Prepared for

Clackamas River Water Providers
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Source Water Assessment Plan

National Water Quality Initiative, NRCS, USDA

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ALB	Aquatic-Life Benchmarks
BLM	Bureau of Land Management
BMP	Best Management Practice
BOD	Biological Oxygen Demand
CAFO	Confined Animal Feeding Operation
CRBC	Clackamas River Basin Council
CRP	Conservation Reserve Program
CRW	Clackamas River Water
CRWP	Clackamas River Water Providers
CSWCD	Clackamas Soil and Water Conservation District
DIN	Dissolved Inorganic Nitrogen
DEQ	Department of Environmental Quality
DO	Dissolved Oxygen
DWPP	Drinking Water Protection Plan
EE	Environmental Evaluation
EMC	Event Mean Concentration
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
ETART	Erosion Threat Assessment and Reduction Team
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
IGDO	Inter-Gravel Dissolved Oxygen
K_{OC}	Organic Carbon-Water Partition Coefficient
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MGD	Million Gallons per Day
N	Nitrogen
NCCWC	North Clackamas County Water Commission
NEPA	National Environmental Policy Act
NH_4^+	Ammonium
NH_3	Ammonia
NLCD	National Land Cover Data
NO_3^-	Nitrate Nitrogen
NRCS	Natural Resources Conservation Service
NWQI	National Water Quality Initiative
OAN	Oregon Association of Nurseries
O&C Lands	Oregon and California Lands
ODA	Oregon Department of Agriculture

OSU	Oregon State University
OWEB	Oregon Watershed Enhancement Board
P	Phosphorus
PFAS	Per- and Polyfluoroalkyl Substances
PGE	Portland General Electric Company
PLM	Pollutant Load Model
PRMS	Precipitation Runoff Modeling System
PSP	Pesticide Stewardship Partnership
PTI	Pesticide Toxicity Index
RLIS	Regional Land Information System
RMU	River Mill Unregulated
SIA	Strategic Implementation Area
SFWB	South Fork Water Board
SRP	Soluble Reactive Phosphorous
SWAP	Source Water Assessment Plan
SWE	Snow Water Equivalence
SWMM	Stormwater Management Model
SWP Area	Source Water Protection Area
TDG	Total Dissolved Gas
THM	Trihalomethanes
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
USDA	United States Department of Agriculture
USFS	United State Forest Service
WUI	Wildland Urban Interface

EXECUTIVE SUMMARY

This Source Water Assessment Plan (Plan) for the Clackamas River was commissioned by the Clackamas River Water Providers, a coalition of the municipal water providers that source drinking water from the Clackamas River. The Plan was funded by a grant from the Natural Resources Conservation Service (NRCS) National Water Quality Initiative (NWQI). The purpose of the Plan is to further source water protection and agricultural conservation efforts within the Clackamas Basin to benefit water quality and protect the Clackamas River as a drinking water source. The CRWP relies on the high water quality of the Clackamas River to reduce risks to drinking water treatment processes and finished water quality.

The Plan includes a detailed watershed assessment, a description of recommended actions and agricultural practices to improve water quality, and strategies for outreach to agricultural producers. The intention is to prepare the area defined in the Plan for eligibility to receive federal Farm Bill funding. This additional funding is essential to implement the measures identified in the Plan and reduce agricultural impacts to source water quality.

The Plan focuses on a defined source water protection area (SWP Area) consisting of five key subbasins in the lower Clackamas River watershed. These subbasins consist primarily of agricultural, forested, and urban land. This area was selected as the focus of the Plan due to the agricultural risks present, as well as the close proximity to four drinking water intakes on the lower Clackamas River.

The Clackamas River drains approximately 940 square miles, flowing from its headwaters in the Cascade range to its confluence with the Willamette River near the cities of Gladstone and Oregon City, Oregon. The Clackamas River provides many benefits to surrounding communities, including drinking water, hydropower, fish habitat, and recreational opportunities.

Many factors influence water quality within the SWP Area, including community socioeconomic conditions, land use, climate, dams and wildfires. The majority of residents within the SWP Area do not benefit from the public drinking water utilities served by the downstream intakes, which may disincentivize landowners from implementing best management practices (BMPs) on their land to protect water quality downstream. However, the land uses in this area are highly agricultural, which introduces potential contaminants of concern to nearby waterways. Climate trends may influence water supply and water quality, such as by reducing summer baseflow and increasing frequency and intensity of winter storms. These trends may reduce dilution of contaminant concentrations in the summer and increase pollutant loads carried by stormwater runoff during storm events. Increased wildfire frequency is expected in this region due to the effects of climate change; fires within the Clackamas River basin have shown varying potential risks to drinking water quality depending on drinking water system facilities and operation. Dams along the mainstem of the Clackamas River upstream of the SWP Area may mitigate some risks from wildfires occurring in the upper part of the watershed, but drinking water facilities may be vulnerable to the impacts of fire that occur downstream of the dams, especially within the SWP

Area. While all of these factors are important considerations to managing source water quality, only land use presents actionable opportunities to improve water quality through the implementation of the NWQI Program.

Water quality concerns are closely related to specific land uses within the watershed, which in the SWP Area include a large percentage of forested and agricultural area, along with some developed urban area. The specific types of agriculture practiced within the SWP Area influence the types of pollutants entering waterways via surface water runoff. Pasture and hay, Christmas trees, nurseries and greenhouses, tree nuts, and seed and sod grass dominate agricultural landscapes. Common pesticide profiles for these specific crop types can be used to predict potential contaminants of concern that may occur in runoff, many of which have been observed in ambient surface water quality monitoring performed throughout the lower Clackamas River basin. The most prominent pesticides identified in historical studies of the Clackamas River and tributaries were Atrazine, Simazine, Glyphosate, Triclopyr, and 2,4-D (Carpenter et al., 2008). Several of these pesticides are applied to pasture and hay, which make up the vast majority of agricultural land in the SWP Area. Other pesticides of high concern such as Bifenthrin, Imidacloprid, and Simazine were detected during recent sampling efforts in North Fork Deep, Noyer, and Sieben Creeks (Kilders 2021). These pesticides are applied to both Christmas trees and nurseries, which are prominent crop types in drainages to waterways within the SWP Area.

