water quality data, applicable studies, and any potential pollution sources that occur in the watershed. Very limited water quality data are available for Abernethy Creek subwatershed and virtually no data are available for Beaver Creek subwatershed. Appendix A outlines the sources of water quality data, sample site locations, and criteria used for this assessment.

This section focuses on what is known about the water quality characteristics that are important for maintaining watershed health and restoring salmon and trout populations: temperature; toxics, which include pesticides, herbicides, and heavy metals; and stormwater, which includes a variety of parameters such as bacteria and sediment.

Relationship to Land Use

Because there is limited water quality data for streams in the watershed assessment area, the evaluation of water quality depends to a large extent on studies in the Clackamas River watershed and nearby lower Willamette Basin tributary streams. Fortunately, several comprehensive studies have been completed by USGS that provide a good idea of what water quality issues to expect in urbanizing watersheds similar to the watershed assessment area. The Clackamas River is a good case study, because its watershed characteristics, land uses, and crops are similar to those in the watershed assessment area. The lower Clackamas River basin transitions from forested land cover to agricultural and rural residential then to urban land uses similar to the Abernethy Creek and Beaver Creek subwatersheds. The general mix of pollutant sources for temperature, sediment, nutrients, pesticides, and herbicides are similar in composition to the lower Clackamas.

- The study of nutrients and algal conditions in the Clackamas River (Carpenter 2003) established the relationship between pollution sources, nutrients, and effect on water quality.
- The USGS study of pesticides (Carpenter et al. 2008) in the lower Clackamas Basin provides a useful analogy for what pesticides/herbicides to expect in these watersheds due to the similarity in land uses.
- Another USGS study shows the effects of urbanization in stream ecosystems in the Willamette River (Waite et al. 2008).

The issues identified in these studies are also highlighted in the Willamette Basin TMDLs, which list elevated stream temperatures, bacteria, mercury, and pesticides.

The percent impervious surface area plays a key role in determining water quality (see "Watershed Overview"). USGS correlated urbanization and impervious surfaces to water quality in the Willamette River Basin, including Portland area watersheds that are similar to the Oregon City watersheds such as Kellogg and Abernethy Creeks (Waite et al. 2008). The USGS study found strong correlations between the degree of urbanization and water quality measurements including the total pesticide concentration, toxic equivalents, and dissolved oxygen. There is also a high correlation between urbanization and altered biological communities. Fish and aquatic insect communities appear to be affected at an impervious surface threshold of 5%, which corresponds to a number of streams in the watershed assessment area (Figure 3).

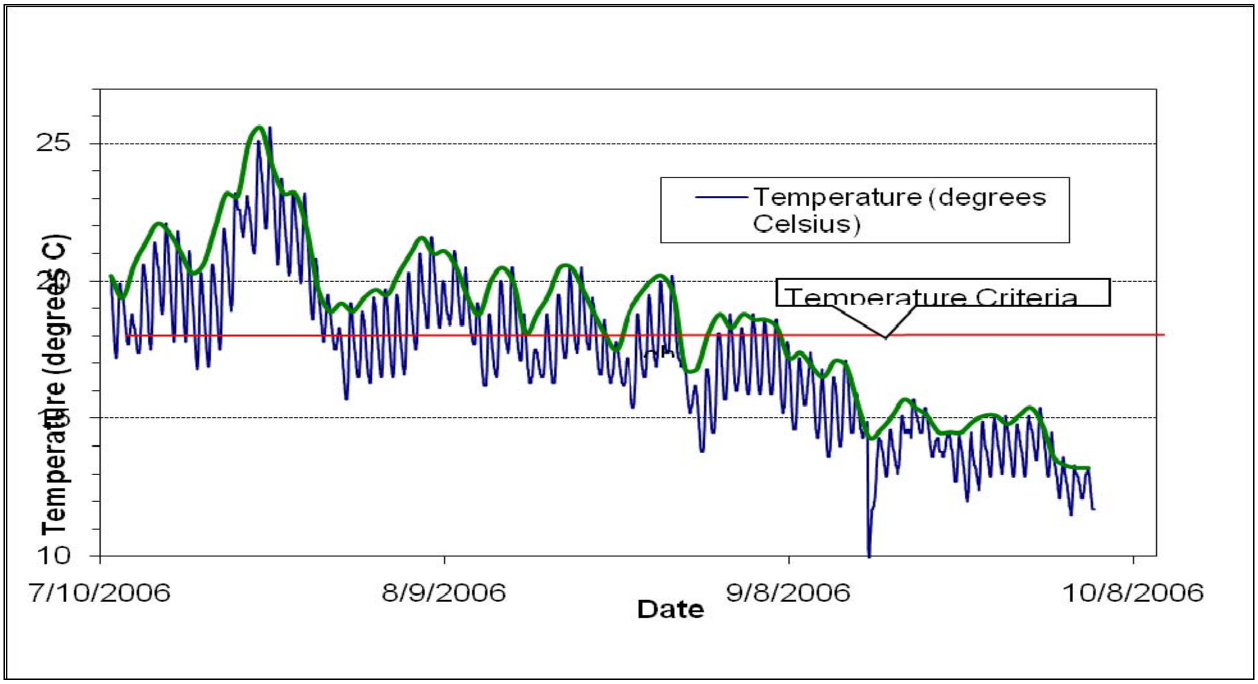
Water Temperature

Temperature is listed as water quality limited for one stream in the watershed assessment area, Abernethy Creek. One temperature station in Abernethy Creek provides a snapshot of temperature conditions; no other temperature records are available for the watershed assessment area.

Water temperature was measured continuously by the Oregon Department of Environmental Quality (ODEQ) in Abernethy Creek near Atkinson Park within Oregon City from July 11 to October 4, 2006 (Figure 21). The water quality criterion for this period of time is 18 degrees Celsius (64.4 degrees Fahrenheit), which has been established to protect salmon and trout rearing and migration.

Water temperature exceeded the temperature criteria 100% of the time during the months of July and August, indicating that the lower section of Abernethy Creek is not conducive to salmon or trout populations.

Figure 21. Water Temperature and 7-Day Average Water Temperature Recorded for Abernethy Creek



Source: Oregon Department of Environmental Quality 2006.

Toxics

Toxic pollutants of concern in the aquatic environment include heavy metals, organic pesticides, herbicides, polyaromatic hydrocarbons (PAHs), polychorinated biphenyls (PCBs), pharmaceuticals and other human-made chemicals. The best local information on potential toxic chemicals is contained in the detailed study completed by USGS between 2000 and 2005 on pesticide occurrence in the lower Clackamas Basin (Carpenter et al. 2008).

The USGS study reported the following:

> In all, 63 pesticide compounds were detected, including 33 herbicides, 15 insecticides, 6 fungicides, and 9 pesticide degradation products. Atrazine and simazine were detected in about half of samples, and atrazine and one of its degradates (deethylatrazine) were detected together in 30 percent of samples. Other high-use herbicides such as glyphosate, triclopyr, 2,4-D, and metolachlor also were frequently detected, particularly in the lower-basin tributaries. Pesticides were detected in all eight of the lower-basin tributaries sampled, and were also frequently detected in the lower Clackamas River.
>
> The highest pesticide loads were found in Deep and Rock Creeks. These medium-sized streams drain a mix of agricultural land (row crops and nurseries), pastureland, and rural residential areas. "Although most of the 51 current-use pesticides detected have multiple uses, 48 (or 94 percent) can be used on agricultural crops. Ninety-two percent can be used on nursery or floriculture crops; about one-half are commonly used on either lawns and landscaping in urban areas (57 percent), on golf courses (49 percent), along roads and right-of-ways (45 percent), and some can be used on forestland (7 percent).
>
> Some concentrations of insecticides (diazinon, chlorpyrifos, azinphos-methyl, and *p,p'*-DDE) exceeded U.S. Environmental Protection Agency (USEPA) aquatic-life benchmarks in Carli, Sieben, Rock, Noyer, Doane, and North Fork Deep Creeks. One azinphos-methyl concentration in Doane Creek (0.21 microgram per liter [µg/L]) exceeded Federal and State of Oregon benchmarks for the protection of fish and benthic invertebrates. Concentrations of several other pesticide compounds exceeded non-USEPA benchmarks.

The study provides a useful analog for Abernethy Creek and Beaver Creek subwatersheds. Many of the land uses in these subwatersheds are similar to the areas in the lower Clackamas that have the highest pesticide loads. The watershed assessment area contains a large proportion of agricultural and residential land uses, indicating a very high probability that pesticides are an issue in the watershed. In addition, pesticides and herbicides are used on lawns and landscapes in the urban/commercial use areas, providing a further source of toxics to the stream system.

Although none of the USGS studies focused on metals, heavy metals are commonly found in urban stormwater. Copper, lead, and zinc were listed as parameters in a watershed in the Middle Willamette River Basin (Oregon Department of Environmental Quality 2006).

Stormwater Quality

Lower Abernethy Creek flows through Oregon City, and other small tributaries originate in the city and flow into Abernethy and Beaver creeks or into the Willamette River. Key headwater streams that begin in the city include Newell Creek, a tributary to Abernethy Creek, and a number of small tributaries that flow into Beaver Creek. Oregon City has a comprehensive approach to managing and monitoring stormwater. Data for the stormwater evaluation were collected by the city for three dates during the winter of 2007–2008. The November sample was reported as dry, and the December and January samples were reported as wet (City of Oregon City 2008).

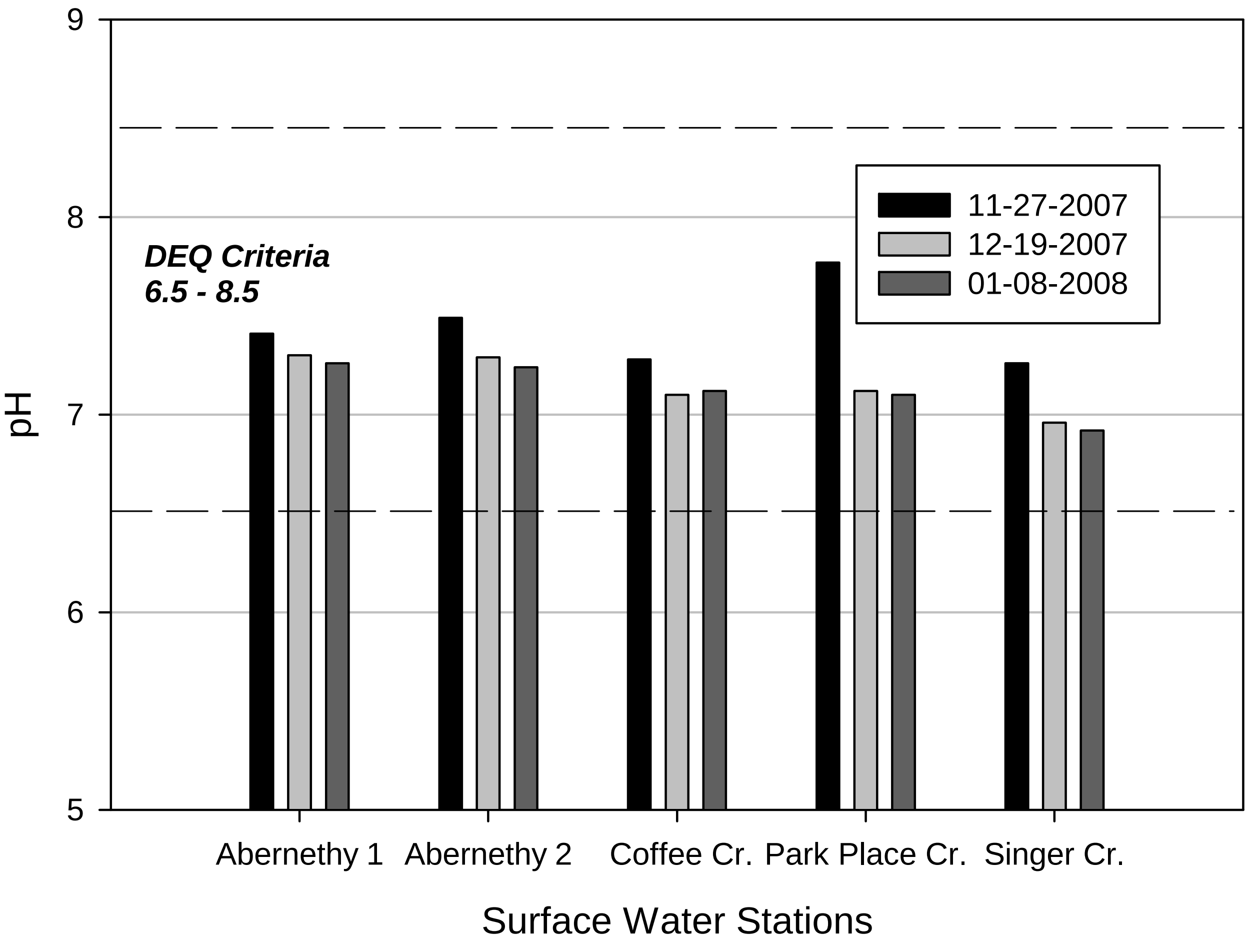
Antecedent rainfall conditions and a numeric summary of the water quality findings are contained in Appendix I. The stormwater quality findings for pH, total dissolved solids, total suspended solids, bacteria, and nutrients are summarized below. In addition to these parameters, the stormwater samples were tested for heavy metals. Dissolved copper, lead and zinc were generally below DEQ chronic criteria, with one exception. Dissolved zinc exceeded criteria in one stormwater sample at Park Place Creek.