Knowledge of the potential sources of contaminants can be combined with an understanding of the hydrology of the region to inform which areas might contribute most to water quality impairments downstream in the basin. Areas with high rainfall, relatively steep topography, and large amounts of impervious areas respond quickly to rainfall and are often highly turbid after storms (Carpenter, 2003). These types of events and hydrologic responses increase the potential transport of dissolved and sediment-bound contaminants to tributaries and the Clackamas River. Additionally, water quality in the lower Clackamas may be more sensitive to runoff from drainages with tributaries that empty directly into the SWP Area. Modeling has been performed to quantify these trends across the subbasins of the SWP Area, finding that the highest pollutant loads come from drainages to Lower Clear Creek, North Fork Deep Creek, small creeks along the lower mainstem of the Clackamas River, and the lower mainstem of the Clackamas River itself.

The goal of implementing this Plan is to reduce concentrations of pesticides, nutrients, and sediments in receiving waters stemming from agricultural sources to improve overall water quality at drinking water facility intakes. This can be achieved through increased partnerships with producers and agricultural communities, increased producer program participation, increased funding acquisition for project implementation, and an increase in impactful BMPs. To this end, numerous plans, management programs, and partnerships exist among local, state, and federal entities. Many of these are primarily based on information and outreach, with some provisions for financial and technical assistance. However, additional opportunities to support agricultural producers interested in BMPs to manage runoff of pesticides, nutrients, and other pollutants from their land are necessary to improve water quality concerns associated with agricultural land uses.

This Plan identified treatment opportunities targeted at crop types and land uses which are at highest risk of degrading water quality, whether from high acreage, high pollutant application rate, or proximity to water bodies. Effective BMPs were also identified including integrated pest management, organic farming, vegetated field buffers and filter strips, no-till practices, and cover crops.

Outreach to agricultural producers to encourage the adoption of such practices should consider the avenues through which producers already share information, the timing of outreach with respect to the seasonality of crops, the media through which information is shared, and the establishment or strengthening of strategic partnerships. Producers may be reached through existing groups and associations, or through targeted outreach, for example by mailing list. These and other strategies are discussed in the outreach plan included in the Plan.

The Plan concludes that there are many effective agricultural BMPs that may support solutions to the water quality concerns in the SWP Area. Specific BMPs exist at the intersection of feasibility of implementation by landowners in the basin, compatibility with high-priority crop types, and relevant treatment mechanisms for high-priority pesticides. The final parts of the Plan are dedicated to exploring these combinations to inform future implementation efforts.

1. INTRODUCTION

1.1. Background

The Clackamas River Water Providers (CRWP) is a coalition of the municipal water providers that draw their drinking water from the Clackamas River. Their purpose is to fund and coordinate efforts regarding source water protection and public outreach and education around watershed issues, drinking water, and water conservation with the aim of preserving the Clackamas River as a high-quality drinking water source and minimizing future drinking water treatment costs.

The organization is made up of representatives from Clackamas River Water, the City of Estacada, the City of Lake Oswego, the City of Tigard, the North Clackamas County Water Commission (City of Gladstone and Oak Lodge Water Services), South Fork Water Board (Oregon City and West Linn), and Sunrise Water Authority (Happy Valley and Damascus). Together these water providers serve more than 300,000 people with safe, affordable, and reliable drinking water.

Figure 1 shows the water providers included in the Clackamas River Water Providers.

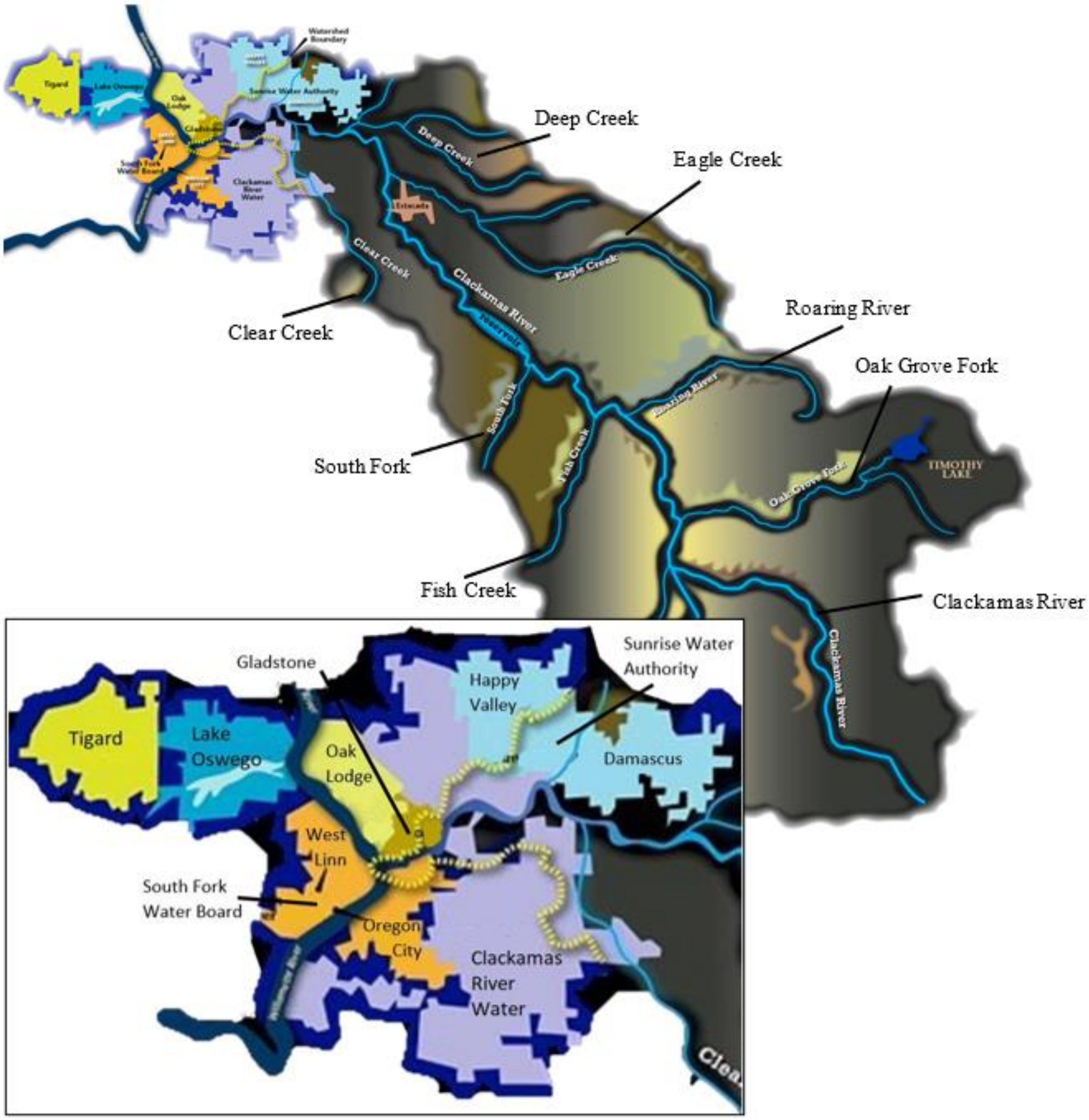

Figure 1. Water providers within the Clackamas River Water Providers. Adapted from figure at CRWP web address: https://www.clackamasproviders.org/.

The Clackamas River watershed can roughly be divided in half. Nearly all of the upper watershed is within the Mt. Hood National Forest and managed by the US Forest Service (USFS). By contrast, most of the lower watershed is in agricultural and densely populated areas. The middle watershed, area between Mt. Hood National Forest and the lower watershed, includes parcels owned by private timber companies, the Bureau of Land Management (BLM), and the USFS. In addition to being a drinking water source, the Clackamas River watershed supports naturally spawning anadromous fish, including Chinook and Coho salmon and steelhead trout. It also provides important habitat for many wildlife species, both game and non-game, supports recreational activities such as fishing, boating, and camping, and provides a hydropower supply for multiple utilities.

This Source Water Assessment Plan (SWAP or Plan) focuses on the US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) and CRWP designated Source Water Protection (SWP) Area, which consists of five key subbasins in the lower Clackamas River watershed (**Figure 2**). These subbasins were selected due to their immediate proximity to CRWP drinking water intakes and the density of agricultural activities in these subbasins compared to the upper reaches of the watershed. The predominant land use in the SWP Area is agriculture, which offers opportunities to improve source water quality through voluntary partnerships with local producers implementing best management practices (BMPs) to reduce pollutant loads to the Clackamas River.

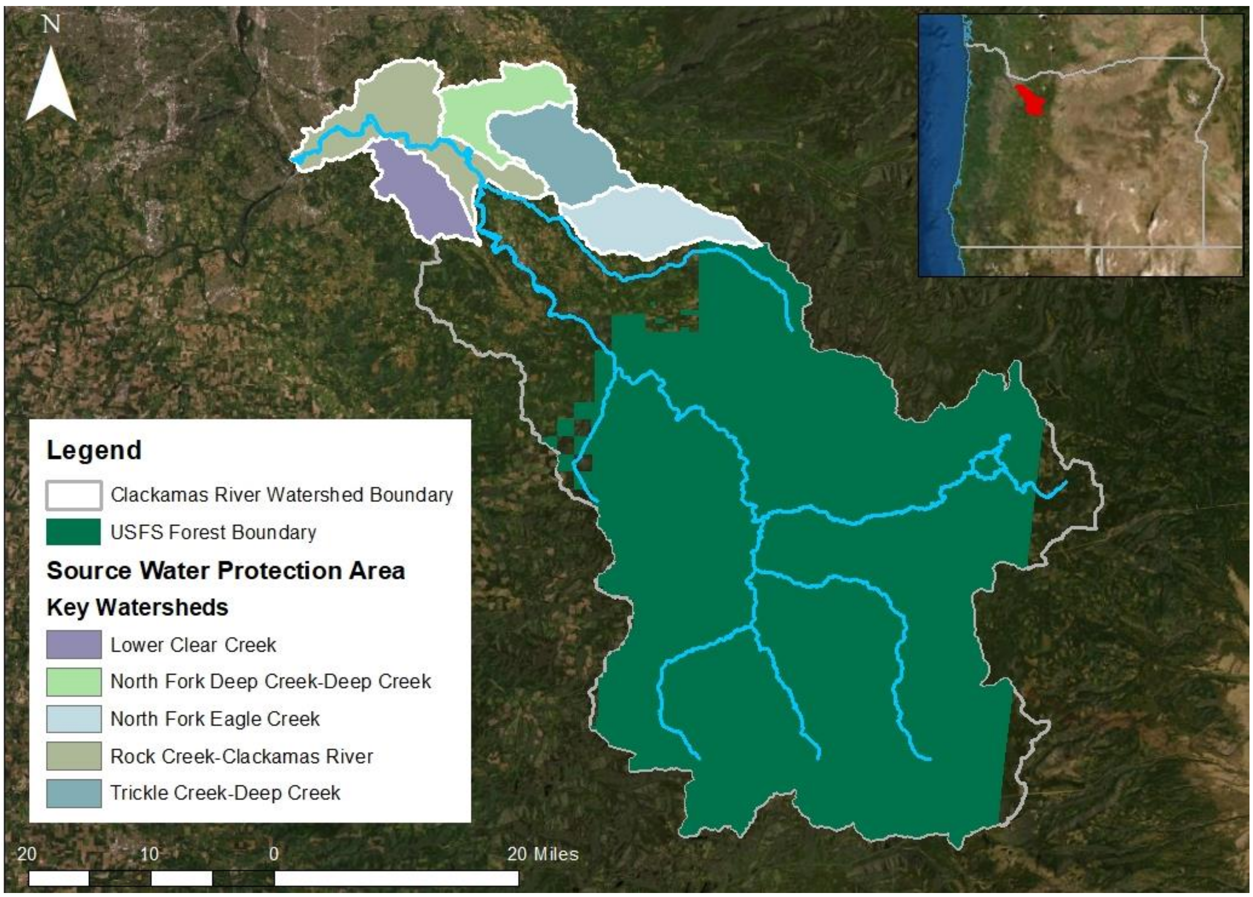

Figure 2. Key subbasins in the source water protection area (SWP Area) of the Clackamas River watershed.

1.2. Purpose and Function of the Plan

This Plan development is funded by a grant from the NRCS National Water Quality Initiative (NWQI) and includes a detailed watershed assessment, a description of recommended actions and

BMPs to improve water quality, and an outreach strategy to agricultural producers that will result in the completion of the NRCS "readiness phase" (or "planning phase"). Following this NRCS "readiness phase", the defined area is eligible to receive federal Farm Bill funding to implement the identified measures specific to agricultural impacts (known as the "implementation phase").

The purpose of this SWAP is to further the source water protection and agricultural conservation program work (by NRCS and others) completed up to now, building on the Drinking Water Protection Plan (CRWP, 2010) and other efforts undertaken by CRWP, to meet the requirements of the NRCS NWQI Program. For the SWP Area, the Plan will:

- characterize watershed and source area conditions;
- identify contaminates and resources of concern;
- assess BMPs and conservation approaches for protecting the SWP Area;
- document implementation goals and objectives;
- describe effectiveness monitoring approaches; and
- outline targeted outreach strategies for working with agricultural producers to protect water quality.