pH

pH measures the hydrogen ion concentration and is influenced by the buffering capacity of the water. Daily fluctuation in pH is expected, because pH increases during the daytime hours as dissolved carbon dioxide is being drawn out of the water column for algal photosynthesis. Daily extremes in pH are, therefore, an indicator of eutrophication (high nitrogen and other nutrient loads leading to increased algae and other aquatic plants), but this effect can only be detected by using continuous sampling.

pH, as measured by the three discrete stormwater samples, is within the state water quality criteria (6.5–8.5) (Figure 22), and does not vary substantially between monitoring stations.

Figure 22. pH—Stormwater Monitoring (2007–2008). Monitoring site locations are described in Appendix A

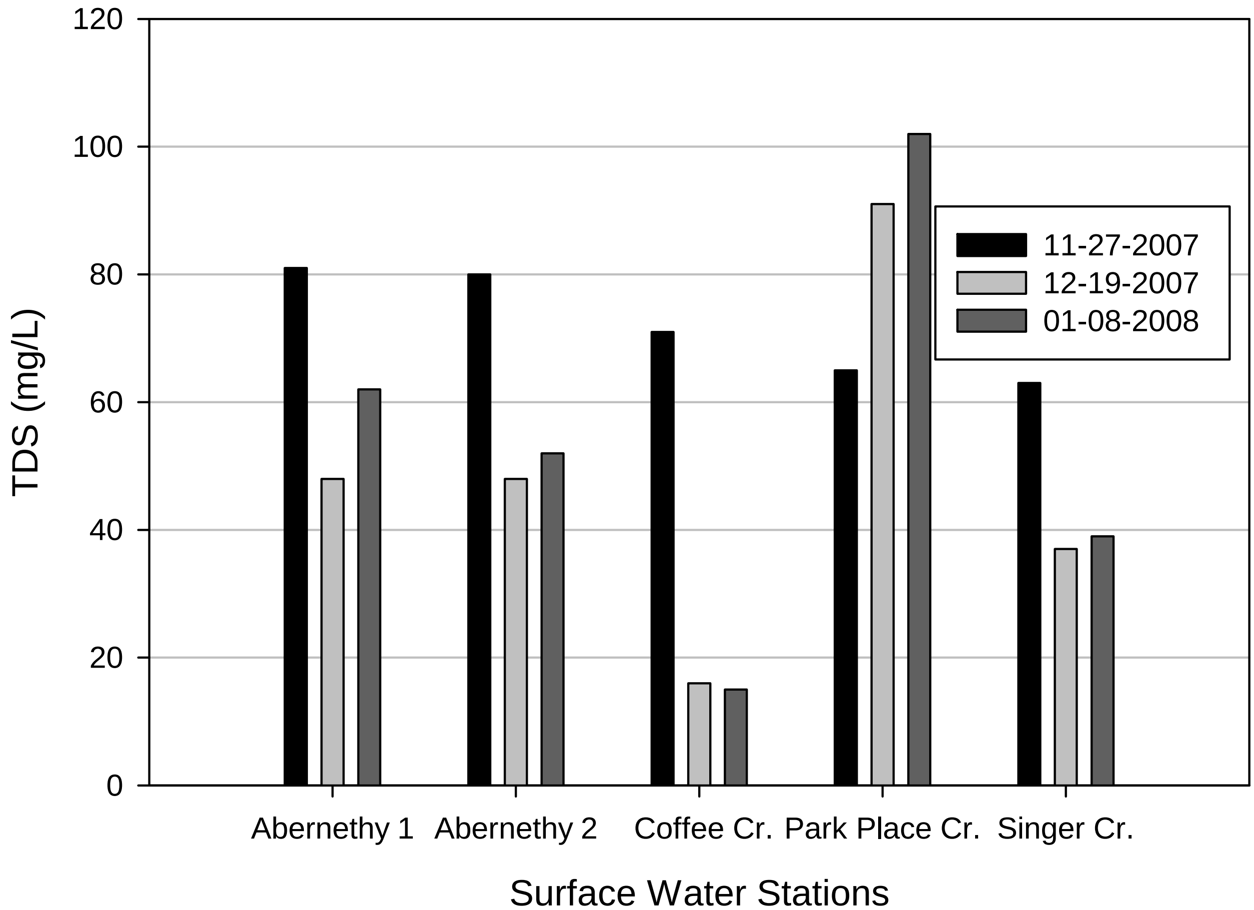


Total Dissolved Solids

Total Dissolved Solids (TDS) is a measure of the dissolved salts in the water column (e.g., sodium chloride, calcium, magnesium carbonates). In general, an increase in TDS is an indicator of pollution, because both rural and urban pollution often increase dissolved salts.

Generally, TDS decreases during storm flows as a result of dilution by rainwater. This pattern is reflected in the comparison in Figure 23, where most sites had higher TDS levels during the dry sample period (November 2007) in comparison to lower levels during the wet sample periods (December 2007 and January 2008). The pattern is reversed for Park Place Creek indicating likely urban stormwater pollution sources. TDS at Park Place Creek, as measured in January 2008, slightly exceeds the water quality criteria of 100 milligrams per liter.

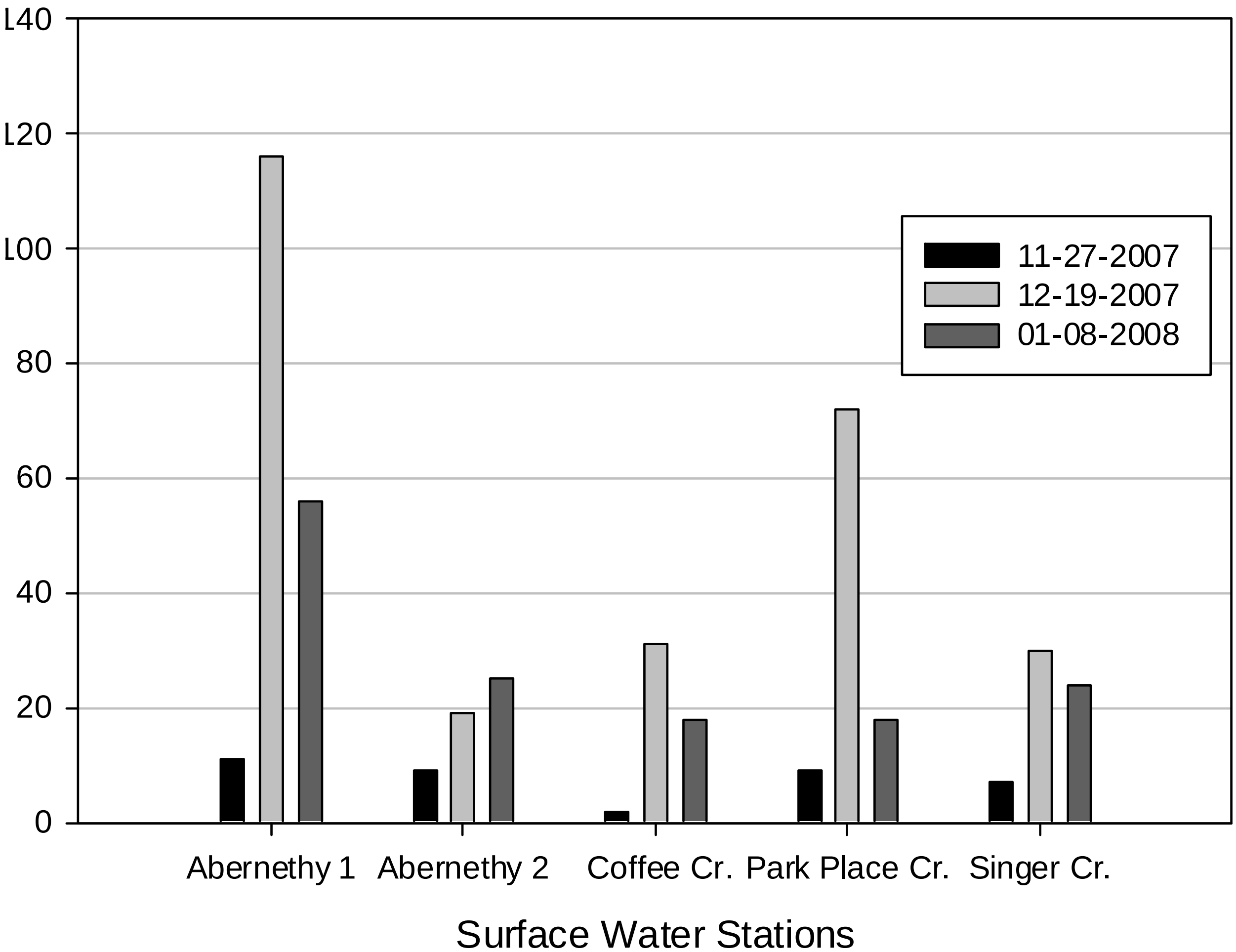
Figure 23. Total Dissolved Solids—Stormwater Monitoring (2007–2008). Monitoring site locations are described in Appendix A



Total Suspended Solids

Total suspended solids (TSS) measures the organic and inorganic solids that are retained on a filter, primarily soil and fine sediment particles. TSS increases during rainfall events as soil is eroded from fields, stream banks break down, and solids collected on road surfaces are washed into ditches and stream channels. TSS increased during the storm events in December and January (Figure 24) at all of the stormwater stations monitored. The upstream-downstream increase in Abernethy Creek, from Holly Lane to the railroad trestle, during the storm events, can be attributed to urban stormwater runoff. As with TDS, the higher magnitude increase at Park Place Creek (from 9 to 72 milligrams per liter) is indicative of an urban stormwater source.

Figure 24. Total Suspended Solids—Stormwater Monitoring (2007–2008). Monitoring site locations are described in Appendix A



Bacteria

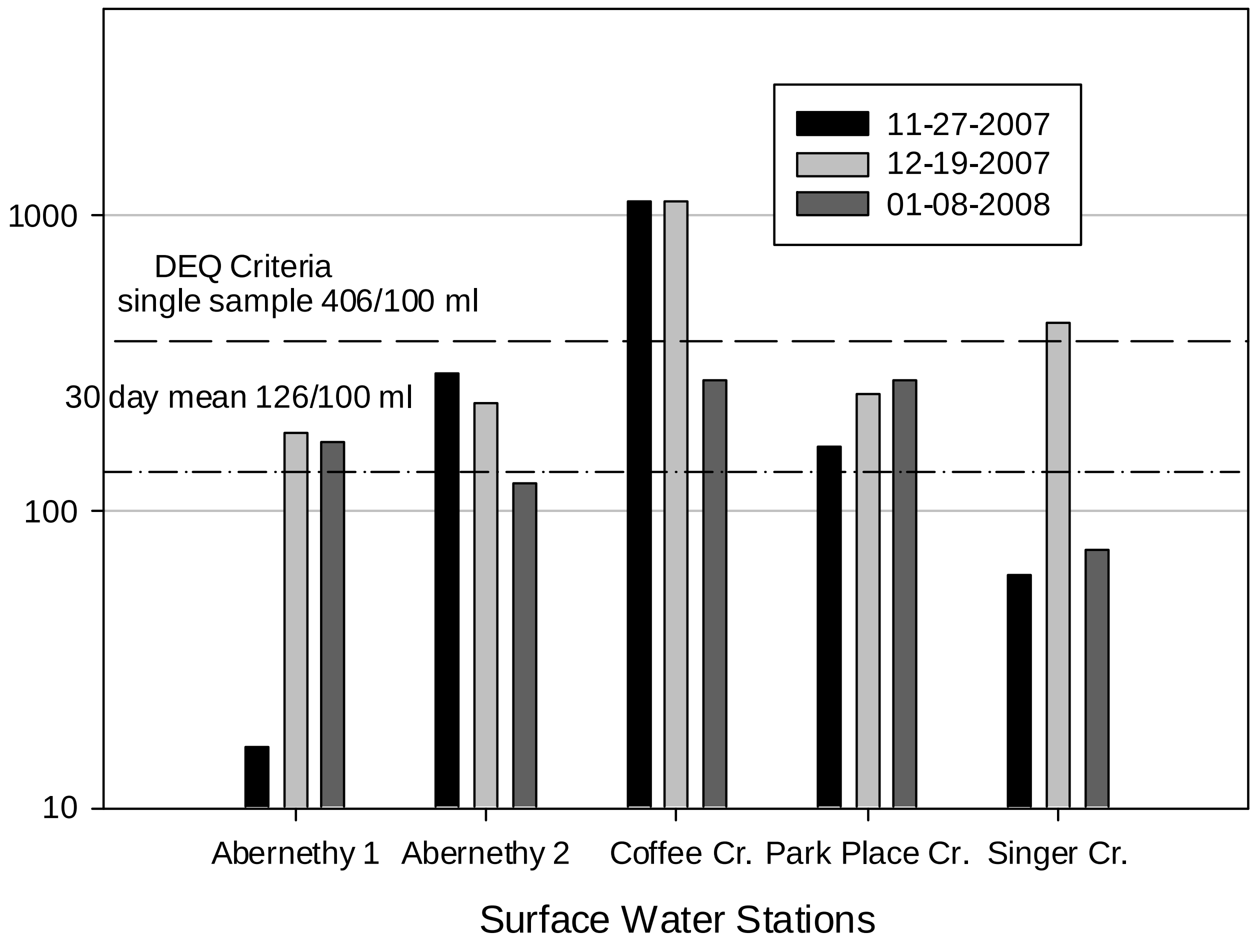
E. coli (*Escherichia coli*) is a type of fecal coliform bacteria commonly found in the intestines of warm-blooded animals and humans. The presence of E. coli in water is an indication of recent sewage or animal waste contamination, and a possible indication that other pathogens may also be present. Two of the water quality criteria are based on monitoring frequency. For water contact recreation, a single sample is not to exceed 406 per 100 milliliters, and the 30-day log mean is not exceed 126 per 100 milliliters.

Bacteria and other potential pathogens occur in water as a result of both natural and pollution sources. Background sources of E. coli are wild birds and mammals, and these bacteria may increase where animals are concentrated (e.g., flocks of ducks and geese). But generally, E. coli numbers are relatively low in unpolluted waters (less than 10 per 100 milliliters).

The monitoring stations indicate a fairly high bacterial load during both the dry and wet season samples (Figure 25). Surface water that is not subject to pollution sources will often have a very low background concentration, such as the values observed at the Clackamas River station with a mean value of 4 per 100 milliliters.

Water quality criteria are designed to recognize the variable nature of bacterial growth, allowing a higher value for a single sample (406 per 100 milliliters) versus an average taken over a longer period of time (126 per 100 milliliters). Single samples were generally below 406-per-100-milliliter criterion (Figure 25); however, if sample frequency had been sufficient to calculate mean values, it appears likely that bacteria numbers would exceed criteria during storm events. Bacteria are washed into streams during storms and get resuspended with bottom sediments in stream channels.

Figure 25. Bacteria—Stormwater Monitoring (2007–2008). Monitoring site locations are described in Appendix A



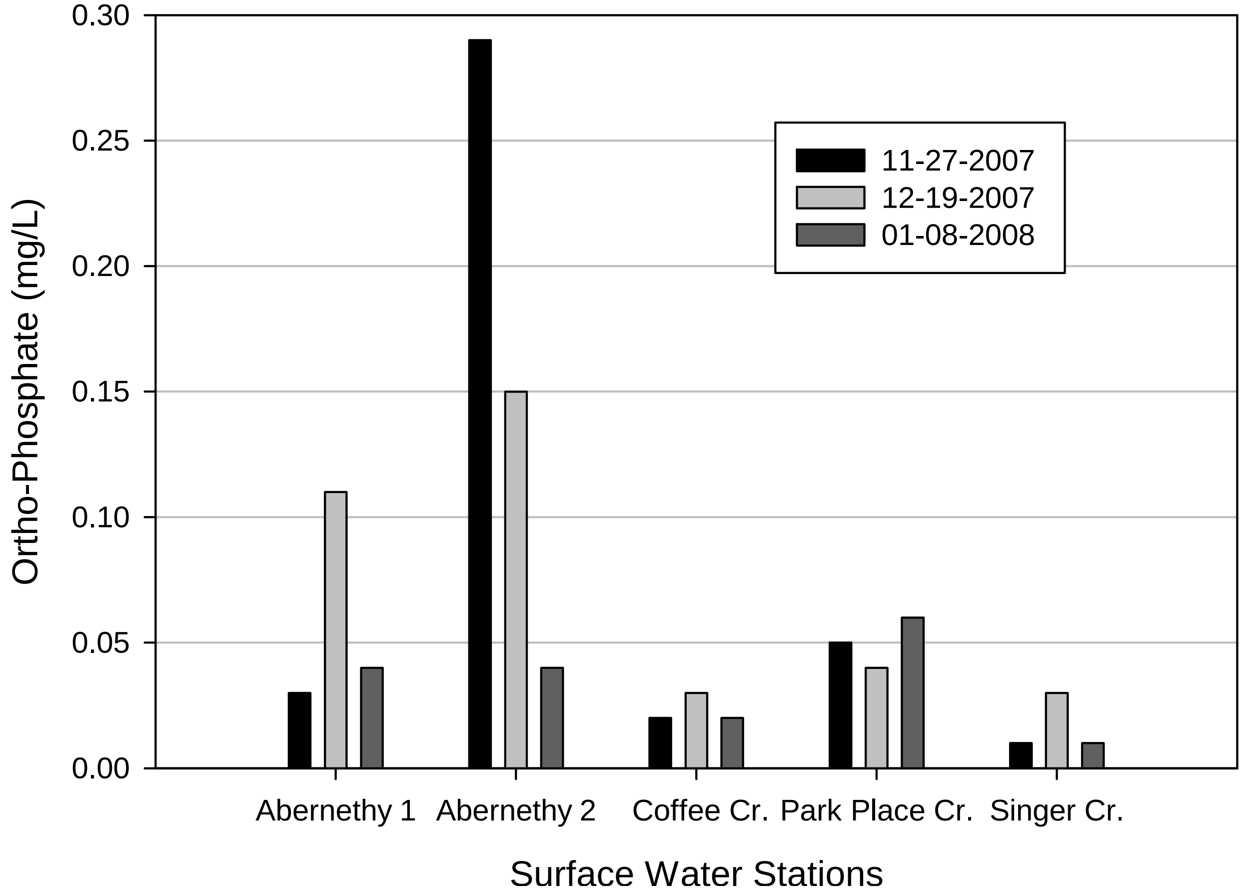
Nutrients and Eutrophication

Fairly low phosphorus and nitrogen concentrations can stimulate algal growth and lead to undesirable effects of eutrophication. Values recommended by the U.S. Environmental Protection Agency for preventing eutrophication in the Willamette Valley ecoregion are 0.04 milligram per liter for total phosphorus[2] and 0.15 milligram per liter for nitrogen. Figure 26 and Figure 27 provide the ortho-phosphorus and nitrogen levels, respectively, in the watershed assessment area.

[2] EPA-recommended values are expressed as milligram per liter for total phosphorus where total represents dissolved and suspended fractions. The variable used here is ortho-phosphate, which represents the dissolved fraction. Ortho-phosphate is readily bioavailable and is, therefore, more meaningful for understanding the likelihood of stimulating algal growth.

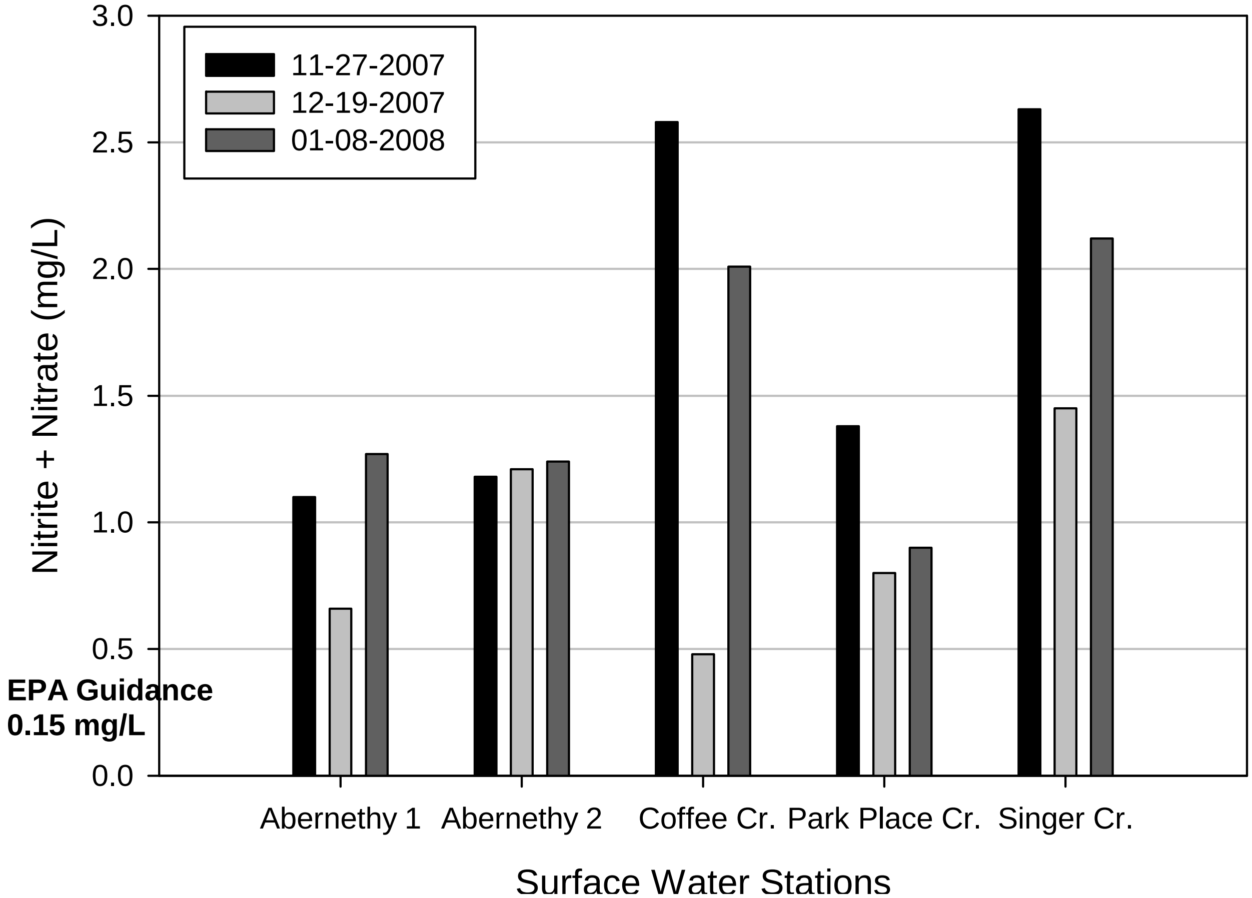
As shown in Figure 26, ortho-phosphate at stormwater stations in the watershed assessment area is generally below the EPA-recommended value; however, the value is exceeded in Abernethy Creek above the city limits. This pattern indicates that the phosphorus values are likely associated with sources in the agricultural/rural residential areas rather than in the urban zone. Likely sources of phosphorus are crop fertilizers and livestock waste. In comparison, the average ortho-phosphate concentration during the same period of time on the upper Clackamas River was 0.01 milligram per liter.