1.3. CRWP Drinking Water Protection Plan

In 2007, CRWP was created by Intergovernmental Agreement of the coalition of the water providers in the Clackamas River watershed. In 2010, CRWP adopted a Drinking Water Protection Plan (DWPP) that offered a comprehensive roadmap for source water protection to address identified threats to the drinking water systems. At present, CRWP continues to follow its established roadmap, considering the SWAP to be a more focused way post along the route mapped by previous planning effort. The DWPP identified three primary goals for establishing a source water protection program for the Clackamas River. They remain relevant today. They are to:

- identify, prevent, minimize and mitigate activities that have known or potentially harmful impacts on drinking water quality so that the Clackamas River can be preserved as a high-quality drinking water source that meets human future needs and minimizes drinking water treatment costs;
- identify climate mitigation and adaption strategies that will help ensure a more resilient watershed and drinking water source; and
- promote public awareness and stewardship of healthy watershed ecology in collaboration with other stakeholders.

The purpose of the DWPP was to formulate a strategy to preserve the Clackamas River as a high-quality drinking water source and to minimize future drinking water treatment costs by addressing the threats to source water quality and the long-term viability of the Clackamas River as a drinking water source. The strategy included nine elements, as follows.

1. Basin Analysis: Studies, GIS, Modeling and Water Quality Monitoring Subprogram. The objective of this program is to better understand the Clackamas River watershed and the potential drinking water threats, the Clackamas River water providers need to have the ability to measure the balance between watershed health and human use over time and implement actions that maintain a healthy balance for production of exceptional water quality. This includes watershed studies, use of GIS to map land use and potential threats, pollutant load modeling, and maintaining a comprehensive water quality monitoring program.

2. Climate Change/Water Supply Subprogram. The objective of this program is to better understand how climate change may impact the future of the Clackamas River in terms of both water quality and water quantity. This include looking at climate adaptation strategies as well as water supply planning.

3. Education and Research Assistance Subprogram. The objective of this subprogram is to encourage and promote work with college students and professors on research issues related to watershed health, and protection of the Clackamas River as a valuable resource. Programs under this subprogram will also help to promote future professional interest in watershed topics.

4. Point Source Evaluation and Mitigation Subprogram. The objective of the point source subprogram is to inventory, track, evaluate, and monitor point sources (water quality and other permits) of potential pollution to understand these potential threats and work with regulatory agencies, facilities, and permittees to reduce these potential threats to drinking water.

5. Nonpoint Source Evaluation and Mitigation Subprogram. The objective of the nonpoint source subprogram is to inventory, track, evaluate, monitor, and identify ways to mitigate for nonpoint sources of potential pollution. Stormwater runoff from urban and rural areas, and from agricultural and forestry activities is the biggest contributor to nonpoint source pollution in the Clackamas watershed. Programs identified in this subprogram will identify ways to work with other stakeholders to reduce non-point source pollution.

6. Disaster Preparedness and Response Subprogram. The purpose of the disaster preparedness and response subprogram is for the CRWP to recognize and be prepared for events that may have a low probability of occurring, but if they happen may cause extensive problems for the CRWP member's drinking water source.

7. Public Outreach and Information Sharing Subprogram. The objective of the public outreach and information sharing subprogram is to widely disseminate data and information collected as part of the source protection program as well as information on how to conserve water to CRWP water customers, Clackamas River watershed residents, and other stakeholders through the CRWP

Public Outreach and Education Program. The overarching goal is for water customers, and the watershed community to help conserve and protect the water quality of the Clackamas River and be engaged in implementing this Plan.

8. Watershed Land Use Tracking and Management Subprogram. The objectives of the land use tracking and management subprogram are to gain a thorough understanding of current land use activities and zoning regulations in the watershed; to develop a mechanism for tracking land use activities; and, become an active participant in shaping land use and zoning policy in the watershed to protect the Clackamas River as a drinking water source.

9. Land Acquisition Subprogram. The objective of the land acquisition subprogram is to target critical properties in the Clackamas River watershed for purchase or conservation easement in order to protect the watershed over the long term as a high-quality source of drinking water.

As part of the DWPP implementation since 2010, CRWP has made great strides in identifying risks to the drinking water supply and implementing protective strategies. CRWP has moved forward with a number of initiatives designed to address high priority threats associated with urban expansion and stormwater runoff, increased floodplain development, septic systems, hazardous material use and spills, pesticide use, pollutant load modeling, GIS risk analysis, climate change impacts on baseflow, and loss of riparian forests; these are discussed in relevant sections of this SWAP.

This planning effort offers CRWP an opportunity to focus on threats and opportunities associated with the agricultural production in the SWP Area. While drinking water quality of the Clackamas River remains high at present, human activity and development within the watershed pose significant challenges for the long-term protection of this drinking water source. A thorough listing of completed activities is summarized in the publicly available CRWP Annual Reports (CRWP, 2021).

2. OVERVIEW OF THE SOURCE WATER PROTECTION AREA AND AT-RISK PUBLIC WATER SYSTEM

The Clackamas River watershed is located in Clackamas and Marion Counties, Oregon, southeast of the Portland metropolitan area. The Clackamas River is the last major tributary to the Willamette River, entering at approximately River Mile 25 downstream of Willamette Falls. The Clackamas River begins on the slopes of Olallie Butte, a High Cascade volcano, and flows about 83 miles from its headwaters to its confluence with the Willamette River near the cities of Gladstone and Oregon City, Oregon. The watershed begins at an elevation of approximately 6,000 feet and ends at 12 feet (NAVD88). In total, the Clackamas River watershed is made up of 16 subbasins, draining more than 940 square miles.

2.1. Beneficial Uses of the Clackamas River Watershed

In addition to serving as a drinking water source to more than 300,000 people, the Clackamas River watershed supports naturally spawning anadromous fish, including Chinook and Coho salmon and steelhead trout. It also provides important habitat for many wildlife species, both game and non-game, and supports recreational activities such as fishing, boating, and camping.

In 1988, Congress incorporated approximately 50 miles of the Clackamas River into the National Wild and Scenic Rivers System, and a segment of Eagle Creek was added in 2009 (**Figure 3**). In addition, four sections are also designated as State Scenic Waterways. The purpose of these designations is to preserve river segments with outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations. The designations generally provide the incidental benefit of protecting source water quality to water providers downstream.

The Clackamas River mainstem is also a source of clean energy; Portland General Electric (PGE) operates three hydroelectric dams on the Clackamas River mainstem. They are Faraday (just east of Estacada), River Mill (west of Estacada), and North Fork (upstream from Faraday). The three dams have adult fish passage facilities. In addition, Faraday and River Mill have juvenile fish passage facilities.

The Oak Grove Fork of the Clackamas River has two dams used for hydroelectric energy production: Harriet Lake (23 miles east of Estacada) and Timothy Lake. Frog Lake, an off stream forebay downstream of Harriet Lake, is also operated by PGE. These dams are located upstream of the SWP Area (**Figure 3**).

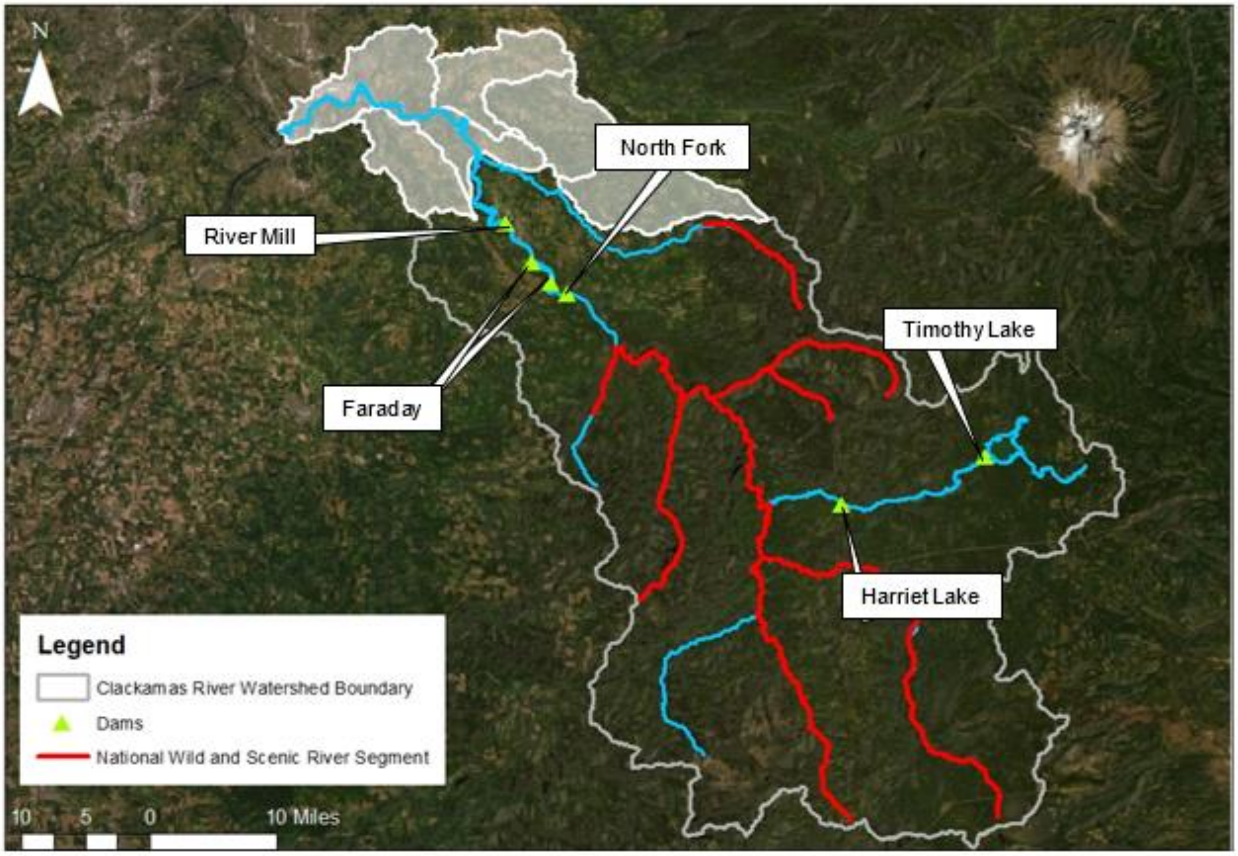

Figure 3. Clackamas River and tributary segments designated as National Wild and Scenic Waterways and hydroelectric dams in the Clackamas River watershed.

2.2. Source Water Protection Area

As stated previously, this Plan focuses on the SWP Area, which consists of five key subbasins in the lower Clackamas River watershed (**Figure 2**). The SWP Area drains nearly 140 square miles and include public and private land. The drainage areas of each subbasin in the SWP Area are defined in **Table 1.**

Table 1. Drainage area of key subbasins in the Clackamas River watershed, SWP Area.

Subbasin	Area (square miles)
North Fork Eagle Creek	27.9
Tickle Creek – Deep Creek	27.9
North Fork Deep Creek – Deep Creek	21.5
Lower Clear Creek	19.5
Rock Creek – Clackamas	42.7
Total	**139.5**

Portions of the Cities of Sandy, Gladstone, Oregon City, Happy Valley, and Damascus are located within the SWP Area. The City of Estacada is located upstream of the SWP Area. In addition, important transportation routes pass through the SWP Area, including State Highways 212, 213, and 224; US Highway 26; Interstate Highway 205; and the north-south mainline of the Union Pacific Railroad.

2.2.1. Land Ownership and Use

Overall, the watershed includes both public and private land with about 72 percent publicly owned, 3 percent tribally owned, and 25 percent privately owned (Oregon Department of Environmental Quality [DEQ], 2006). By contrast, the SWP Area, where the predominant land use is agriculture, is 5 percent publicly owned and 95 percent privately owned. Land ownership in the watershed is shown in **Figure 4**. Oregon and California Lands (O&C Lands) are administered by BLM and USFS and lie in a checkerboard pattern across several counties in Western Oregon. Originally dedicated to facilitating the completion of railroad lines along the coast, the O&C Lands now serve as dedicated timberlands offering multi-benefits, such as watershed protection, stream flow regulation, and recreational facilities.