Figure 26. Ortho-Phosphate—Stormwater Monitoring (2007–2008). Monitoring site locations are described in Appendix A



Nitrate concentrations are elevated at all the stations both in the dry and wet sampling periods (Figure 27) indicating a high potential for contributing to eutrophication. For comparison, the average nitrate concentration in the upper Clackamas River was 0.02 milligram per liter, which indicates that EPA-recommended value is both appropriate and achievable for this ecoregion.

Figure 27. Nitrates—Stormwater Monitoring (2007–2008). Monitoring site locations are described in Appendix A



Introduction

This section summarizes what is known about fish populations and stream habitat in Abernethy Creek, Beaver Creek, and tributary streams. The natural and human management factors that influence the presence and abundance of fish, steam habitat quality, and fish movement through streams in the Abernethy Creek and Beaver Creek subwatersheds are described. Because the small streams of the Willamette River subwatershed fall off the steep hillsides of Oregon City and are very high gradient, these streams do not contain fish with the exception of lower channel habitats within the Willamette River floodplain; we do not describe the status of fish populations and habitat for this subwatershed.

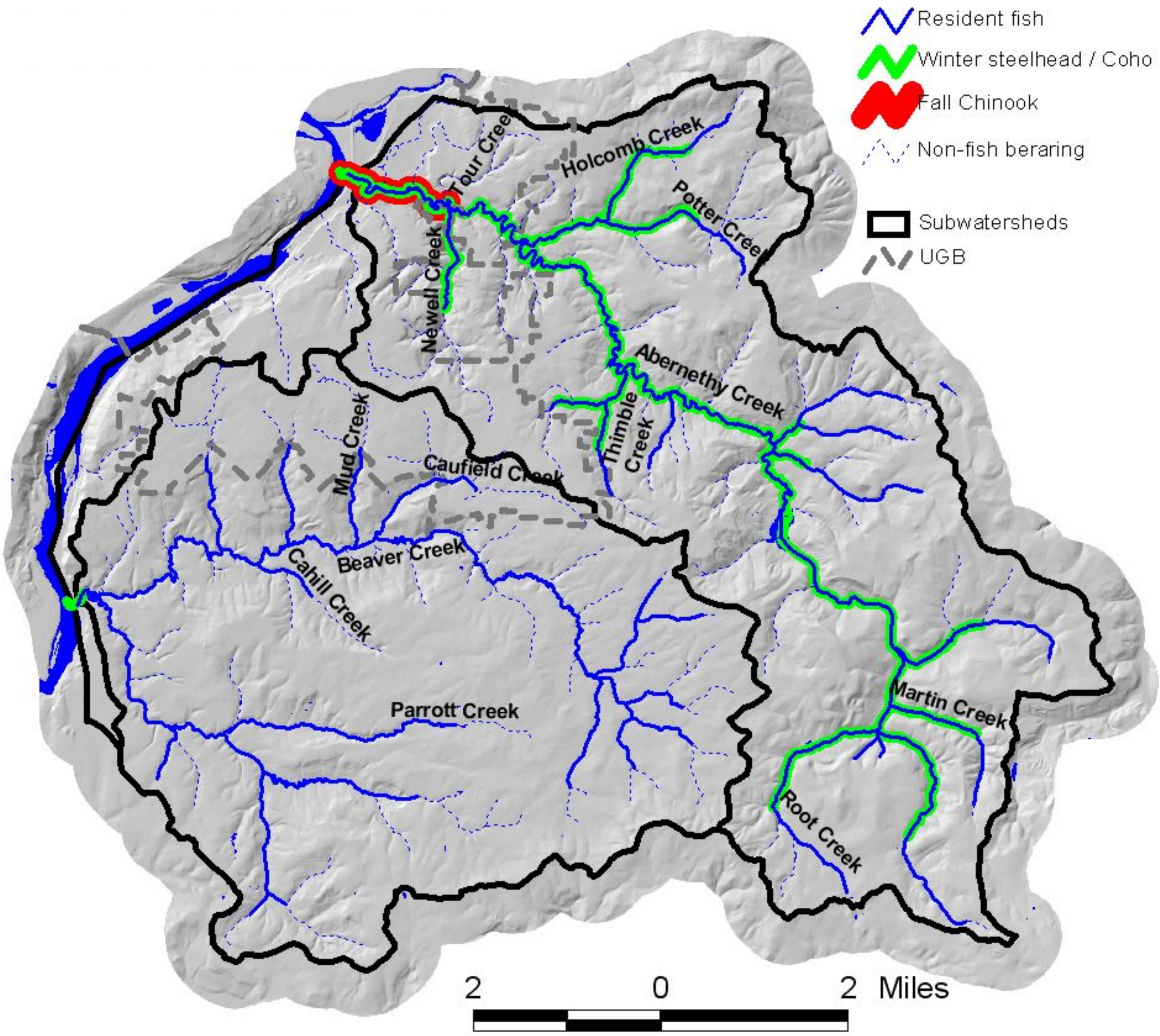
Studies, inventories, and other documents produced by the Oregon Department of Fish and Wildlife (ODFW), ODEQ, Clackamas County, and other sources provided information on fish habitat, spawning and rearing fish populations, and fish passage barriers. These studies were supplemented by field reconnaissance of selected stream areas. Very little information is available on fish presence and populations in the watershed assessment area; studies from similar Portland area tributary streams, such as Johnson and Kellogg Creek, inform the description of fish populations and habitat quality.

Overview of Fish Presence and Distribution

Four salmonid species (family *Salmonidae*), and a variety of native non-salmonid fish species inhabit streams in the watershed assessment area for at least a portion of their life cycle. The fish life cycle stages include migration (by adults and juveniles), spawning, juvenile rearing, and adult residence. Coho salmon (*Oncorhynchus kisutch*), fall Chinook salmon (*Oncorhynchus tshawytscha*), and steelhead trout (*Oncorhynchus mykiss*) were historically abundant in the lower Willamette River and its tributaries. These anadromous (i.e., residing in the ocean as adults and returning to rivers and streams to spawn) fish have experienced significant declines; some populations from Portland area urban streams, including streams within the watershed assessment area, have been virtually eliminated (Myers et al. 2006). Resident cutthroat trout (*Oncorhynchus clarki*) are also present in the watershed assessment area. Cutthroat trout populations are also likely lower in abundance due to habitat loss and other factors (Johnson et al. 1999). Figure 28 shows the historic distribution of anadromous salmon and steelhead and resident cutthroat trout in Abernethy Creek and Beaver Creek subwatersheds.

In addition to the salmon and trout populations noted above, chum salmon and a migratory form of cutthroat trout from the Willamette River may have been historically present in Abernethy Creek (Sanders pers. Comm.). Chum salmon are not present in the watershed at this time and the continued presence of migratory cutthroat trout is unknown.

Figure 28. Fish Distribution of fall Chinook, Steelhead, Coho, and Resident Cutthroat Trout in the Watershed Assessment Area



Abernethy Creek is thought to have once had a small run of fall Chinook salmon that was part of the larger population associated with the lower Clackamas River and Johnson Creek (Huntington 2007). Most of this population was eliminated when water pollution blocked adult migration in the early 1900s (McElhany et al. 2000). A small run of fall Chinook related to the historical population reestablished in the lower Clackamas River after the water quality issues were addressed, but the Abernethy Creek population has not returned (Huntington 2007). The focus of this section is on summarizing the status of coho, steelhead, resident trout, and other fish species in the watershed assessment area; fall Chinook salmon are not described because this population is not longer present in the system.

Native non-salmonid fish present in the watershed assessment area include two lamprey species, sculpins, and members of the minnow family (dace and shiners). Much less is known about the distribution and status of these non-salmonid fish species. Pacific lamprey are anadromous and brook lamprey are resident species. Because a serious decline in abundance has been noticed since the 1950s, both lampreys are listed as Oregon State sensitive species (Kostow 2002).

In addition to native fish, fish species that are not native to Abernethy Creek, Beaver Creek, or other Pacific Northwest streams are probably present in the watershed assessment area. There are no recorded observations of non-native fish in the watershed assessment area; however, recorded observations in nearby Portland area streams indicate that these introduced fish are likely present in the system. A variety of nonnative fish, including largemouth bass, bluegill, pumpkinseed, and mosquito fish, have been observed in nearby Kellogg Creek (StreamNet 2010). Nonnative fish are a concern because they occupy habitats inhabited by native species, can prey upon juvenile trout and salmon, and are an indication of degraded habitat conditions, including elevated water temperatures (Waite et al. 2008).

Beaver Creek is above Willamette Falls. Because the falls historically blocked some fish runs, the Beaver Creek subwatershed is part of the upper Willamette River fish populations, including distinct salmon and steelhead runs. The Beaver Creek subwatershed contains resident cutthroat trout and, as discussed in the "Fish Passage" section, below, may now be accessible to Upper Willamette River steelhead. Steelhead from the upper Willamette River are genetically distinct from those in the lower river. Reproductive isolation from lower river populations may have been facilitated by Willamette Falls, which is known to be a migration barrier to some anadromous fish. For example, winter steelhead and spring Chinook salmon occurred historically above the falls, but summer steelhead, fall Chinook salmon, and coho salmon did not.

The Abernethy Creek coho and steelhead are part of lower Willamette River and Columbia River populations, all of which are listed as threatened under the federal Endangered Species Act (ESA). Coho in the lower Willamette River are part of the lower Columbia River coho evolutionarily significant unit (ESU); steelhead are part of the lower Columbia River steelhead distinct population segment (DPS). Critical habitat for these fish has been designated and includes the Willamette River, but has not been designated for Abernethy Creek or Beaver Creek.

Sustainable populations of lower Columbia River coho, fall Chinook, and steelhead exist in the nearby Clackamas River. Coho and steelhead are still present in Abernethy Creek and its tributaries, but they are not considered to be self-sustaining and are probably supported to a large degree by the more productive populations in the Clackamas River.

Fish that spawn in Abernethy Creek contribute to the lower Willamette River coho and steelhead population complexes. It is the collective array of river and tributary stream habitats across the lower Willamette River that supports the health of the salmon and steelhead populations. The quantity, quality, diversity, and distribution of habitats in the river and tributary streams contribute to the overall abundance and productivity of the steelhead and salmon population complex. Some areas such as the upper Clackamas River may contribute more strongly to population abundance; whereas the urban tributary streams, including Abernethy, Kellogg, Tryon, and Johnson creeks, all contribute habitats that increase the spatial diversity of the population.