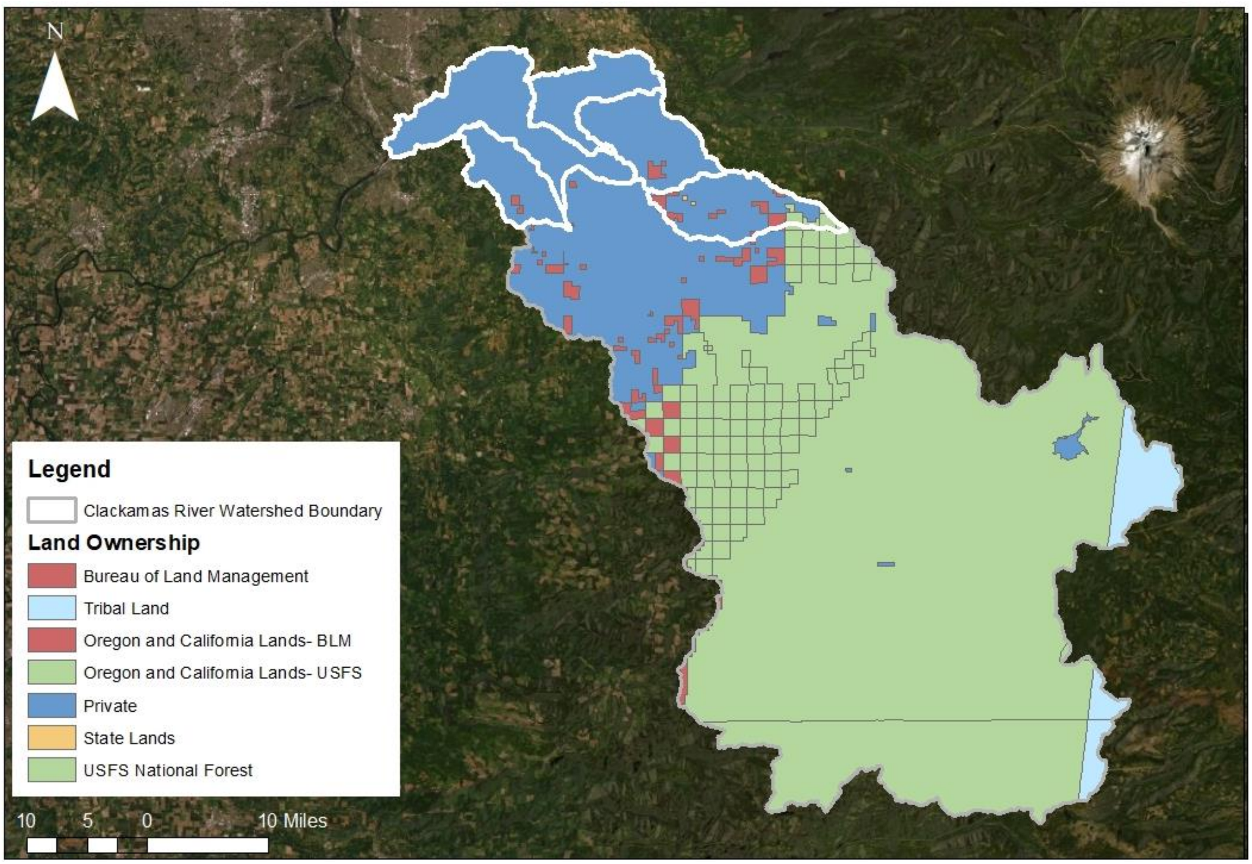

Figure 4. Land ownership within the Clackamas River watershed.

As noted previously and shown in **Figure 2**, the Clackamas River watershed can roughly be divided in half. Nearly all the upper watershed is within the Mt. Hood National Forest and managed by the USFS. By contrast, most of the lower watershed includes agricultural and densely populated areas. The area between the Mt. Hood National Forest and the lower watershed includes parcels owned by private timber companies, the BLM, and USFS (**Figure 2)**.

Land use in the lower watershed is comprised mostly of agricultural (41 percent) and forested (39 percent) uses, with some residential (5 percent), transportation (3 percent), commercial (2 percent), and open and public (9 percent) areas (**Figure 5**) (RLIS, 2021 and Schmidt, 2021).

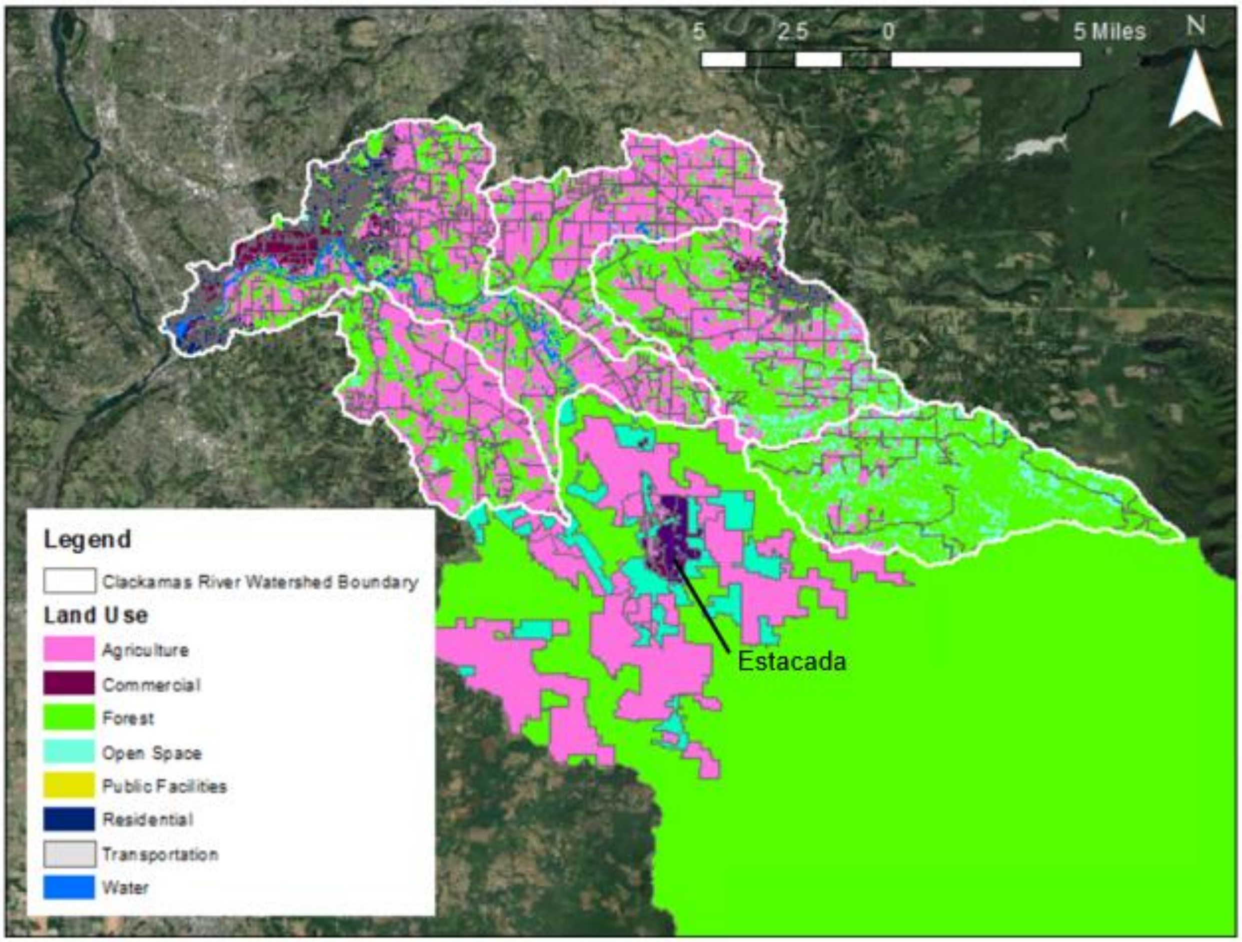

Figure 5. Land use in the SWP Area.

Agriculture in the SWP Area is dominated by pasture and hay, along with Christmas trees, seed and sod grasses, grapes, and other cultivated products in greenhouses and nurseries. The types of crops along with their percentage of acreage relative to the total agricultural acreage in the SWP Area are presented in **Table 2**.

Table 2. Agriculture by crop type in the SWP Area.

Crop Type	Percent of Agricultural Acreage
Pasture and Hay	85.9%
Christmas Trees	4.4%
Nurseries and Greenhouses	3.8%
Tree Nuts	1.7%
Other Hay	1.7%
Seed and Sod Grass	0.8%
Grapes	0.3%
Other	1.1%
Total	**100%**

Nurseries and greenhouses are vital to agriculture in Clackamas County, representing the largest single cluster in the county's agricultural sector. In 2017, there were over 270 nursery stock crop farms in Clackamas County (USDA, 2017). In 2019, greenhouse and nursery sales in the state of Oregon were valued at nearly 1 billion dollars (ODA, 2021), about 20 percent of which was produced by Clackamas County. Nursery and greenhouse crops include garden plants, cut flowers, aquatic plants, cuttings, flower and vegetable seeds, vegetable transplants for farm fields, sod, vegetables and herbs, berries, mushrooms, and Christmas trees (USDA, 2017).

Information regarding livestock operations was available for Clackamas County, within which nearly the entire Clackamas River watershed lies. According to the 2012 US Census of Agriculture (Vilsack and Clark, 2014), predominant livestock operations included equine, beef cow, and poultry farms. Also present to a lesser extent were goat, sheep, hog, llama, alpaca, bison, and milk cow farms. According to the Confined Animal Feeding Operation (CAFO) Program under the Oregon Department of Agriculture (ODA), there were eight CAFOs in Clackamas County in 2019 (DEQ, 2019).

Agricultural production in the Clackamas River watershed represents a significant portion of the agricultural sector in the state. Clackamas County consistently outperforms other counties in Oregon in the total numbers of farms, farm sales, and nursery sales. It is often the top producer in the state of commodities such as nursery and greenhouse production, poultry and eggs, horses and ponies, and bee colonies.

It should be noted that forestry is defined as activites on federal, state, county, and private forest land including fertilizer and herbicide use, clearcutting, pre-commercial and commercial thinning, burning, road construction, site preparation, and other harvest activities (Schmidt, 2021). Forestry land use does not include Christmas Trees, which are instead classified as agricultural (**Table 2**).

2.2.2. Population

More than 300,000 people are served by public water systems with source water originating from the overall Clackamas River watershed and the SWP Area. Most of the people served by the public water systems are not in the Clackamas River watershed. They make up residential bedroom communities on the edges of the larger Portland metropolitan area. In fact, some residents relying on this water are on the other side of the Willamette River from the Clackamas River watershed.

Meanwhile, many of the people in the SWP Area live in rural communities, on farms or ranches, and rely on local wells for water supply and septic systems for wastewater treatment.

In 2018, Clackamas County, Oregon had a population of 416,000 people with a median household income of $81,300, which represented a 1.75 percent increase over 2017 (Data USA, 2021). In 2019, the population had increased to 418,200 (Census Reporter, 2021). Because the median household income is reported county wide, the results may be skewed toward the higher-earning urban areas, and one could reasonably expect that household incomes in rural areas may be lower.

2.3. At-Risk Public Water Systems

The Clackamas River is a drinking water source for people in Clackamas and Washington counties and is identified in the Regional Water Supply Plan (Regional Water Providers Consortium, 2004) as a source to meet future water demand.

There are five municipal surface water intakes on the Clackamas River represented by the CRWP which serve a total of nine municipal water providers (**Figure 6**). The intakes serve:

- City of Estacada (not located within the SWP Area)
- Clackamas River Water District
- North Clackamas County Water Commission (Sunrise Water Authority, Oak Lodge Water District, and the City of Gladstone)
- South Fork Water Board (Oregon City and West Linn)
- City of Lake Oswego and City of Tigard

The municipal water systems are owned, operated, and maintained by these water providers and represent the public drinking water systems at risk from impaired source water quality in the Clackamas River watershed. The water supply systems are described in detail in the subsections below.