Coho Salmon

Coho salmon occupy about 26 miles of Abernethy Creek and tributary streams as migration corridors or juvenile rearing habitat (Figure 28). The Abernethy Creek coho population follows the standard lower Columbia River life history pattern. In Abernethy Creek, coho likely move upstream into spawning areas from mid-October through the end of January and die after spawning (Huntington 2007). Coho generally spawn in small, lower-gradient stream reaches (Lestelle 2007). No comprehensive data exist on where coho spawn in the Abernethy Creek subwatershed, but spawning areas appear to include Abernethy Creek upstream of Holcomb Creek, and tributary streams that offer cool water temperatures and appropriate habitat—Newell, Holcomb, Potter, Thimble, Martin, and Root creeks (Sanders pers. Comm.).

Juvenile coho rear in Abernethy Creek in areas of better habitat quality and cooler water temperatures for about a year before migrating to the Pacific Ocean as smolts during late winter or spring of their second year of life (Lestelle 2007). Juvenile coho favor relatively slow-moving water such as pools downstream of riffles. High quality juvenile coho rearing habitat includes cover, large wood, water temperatures of less than 64°F, and high dissolved oxygen levels. There are no comprehensive inventories of juvenile coho rearing areas, but they appear to be occupying the tributary streams that have cooler water temperatures and higher quality habitat. Juvenile coho have been observed in Newell, Holcomb, and Potter creeks (Sanders pers. comm.; Adolfson Associates 2000).

Little information exists on Abernethy Creek coho abundance or trends, but it appears that they are below historical population levels (Huntington 2007). Willamette River and Columbia River coho populations have declined overall; factors contributing to population declines include spawning and rearing habitat loss, fish passage barriers, altered streamflow regimes, water quality, and negative impacts from hatchery fish (Weitkamp et al. 1996).

Winter Steelhead

Abernethy Creek supports a small run of winter steelhead trout (Huntington 2007). The extent of steelhead habitat in Abernethy Creek subwatershed roughly overlaps coho habitat; about 26 miles of Abernethy Creek and tributary streams are occupied as migration corridors or juvenile rearing habitat (Figure 28).

Adult winter steelhead enter Abernethy Creek from mid-November through May, with the heaviest entry occuring from mid-January through April (Huntington 2007). Steelhead spawn in upstream areas and tributaries from February through June, and emerge from the spawning areas as fry during spring and early summer.

Juvenile steelhead rear in Abernethy Creek in areas of better habitat quality and cooler water temperatures for 1 to 2 years before migrating to the Pacific Ocean as smolts in the late winter, spring, or early summer (Oregon Department of Fish and Wildlife 2003). No comprehensive inventories of juvenile steelhead rearing areas are available; however, rearing juveniles appear to be occupying the tributary streams that have cooler water temperatures and higher quality habitat. Juvenile steelhead have been observed in Newell, Holcomb, and Potter creeks (Sanders pers. comm.; Adolfson Associates 2000).

Very little information is available on the status of the Abernethy Creek steelhead population, but all lower Willamette River and Columbia River steelhead populations are known to be in serious decline. Factors contributing to steelhead population declines include habitat loss, fish passage barriers, altered streamflow regimes, water quality, and negative impacts from hatchery fish (Busby et al. 1996).

Cutthroat Trout

Cutthroat trout have the widest distribution of any fish in the watershed assessment area, and are found throughout the Abernethy Creek and Beaver Creek subwatersheds (Figure 28). Juvenile and adult resident cutthroat trout can reside in tributary streams, with gradients of up to 12%, often in very small streams above the distribution of coho and steelhead (Figure 28). Two life history patterns are native to the watershed assessment area: a fluvial population that migrate Willamette River or Columbia River estuary into small streams to spawn and resident populations that occupy small streams throughout the watershed assessment area and are the dominant species in small headwater tributaries. A fluvial cutthroat trout population is known to exist in the lower Willamette River, but it is not known if this life history is present in Abernethy Creek (Johnson et al. 1999).

Resident cutthroat trout often grow, mature, and spawn very close to the location from which they hatched; these fish will move up and down the stream system for spawning and to escape warm water temperatures in the summer and into seasonal streams to escape high flows in the winter. Cutthroat trout spawn in the spring in small headwater streams with abundant gravels that are free from sediments. Cutthroat trout spawning habitat requires connected habitats that are free from fish passage barriers. Adult and juvenile cutthroat trout require cool water temperatures, usually less than 64°F, and high dissolved oxygen levels; habitat needs include abundant pools, complex cover from logs and undercut banks, and shade from riparian vegetation.

Very few systematic studies of cutthroat trout population trends have been conducted for lower Willamette tributary streams. Resident cutthroat trout are likely lower in abundance due to spawning and rearing habitat loss and fish passage barriers (Johnson et al. 1999). Cutthroat trout habitat loss is especially pronounced in the Portland area streams that have experienced urbanization and other development.

Lamprey and Other Fish Species

Non-salmonid fish species found in the watershed assessment area include Pacific and brook lamprey, sculpins, dace, and shiners. The status of Willamette River basin lamprey has been studied, but very little information is available on sculpins, dace, or shiner distribution or population status. All of these species have been observed in Newell Creek, a tributary to lower Abernethy Creek, but there are no other observations in this subwatershed (Adolfson Associates 2000). No information is available on the presence or distribution of lamprey, sculpins, shiners, or dace in the Beaver Creek subwatershed; however, given the general distribution of these species in the Willamette Basin, they are almost certainly present.

Two species of lamprey are distributed above and below Willamette Falls, and are present in the watershed assessment area. The Pacific lamprey is a large, anadromous species that has received the most research and management attention. The western brook lamprey is smaller and resides in small streams throughout all life stages (i.e., nonanadromous). No systematic inventories of lamprey distribution and abundance have been conducted for the watershed assessment area. Most observations of lamprey have been incidental observations during electrofishing surveys, stream habitat inventories, spawning surveys, or incidental catches in smolt traps. Both Pacific and brook lamprey were observed in Newell Creek (Adolfson Associates 2000). No observations have been recorded in Beaver Creek, but populations are likely present.

While lamprey abundance has been declining, the Willamette Basin is probably the most important production area for Pacific lamprey in the Columbia River system (Kostow 2002). Lamprey abundance can vary dramatically from one stream to the next and from one year to the next. This variability in abundance is reflected in juveniles collected in smolt traps in 2001 on tributaries to the lower Clackamas River. Because it is very difficult to distinguish between juvenile brook and Pacific lamprey, they were not identified to species. In Kostow's Clackamas basin study, Clear Creek had extremely large numbers of juvenile lamprey (9,480), whereas far fewer were observed in Deep (173) and Eagle (101) creeks (Kostow 2002). Lamprey populations have been declining from as a result of the same factors affecting other fish species—habitat loss and restricted access to upstream areas. Instream barriers including road crossing culverts and other obstructions substantially restrict lamprey distribution. Evidence has shown that lamprey have difficulty passing above fish ladders (Kostow 2002).

Abernethy Creek: Fish Use and Habitat

Very little information is available on fish use and habitat in the Abernethy Creek subwatershed (Huntington 2007). Abernethy Creek is very similar to other urban streams in the Portland area, and information can be extrapolated from studies in other streams below Willamette Falls, including Kellogg, Tryon, and Johnson creeks. Some information exists on fish populations and habitat in the system, primarily from an inventory of Newell Creek and several other studies.

Limited field data on coho abundance for Abernethy Creek is consistent with the overall pattern of population declines noted above. Abernethy Creek coho spawning ground counts collected between 1949 and 2001 illustrates this declining trend, with peak counts during the 1950s. Spawning coho counts averaged 7 fish (range 0 to 30 fish), with the peak count in 1956, and no fish observed between 1973 and 2001 (ODFW 2010).

Based on a review of three ODEQ sampling sites (Mile 0.6 and Mile 7.8, and Tour Creek), Huntington (2007) noted that available data on stream channels suggest a general pattern in the lower Abernethy Creek watershed of habitat simplification, including limited deep pools with minimal large wood to create structure and cover, channel down-cutting, and localized bank instability (Table 6). Very few pieces of large wood are present in the channel, and accumulations of long, stable logs (key pieces), which help form pools and create hiding areas for fish, are almost nonexistent.

ODEQ data on the two sites confirm that the mainstem of Abernethy Creek is very low gradient, with few, relatively deep pools, averaging about 0.5 meter (approximately 1.5 feet) in depth. It appears that large sections of the channel are primarily glides (i.e., areas with generally uniform depth and flow with no surface turbulence, generally in reaches of less than 1% gradient) (Moore et al. 1997). Glides are distinguished from pools by their overall homogeneity, lack of logs and other structure, and low habitat complexity.

Fine sediments will accumulate in low-gradient, depositional channels like lower Abernethy Creek. It appears, however, that fine sediment deposition is higher than would be expected in an undisturbed stream. ODEQ documented at both sites that the channel substrate of Abernethy Creek is dominated by fine sediment deposition. For example, the substrate conditions documented at the upstream site (Mile 7.8) were characteristic of relatively poor habitat conditions for salmon and trout: 78% sand or finer substrates, and 52% of the substrate material finer than sand (e.g., silt and clay). Embeddedness, which is the extent (as an average percentage) that boulders, cobble, and gravel particles on the channel surface are buried by fine sediments, was very high—81% embedded in fine sediment.

In its current condition, it appears that lower Abernethy Creek does not provide high quality habitat for trout and salmon. Limitations on habitat include limited stable large wood, few complex pools, and high levels of streambed sedimentation. The lower portions of the Abernethy Creek serve primarily as a migratory corridor for juvenile and adult fish moving to areas upstream and between the mainstem and tributaries. It appears to provide some rearing habitat for juvenile trout and salmon from fall through spring when water temperatures are lower. The incised channel, limited complex pools, and minimal large wood constrain the quality of seasonal rearing habitat. The channel incision has reduced stream access to the floodplain during flood events. The limited quantities of large wood in the channel, particularly long pieces in complex accumulations, and minimal stream connection to the floodplain have severely degraded fish habitat quality.

While this description focuses on the Abernethy Creek, conditions in the lower Willamette and other tributaries strongly influence the performance of coho and steelhead in the watershed. For instance, habitat in the Willamette River provides rearing and migration habitat (Friesen 2005) that potentially augments habitat in Portland area tributary streams (McConnaha 2003). Other Portland area tributaries with known populations of these fish include Johnson, Tryon, and creeks, and the Clackamas River. These populations form an integrated complex that is connected by the Willamette River and genetically linked, because coho, steelhead, and Chinook stray from one tributary to another and occupy available habitat (ICF Jones & Stokes 2008).

Table 6. Stream Habitat Characteristics in the Abernethy Creek Subwatershed Surveyed by ODEQCharacteristic	Abernethy Creek	Abernethy Creek	Tour Creek
Location	Mile 0.6	Mile 7.8	Mile 06
Year of summer survey	2006	2004	2006
Surveyed length (m)	240	198	150
Channel slope (%)	<1%	<1%	3%
Mean channel incision (m)	2.0	0.5	0.8
Bankfull width/depth ratio	7.5	16.8	5.1
Bankfull width (m)	8.3	6.0	1.9
Mean stream width (m)	7.4	5.2	1.2
Mean stream depth (cm)	48	42	5
Percent sand and finer substrate	69%	78%	45%
Percent finer than sand substrate	56%	52%	29%
Percent substrate embeddedness	85%	81%	80%
Percent pool	4%	11%	10%
Number of pools per 100 m	0.83	2.02	5.33
Number of pools with residual depths > 100 cm, per 100 m	0.00	0.00	0.00
Number of pools with residual depths > 75 cm, per 100 m	0.42	0.51	0.00
Mean maximum residual pool depth (cm)	75	88	20
Percent slow-water habitat	100%	93%	51%
Percent cover: wood pieces	7%	9%	4%
Percent cover: total	45%	36%	31%
Wood pieces, per 100 m: all (>10cm diam., >1.5 m long)	41.7	9.0	17.3
Wood pieces, per 100 m: large (>60cm diam., >1.5 m long)	2.1	2.5	0.7
Wood pieces, per 100 m: key (>60cm diam., >15 m or 2 BFW long)	0.0	ND	0.7
Mean canopy cover: mid-channel (%)	83%	82%	98%
Mean canopy cover: near-bank (%)	92%	93%	99%
Mean riparian canopy cover: large (>30 cm dbh) trees (%)	38%	16%	33%
Mean riparian canopy cover: total (%)	51%	25%	36%

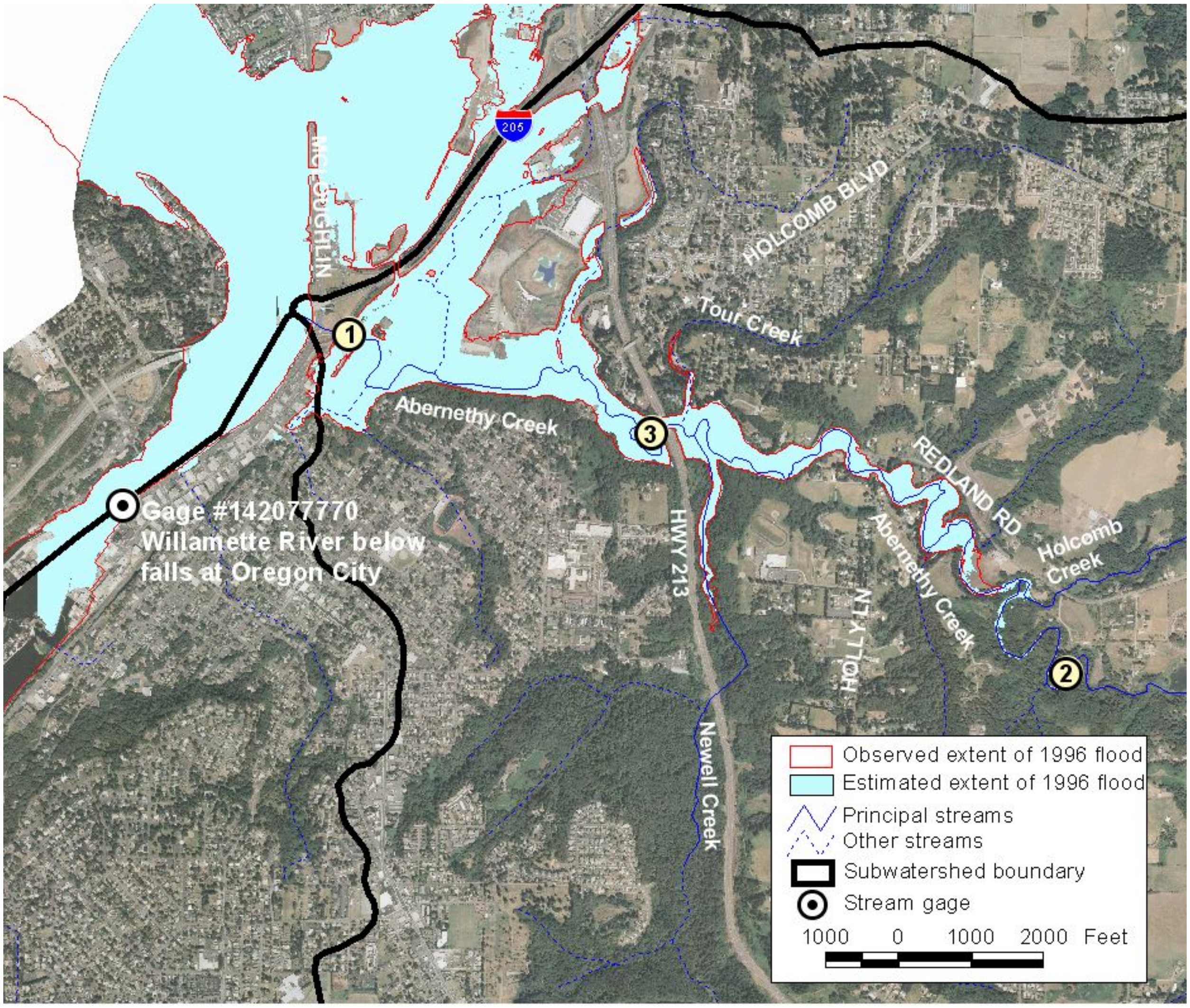
Source: Huntington 2007.
m = meter; cm = centimeter; BFW = bank full width; ND = no data reported;
dbh = diameter at breast height.

Backwatering in Abernethy Creek and Fish Use

The lower portions of Abernethy Creek are very low gradient (less than 1%), and stream levels are influenced by backwatering from the Willamette River during high river stages. This backwatering occurs during the late fall, winter, and spring, when the river's discharge is high and can be exaggerated by daily fluctuations in river levels associated with the tidal cycle.

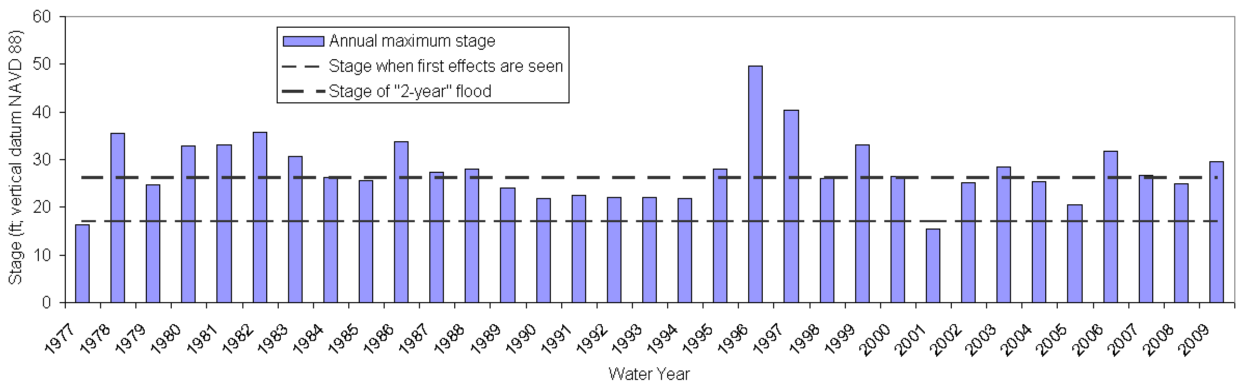
River flow gage data were used to evaluate how far the Willamette River backwaters up Abernethy Creek. The USGS gage (U.S. Geological Survey 2009) is located approximately 0.7 mile upstream of the confluence with Abernethy Creek (Figure 29). Annual maximum river stage values were extracted from the gage's data set (Figure 30).

Figure 29. Area of Inundation During February 9, 1996, Flood—Lower Abernethy Creek Area Showing Portions of Newell Creek and Holcomb Creek



Source: Metro 1996.

Figure 30. Annual Maximum Stage at USGS Gage #14207770, Willamette River Below Falls, Oregon City



The minimum flood stage that would produce a backwater effect in Abernethy Creek is estimated to be approximately 17 feet (Figure 30, lower dashed line). This corresponds with the upstream invert of the large culvert that conveys Abernethy Creek under Highway 99 (Figure 29, Point #1). Only two of the 32 annual maximum stage values in the period of record are lower than 17 feet in elevation (Figure 30), indicating that some backwatering occurs in lower Abernethy Creek almost every year.

The highest recorded stage value was on February 9, 1996. Metro acquired aerial photography during this flood event and created a GIS layer showing the maximum extent of flood inundation (Figure 29). The Metro data is aligned well with the calculated flood elevation at the USGS gage. Based on these data, it appears that the maximum extent of backwatering associated with the 1996 flood was slightly upstream of the Holcomb Creek confluence (Figure 29, Point #2).

The flood stage with an approximate recurrence interval of 2 years was estimated as the median value of the annual maximum stage values over the period of record. This is the elevation that, on average, is exceeded every other year. The estimated value for this 2-year recurrence flood stage is 26.25 feet (Figure 30, upper dashed line). The upstream extent associated with this flood stage is approximately the Highway 213 Bridge over Abernethy Creek (Figure 29, Point #3).

Off-channel areas include side channels and the lower portions of tributary streams. Juvenile steelhead and coho salmon spend relatively long periods of time in the lower Willamette River and use off-channel areas for feeding (Friesen 2005). Backwatering of Abernethy Creek during high flows adds to the limited availability of off-channel habitat in the lower Willamette River and contributes to the success of fish spawned in other areas of the Willamette River basin. While no sightings of juvenile coho or steelhead have been recorded from upstream populations in lower Abernethy creek, these fish have been observed in similar Portland area streams. For example, when fall and winter high-flow conditions permit movement through the Highway 43 culvert, juvenile coho and steelhead enter Tryon Creek from the Willamette River (ICF Jones & Stokes 2008).

The loss of shallow, complex, off-channel habitat is a major limiting factor for salmon in the lower Willamette River (McConnaha 2003). Restoration of urban streams, including Abernethy, Kellogg, Tryon, and Johnson creeks, is one of the few opportunities to improve this kind of habitat in the lower Willamette River (ICF Jones & Stokes 2008). Potential habitat improvements to the backwater areas in Abernethy Creek would contribute to the recovery of listed coho and steelhead by increasing the extent and diversity of productive stream habitats that flow into the lower Willamette River.

Abernethy Tributary Streams

Based on field reconnaissance, Huntington (2007) suggests that the tributaries to Abernethy Creek have better channel habitat conditions and water quality than the mainstem. Tour Creek, for example, has cooler summer temperatures than the mainstem and has cutthroat trout during the summer when they are absent from the sampled portions of Abernethy Creek (Huntington 2007). The following paragraphs describe the habitat and fish use in three important Abernethy Creek tributaries that contain coho salmon and steelhead—Newell, Holcomb, and Potter creeks.

Newell Creek begins on the Clackamas Community College campus and in headwater streams draining the eastern portions of Oregon City; it then flows over steep walls into the canyon area. Because much of Newell Creek is within a steep-sided, inaccessible canyon, the creek's habitats are in better condition than most urban streams. Metro has purchased nearly 300 acres of open space on both sides of the canyon, which provide some protection for the stream and riparian areas. With the Metro property and lands owned and managed by Oregon City and the Oregon Department of Transportation, Newell Creek watershed includes the largest intact forested natural area in the southern Portland metropolitan area (Metro 2009a).

Newell Creek supports significant native populations of fish, including coho salmon, cutthroat trout, and steelhead. Adolfson Associates (2000) surveyed habitat and sampled fish population for 90% of Newell Creek's length. The survey yielded a greater number and diversity of fish than expected (Table 7). All of the observed fish were native, including three species of salmonids: some juvenile coho, significant numbers of juvenile steelhead, and resident cutthroat trout. Riffle sculpins were the most abundant fish present. Redshide shiners and other members of the minnow family (dace and shiners) were observed along the entire length of stream. Brook and Pacific Lamprey were also found, with Pacific lamprey the most abundant and widely distributed of the two.

Table 7. Fish Species Observed in Newell Creek

Species	Total observed
Coho salmon	6
Rainbow trout (steelhead)	43
Cutthroat trout	48
Long-nose dace	2
Speckled dace	3
Redside shiner	56
Riffle sculpin	198
Reticulate sculpin	2
Pacific lamprey	14
Brook lamprey	2
Crawfish	6

Source: Adolfson Associates 2000.

The Newell Creek habitat assessment assigned ranked scores (poor, marginal, suboptimal, optimal) for the following in-channel and riparian habitat elements: pool substrate, pool variability, sediment deposition, channel flow, channel alteration, channel sinuosity, bank stability, vegetation protection on the banks, and width of the riparian zone (Adolfson Associates 2000).

The habitat assessment found that Newell Creek habitat, particularly in the middle portions of the stream, is in very good condition, with minimal alteration of the channel or riparian area. Sections of the stream have deep pools and large wood providing complex habitat and cover for fish. A series of beaver dams in the central canyon add habitat complexity and capture sediments and moderate high flows during storm events (John Inskeep Environmental Learning Center n.d.).While the canyon has been subject to logging in the past, portions of the stream with wide areas of intact riparian vegetation and mature trees remain. Trees include Douglas-fir, cedars, maple, alder, and cottonwoods. A large number of springs provide cool, high quality water to the stream, which is especially important during summer (John Inskeep Environmental Learning Center n.d.).

The assessment identified habitat quality issues for the lower and upper sections of Newell Creek. Sediment deposition, channel sinuosity, and riparian area width were noted to be marginal quality for the lowest segment of Newell Creek from its confluence with Abernethy Creek to the Highway 213 culvert. The upper sections of the stream have variable habitat quality, but portions of the stream have marginal habitat ratings for pool substrate, pool variability, channel sinuosity, and bank stability. The major issue for the upper portions of Newell Creek is sediment deposition, which was rated as "poor," based on the presence of heavy deposits of fine material covering more than 80% of the stream bottom. The *Newell Creek Watershed Restoration and Conservation Strategy* noted that 25% of the watershed is covered by impervious surface and concluded that stormwater flows from the headwaters within Oregon City contribute to the sediment deposition issue (John Inskeep Environmental Learning Center n.d.).

No detailed field inventories of fish habitat have been conducted for Abernethy Creek tributary streams. Based on limited field reconnaissance, portions of Holcomb Creek and Potter Creek contain high quality fish habitat. These observations are supported by fish presence information: coho and steelhead juveniles observed during snorkel surveys (Sanders pers. comm.). Sections of Holcomb and Potter creeks have abundant pools, logs in the channel, and wide riparian areas with trees and shade (Figure 31).

Limited field data on coho abundance for Holcomb Creek is consistent with high quality habitat but display the overall pattern of population declines, with peak coho counts in 1950 (27 fish) and no fish observed between 1973 and 2001(ODFW 2010). Surveys of juvenile coho in Holcomb Creek conducted between 1972 and 2002 demonstrated the same trend: some fish were observed in most years but in generally declining numbers, and no fish have been observed after 1991 (ODFW 2010).

Figure 31. An Example of High Quality Holcomb Creek Stream and Riparian Habitat

Beaver Creek: Fish Use and Habitat

The Beaver Creek subwatershed comprises more than 33 miles of fish-bearing streams. Currently, Beaver Creek's tributary streams are occupied by cutthroat trout and probably other native fish species (e.g., sculpins, dace, and shiners). The Beaver Creek subwatershed probably had historical runs of steelhead (Sanders pers. comm.). In about 1871, a grist mill and dam were constructed on lower Beaver Creek, approximately 1000 yards upstream from its confluence with the Willamette River (Dean pers. comm.). The dam created an impoundment, Sevick Pond, which backed up water in the area upstream and blocked fish access. Sevick Pond covered approximately 12 acres, and the area of standing water included the junction of Parrott and Beaver creeks.

In 1969, the grist mill dam washed out in a flood event and a new dam was constructed (Dean pers. comm.). The new dam did not provide fish passage. This dam remained in place until the January 2, 2009, flood. In this flood, Beaver Creek eroded the northern portion of dam, creating a channel that is passable to fish.

The Beaver Creek subwatershed is now accessible to steelhead and Pacific lamprey. Because steelhead will quickly move into new habitat, it is expected that that they will recolonize the system for spawning and juvenile rearing (Sanders pers. comm.). Unfortunately, because no information is available on fish habitat quality in the Beaver Creek subwatershed, it is not possible to predict the capability of the stream network to support steelhead or resident cutthroat trout populations.

Fish Passage Barriers

Fish passage barriers on Abernethy Creek, Beaver Creek, and tributary streams can pose a significant problem for fish populations. Dams and road crossing culverts are examples of fish passage barriers in the watershed assessment area. Fish move around the stream network through the different phases of their life cycle and in response to changing conditions. Fish passage barriers, prevent fish from accessing important areas for spawning or from moving into cool tributary streams when Abernethy Creek or Beaver Creek warm during the summer months.

Fish passage barriers can totally block fish movement during all times or they can partially block movement during periods of high or low flows. Partial fish passage barriers can significantly slow the migration of coho and steelhead through the system. Fish will often hold in pools at the base of a barrier waiting for conditions to change. This can delay migration and create problems such as stress on the fish, which provide opportunities for poaching and predation.

While fish passage is a concern, adult fish and juvenile fish are usually the most vulnerable to passage issues. In comparison to adults, small juvenile fish are the weaker swimmers and can be stopped by a stream channel drop of less than 6 inches. For this reason, most criteria for fish passage are designed to accommodate juveniles. For example, the guidelines for fish passage developed by ODFW specify that road-crossing culverts need to be installed at a gradient of less than 0.5% and have no more than a 6-inch drop at the outlet (Oregon Department of Fish and Wildlife 2010).

Dams

Dams, which are often constructed in streams to impound water for irrigation or recreation, can impede fish passage if fish ladders or other mechanisms are not in place. Several dams on Abernethy Creek may present obstacles to fish passage. The Hidden Lake water diversion dam just upstream from Holcomb Creek may be a fish passage barrier, but its status needs to be confirmed (Sanders pers. comm.). The Beaver Lake dam on upper Abernethy Creek has a fish ladder in place (Figure 32). Although fish passage at this ladder has not been studied, some evidence shows that it impedes adult coho and steelhead movement into spawning and rearing streams above the lake (Sanders pers. comm.).

Figure 32. Beaver Lake Fish Ladder on Upper Abernethy Creek

The Sevick Pond dam on lower Beaver Creek washed out in the January 2, 2009, flood event. Steelhead, lamprey, and other fish species can now move into the upper portions of the Beaver Creek subwatershed. Because Sevick Pond captured substantial sediments, the stream channel is now down-cutting through these sediments (Figure 33). As the stream erodes this large volume of sediment into the channel, a "headcut" in the deep sediments has developed. This headcut creates a steep fall over the sediments that could block upstream fish movement in the channel, but a field inventory would be necessary to confirm the ability of fish to pass through this area.

Figure 33. Sevick Pond Sediments in the Channel Beaver Creek after the Dam Washed out in the January 2, 2009, Flood

Road Crossings

Fish passage at many of the road crossings (primarily culverts) in the watershed assessment area have been evaluated using the ODFW criteria. Table 8 provides information on the fish passage status for 14 road crossings in the Abernethy Creek subwatershed and 13 road crossings in the Beaver Creek subwatershed. Most of the road crossings were inventoried by ODFW or Clackamas County, and their fish passage status is known. The road crossing inventory is comprehensive for Abernethy Creek subwatershed, but a number of crossings have not been assessed for fish passage (i.e., designated as unknown) in the Beaver Creek subwatershed; this is useful information for prioritizing future fish passage assessments.

In addition to the road crossings identified below in Table 8, ICF evaluated fish passage for the Abernethy Creek culvert under Highway 99. This culvert is important because it is the first obstacle that salmon and steelhead encounter upon entering Abernethy Creek. The culvert was examined on September 10, 2009. It is approximately 800 feet in length and 40 feet in diameter. The outlet, which is 150 feet upstream from the Willamette River, is tidally influenced. A series of six notched weirs in the culvert slow water velocities and create backwater areas behind the structures.

The evaluation of fish passage through the Highway 99 culvert is based on the culvert diameter, length, and gradient, the characteristics of the weirs, and flow conditions in Abernethy Creek. The weirs appear to provide some fish passage at lower flows, though the jump height exceeds the 6-inch ODFW fish passage criterion and may impede juvenile fish. Adult salmon and steelhead do pass through the culvert (Sanders pers. comm.), though they may have difficulty during very high flow conditions when water velocities exceed fish swimming abilities. This does not appear to severely limit upstream access, however, because fish have been observed.

Figure 1, Watershed Assessment Area Base Map, shows the location and fish status of road crossings in the Abernethy Creek and Beaver Creek subwatersheds. This information will aid in prioritizing culvert replacement to address fish passage. Clackamas County, for example, has improved fish passage in Holcomb Creek by replacing culverts with new structures that meet the ODFW fish passage criteria.

Table 8. Fish Passage Status and Location for Road Crossings in the Watershed Assessment Area

Subwatershed	Stream and Reach Location	Responsible for Inventory and ID Number	Fish Passage Status/Notes[1]
Abernethy			
	Holcomb 01a Holcomb 01b	County 01	Not a barrier
	Potter 02a Potter 02b	County 04	Barrier
	Holcomb 02 Holcomb 03	County 02	Not a barrier
	Holcomb 04a Holcomb 04b	County 03	Barrier
	Thimble 01a Thimble 01b	County 05	Barrier
	Thimble 02 Thimble 03	County 06	Barrier
	Abernethy Trib A 01a Abernethy Trib A 01b	County 07	Barrier
	Abernethy Trib B 01a Abernethy Trib B 01b	County 08	Not a barrier
	Abernethy Trib C 01a Abernethy Trib C 01b	County 09	Not a barrier
	Abernethy Trib C 03a Abernethy Trib C 03b	County 10	Barrier
	Root 02a Root 02b	County 11	Barrier
	Root 03a Root 03b	County 12	Barrier
	Root 03b Root 03C	County 13	Barrier
	Abernethy 16a Abernethy 16b	County 14	Barrier

Subwatershed	Stream and Reach Location	Responsible for Inventory and ID Number	Fish Passage Status/Notes[1]
Beaver			
	Parrott 05a Parrott 05b	ODFW 01	Not a barrier
	Cahill 01a Cahill 01b	County 15	Unknown
	Beaver 11a Beaver 11b	ODFW 02	Not a barrier
	Beaver Trib C 01a Beaver Trib C 01b	ODFW 06	Not a barrier
	Beaver Trib C Trib A 01a Beaver Trib C Trib A 01b	County 16	Unknown
	Beaver Trib D 01a Beaver Trib D 01b	ODFW 03	Not a barrier
	Beaver 15a Beaver 15b	ODFW 04	Not a barrier
	Beaver Trib E 01a Beaver Trib E 01b	County 17	Unknown
	Beaver Trib E 01b Beaver Trib E 01c	County 18	Unknown
	Beaver Trib F 01a Beaver Trib F 01b	County 19	Unknown
	Beaver 17a Beaver 17b	ODFW 05	Barrier
	Beaver 17b Beaver 17c	County 20	Unknown
	Beaver 17c Beaver 17d	County 21	Unknown

[1] The fish passage condition is known for road crossings that were inventoried by Clackamas County and ODFW. Figure 1 shows the locations and status.

Summary and Recommendations

Urbanization, roads, and other land uses have modified stream habitat, riparian vegetation, fish populations, and water quality in the watershed assessment area. Table 9 summarizes the watershed conditions and outlines restoration and other actions that can be taken to improve watershed health. The information in from this table and the watershed assessment provides the foundation for the *Greater Oregon City Watershed Council Restoration Action Plan*. This plan provides the GOCWC with a framework and a roadmap for implementing voluntary watershed restoration projects and landowner education.

Table 9. A Summary of Watershed Conditions and Actions That Will Improve Water Quality and Fish Habitat in the Watershed Assessment Area

Location	Condition Summary	Examples of Actions
Abernethy Creek Subwatershed	• Abernethy Creek and tributaries are important habitat for lower Willamette River populations of coho and steelhead and other native fish species • Water quality issues: temperature and sedimentation • Riparian vegetation composition is modified and the corridor is narrowed; weedy conditions in many areas • Fish passage barriers are present • Stream habitat is simplified with limited wood	• Remove riparian weeds, plant native vegetation, and expand width of corridor • Address fish passage barriers • Educate landowners on riparian area management and sediment-reduction actions
Lower Abernethy Creek	• Most of lower Abernethy Creek is within Oregon City • During flood events the Willamette River creates a backwater area in Abernethy Creek as far upstream as Holcomb Creek • Important migration corridor for coho, steelhead and lamprey • Winter rearing area for Willamette Basin salmon and steelhead populations during floods • Water quality issues: temperature, sedimentation, and stormwater • Riparian vegetation composition is modified and the corridor is narrowed; weedy conditions in many areas • The stream channel is incised and disconnected from the floodplain • Stream habitat is simplified with limited wood	• Remove riparian weeds, plant native vegetation, and expand width of corridor • Reconnect floodplain areas and add wood to the channel • Address stormwater issues in collaboration with Oregon City

Location	Condition Summary	Examples of Actions
Newell Creek	• The headwaters of Newell Creek are within Oregon City • Metro property in the watershed and focus area for protection and restoration • Important stream for coho, steelhead, and lamprey spawning and rearing • Water quality issues: sedimentation and storm water • The stream has cool water temperatures • Some riparian areas have riparian vegetation and weeds • Large portions of the stream have high quality fish and riparian habitat	• Work in collaboration with Metro on restoration actions • Field inventory riparian weeds, particularly knotweed • Remove riparian weeds, plant native vegetation, and expand width of corridor • In selected areas, improve channel complexity by adding wood • Address stormwater issues in collaboration with Oregon City • Monitor water temperature and other water quality conditions
Holcomb/Potter Creek	• Metro focus area for protection and restoration • Important stream for coho, steelhead, and lamprey spawning and rearing • Water quality conditions are unknown, but the stream may have cool water conditions • Some areas of degraded riparian vegetation and weeds • Large portions of the stream have high quality fish and riparian habitat, but some areas are degraded • Fish passage barriers at road crossings	• Remove riparian weeds, plant native vegetation, and expand the width of the corridor • Field inventory riparian weeds, particularly knotweed • In selected areas, improve channel complexity by adding wood • Monitor water temperatures • Address fish passage barriers
Upper Abernethy Creek	• Important stream for coho, steelhead, and lamprey spawning and rearing • Flooding is affecting floodplain landowner • Water quality issues: sedimentation and temperature are unknown • Some areas of degraded riparian vegetation and weeds • Riparian vegetation composition is modified and the corridor is narrowed; weedy conditions in many areas • Fish passage barriers are present • Unknown fish passage conditions at water diversion and Beaver Lake fish ladder • Stream habitat is simplified with limited wood	• Remove riparian weeds, plant native vegetation, and expand width of corridor • Field inventory riparian weeds, particularly knotweed • Address floodplain landowners and flooding through education and other actions • In selected areas, improve channel complexity by adding wood • Address fish passage barriers and study unknown barriers at dams

Location	Condition Summary	Examples of Actions
Oregon City Headwater Streams	• Headwater streams originate in Oregon City and flow into all three subwatersheds • Large area in impervious surfaces • Water quality issues: sedimentation and stormwater	• Remove riparian weeds, plant native vegetation, and expand width of corridor • Address stormwater issues in collaboration with Oregon City through education and actions that retain stormwater • Collaborate with Oregon City to monitor water quality conditions
Beaver Creek Subwatershed	• Beaver Creek, Parrott Creek, and tributaries are now accessible to steelhead and lamprey • Water quality issues: sedimentation; other conditions are unknown • Water withdrawals are probably reducing water flow during the late summer and early fall • Riparian vegetation composition is modified and the corridor is narrowed; weedy conditions in many areas • Fish passage barriers are present • Unknown fish passage conditions at many road crossings • Stream habitat conditions are unknown	• Remove riparian weeds, plant native vegetation, and expand width of corridor • Field inventory riparian weeds, particularly knotweed • Address fish passage barriers and study unknown barriers at road crossings • Educate landowners on riparian area management and sediment-reduction actions • Explore opportunities to increase water flows through voluntary actions
Beaver/Parrott Creek Confluence Area	• Sevick Dam washed out in the January 2, 2009, flood; upstream areas are now accessible to fish • A large quantity of sediment is exposed in the drained Sevick Pond area, which will become a weedy area • The channel is down-cutting through the sediments and may create fish passage issues	• In collaboration with the landowner, develop a plan to restore the drained Sevick pond area with native vegetation • Field inventory riparian weeds, particularly knotweed • Study the Sevick Pond sediment accumulation and develop a plan to control sedimentation and maintain fish passage

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Appendix A. Water Quality Data Sources, Criteria, and Stormwater Quality Summary

Table 1. Availability of Water Quality Data for the Assessment Watersheds

Sources	Application to the Watershed Assessment
Data	
DEQ LASER database: water chemistry	There is a variety of scattered single samples, mostly outdated. Only one station, #10873, is sampled consistently. **Station**: Abernathy Creek @ Highway 213, #10873, 3/2006 – 12/2006. (Oregon City)
DEQ LASER database: temperature data	One-half hour temperature data **Station**: Abernathy Creek near Atkinson Park, #33523, 7/10/2006 – 10/4/2006. (Oregon City). Limited field parameters: DO, pH, conductivity, turbidity
Oregon City Stormwater Monitoring Data (2007-2008)	Three monitoring events at 4 surface water sites. Monitored for 1 dry period and 2 rain events. **Stations**: 1. Abernathy Creek, 17082 Holly Ln., Site # OC019 2. Coffee Creek behind 415 McLoughlin Blvd., Site # OC021 3. Park Place Creek behind 13530 Redland Rd., Site # OC022 4. Singer Creek @ Singer Cr. Park, Site # OC023
Reports	
Oregon City, 2008. NPDES Municipal Stormwater Permit Annual Report.	The City of Oregon City Annual Stormwater Report summarizes stormwater plans, facilities, maintenance, erosion control plan and monitoring program.
DEQ 2006. Middle Willamette TMDL	The lower 15.5 river miles of Abernathy Creek is listed as water quality limited for Temperature during the summer. The TMDL addresses fecal coliform bacteria, DO, dieldrin, and copper/lead/zinc as pollutants in other Willamette basin watersheds, which flags these constituents as parameters of interest.
Carpenter, K.D. 2003. Water quality and algal conditions in the Clackamas River.	This report evaluated nutrient enrichment and water quality effects in the adjacent Clackamas River. This detailed study provides a good corollary for the assessment watersheds in regards to nutrient enrichment, algal conditions and land uses.
Carpenter and others, 2008. Pesticide occurrence and distribution in the lower Clackamas River basin.	The pesticide study identified the occurrence of pesticides and herbicides in the lower Clackamas River. The similarity in land use to Abernathy and Parrot Creeks provide a good indication of what pesticides to expect in these watersheds.
Waite and others, 2008. Effects of urbanization on stream ecosystems in the Willamette River basin and surrounding area.	This study evaluated effects of increasing urbanization on aquatic habitats and water quality throughout the Willamette River Basin. The study used a combination of land use, land cover, infrastructure and socioeconomic variables to measure urbanization. The study provides a good indication of what water quality conditions to expect in similar urban/rural streams.

Table 2. Water Quality Monitoring Stations

Source	Number	Description	Purpose
Abernathy Creek Watershed			
Agency	**Station Id.**	**Station Name and Location**	**Monitoring Purpose**
DEQ	33523	Abernathy Creek within Oregon City (45.362061,-122.592403)	temperature
Oregon City	OC019	Abernathy Creek at Holly Lane Bridge (45.359573,-122.571208)	above Oregon City limits
Oregon City	OC020	Abernathy Creek at Railroad Trestle (45.364088,-122.598437)	below Oregon City limits
Oregon City	OC022	Park Place Creek (at Abernathy Cr.) (45.362953,-122.587542)	high density residential
Oregon City	OC023	Singer Creek (in Singer Creek Park) (45.34751,-122.602108)	mixed use residential & commercial
Willamette Watershed			
Oregon City	OC021	Coffee Creek (outfall at Willamette R.) (45.347721,-122.623093)	mixed use residential & light industrial
Clackamas River Basin—for Reference			
DEQ	13070	Clackamas River at McIver Park	primarily forested

Table 3. Summary of Applicable Water Quality Criteria

Parameter (Beneficial Use)	Criteria
Dissolved Oxygen (Fish and aquatic life, salmonid spawning and rearing)	Salmonid Spawning: greater than 11.0 mg/L Cold Water Aquatic Life: greater than 8.0 mg/L.
pH and TDS (Fish and aquatic life, water contact recreation)	pH: 6.5 – 8.5 TDS: 100 mg/L
Nutrients (Aesthetics)	No State numeric criteria. Recommended EPA target (EPA 2001) Total Phosphorus: 0.04 mg/L Nitrates: 0.15 mg/L
Temperature (Fish and aquatic life, salmonid spawning and rearing)	Seven-day-average maximum temperature Salmonid and trout rearing and migration: 64.4°F (18°C) Salmon and steelhead spawning: 55.4°F (13° C)
Bacteria (Water contact recreation)	30-day log mean—126 colonies/100 ml Single sample—406/100 ml
Toxics (Fish and aquatic life)	Numeric criteria are identified for organic and inorganic toxic substances in Table 20 in the Oregon Water Quality Standards.
Metals (Fish and aquatic life)	Copper Acute Criteria: 4.6 µg/L Chronic Criteria: 3.5 µg/L Lead Acute Criteria: 13.9 µg/L Chronic Criteria: 3.2 µg/L Zinc Acute Criteria: 35.4 µg/L Chronic Criteria: 32.3 µg/L Note: Hardness dependent metals. 25 mg/L hardness used in calculation.

Table 4. Antecedent Rainfall Conditions for Oregon City Stormwater Monitoring as Measured at the Portland Weather Station

November 2007	Precipitation (inches)	December 2007	Precipitation (inches)	January 2008	Precipitation (inches)
21	0	13	0	2	0.61
22	0	14	0.01	3	0.21
23	0	15	0.02	4	0.21
24	0	16	0.10	5	0.22
25	0	17	0.10	6	0.14
26	0.24	18	0.17	7	0.05
27	**0.1**	**19**	**0.46**	**8**	**0.60**
7-Day Average	0.05		0.12		0.29

Table 5. Oregon City Stormwater Water Quality Descriptive Statistics Summary

	Abernathy Creek 1	Abernathy Creek 2	Coffee Creek	Park Place Creek	Singer Creek	Clackamas River McIver Park
Number	3	3	3	3	3	5
pH						
Min	7.26	7.24	7.1	7.1	6.92	7.2
Max	7.41	7.49	7.28	7.77	7.26	7.8
Mean	**7.32**	**7.34**	**7.17**	**7.33**	**7.05**	**7.6**
Total Dissolved Solids (mg/L)						
Min	48	48	15	65	37	33
Max	81	80	71	102	63	58
Mean	**63.67**	**60.00**	**34.00**	**86.00**	**46.33**	**46.20**
Total Suspended Solids (mg/L)						
Min	11	9	2	9	7	1
Max	116	25	31	72	30	11
Mean	**61.00**	**17.67**	**17.00**	**33.00**	**20.33**	**4.0**
E. Coliform Bacteria (count/100 ml)						
Min	16	124	276	166	61	1
Max	186	291	1120	276	435	8
Mean	**124.67**	**216.00**	**838.67**	**230.67**	**190.33**	**3.00**
Ortho Phosphorus (mg/L)						
Min	0.03	0.04	0.02	0.04	0.01	0.01
Max	0.11	0.29	0.03	0.06	0.03	0.01
Mean	**0.06**	**0.16**	**0.02**	**0.05**	**0.02**	**0.01**
Nitrates (mg/L)						
Min	0.66	1.18	0.48	0.80	1.45	0.01
Max	1.27	1.24	2.58	1.38	2.63	0.04
Mean	**1.01**	**1.21**	**1.69**	**1.03**	**2.07**	**0.02**