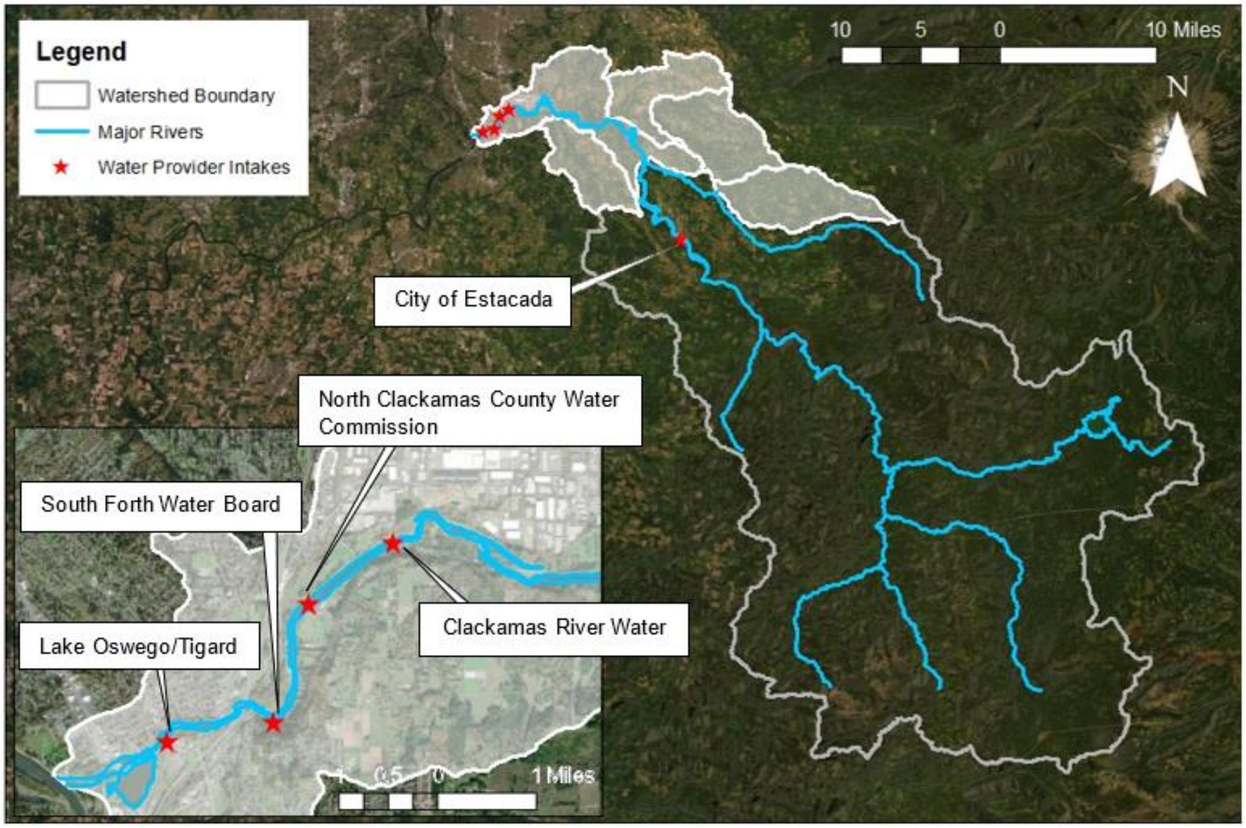

Figure 6. Surface water intakes to municipal water providers included in the Clackamas River Water Providers.

2.3.1. Clackamas River Water

The Clackamas River Water (CRW) district serves approximately 80,000 residents in unincorporated areas of Clackamas County, on the southeast fringes of the Portland metropolitan area. CRW has two service areas: The North Service Area and the South Service Area. The Clackamas (North) Service Area includes portions of Clackamas, Milwaukie, Happy Valley and Portland. Customers in the North Service Area receive water that is treated by CRW's water treatment plant.

Customers who live south of the Clackamas River are located in the Clairmont (South) Service Area and includes portions of Oregon City and unincorporated Clackamas County. These customers receive water that is treated by South Fork Water Board but serviced by CRW (CRW, 2021).

The CRW maintains approximately 260 miles of pipelines, 12 pumping stations, 15 reservoirs, and nearly 12,000 service connections. The following provides information pertaining to the raw water, treatment processes, and finished water quality of the CRW water treatment plant servicing their North Service Area; information regarding finished water quality for their South Service Area can be found in the in **Section 2.3.3** for South Fork Water Board.

The CRW water treatment plant is direct filtration plant. Raw water is drawn from the Clackamas River (see **Figure 6** for intake location) and screened for debris before it is lifted to the treatment facility. The water is disinfected and dosed with coagulants and then allowed to flocculate and settle in a contact basin. Finer particles are removed through a filter with layers of coal, silica sand, and granite sand. pH adjuster and disinfectant are added before water flows to a clear well, after which the water is pumped to the distribution network or a treated water reservoir system (CRW, 2021).

Annual water quality reports for the CRW filter plant show the facility produces water that consistently complies with state and federal Maximum Contaminant Levels (MCLs) for monitored contaminants and achieves maximum contaminant level goals (MCLGs) for most monitored contaminants.

2.3.2. North Clackamas County Water Commission

The North Clackamas County Water Commission (NCCWC) is owned by the City of Gladstone, Oak Lodge Water Service District and Sunrise Water Authority and provides drinking water to 75,000 citizens in those communities. Service areas include the City of Gladstone, Oak Grove community, Jennings Lodge community, Carver, Damascus, the City of Happy Valley, and unincorporated areas of Clackamas County along the Willamette River, with a total service area of over 34 square miles (CRWP, 2021).

Each organization is responsible for maintaining its own distribution infrastructure. The City of Gladstone maintains three reservoirs and over 40 miles of pipeline. Oak Lodge Water Services operates three pumping stations, four reservoirs, 700 fire hydrants, and 8,700 connections (CRWP, 2021). The Sunrise Water Authority maintains 240 miles of pipe, 16 pumping stations, 12 reservoirs, and over 10,000 connections. Each water provider draws some portion of water from the NCCWC water treatment plant; the Sunrise Water Authority also draws from six groundwater wells in Damascus during peak water use.

The NCCWC water treatment plant has a capacity of 20 million gallons per day (MGD). The plant has slow sand filtration and submerged membrane treatment technologies that may be used separately or in tandem depending on water quality needs and demand. Water is disinfected using chlorine, and soda ash is applied for corrosion control (CRWP, 2021).

Annual water quality reports for the NCCWC water treatment plant show that the facility produces water that consistently complies with state and federal MCL for monitored contaminants. Finished water also achieves MCLGs for monitored contaminants except disinfection by-products including haloacetic acids and trihalomethanes (THMs).

2.3.3. South Fork Water Board

The South Fork Water Board (SFWB), owned by the City of Oregon City and the City of West Linn, serves approximately 54,000 residents in the two cities. In addition, the South Fork Water Board serves CRW, its one wholesale customer (see **Section 2.3.1**). In total, the South Fork Water Board provides water for approximately 63,000 residents in Clackamas County (SFWB, 2021).

The South Fork Water Board operates the South Fork Water Board water treatment plant and maintains one pumping station. The South Forth Water Board Treatment Plant is conventional water treatment plant that treats up to 23 MGD. The intake is located just off of Clackamas River Road (see **Figure 6** for intake location). The treatment process includes flocculation via alum and polymer coagulants, sedimentation, filtration through sand and anthracite coal, pH adjustment and chlorination (SFWB, 2021).

Annual water quality reports show that the facility produces water that consistently complies with state and federal MCL for monitored contaminants. Finished water also achieves MCLGs for monitored contaminants except disinfection by-products including THMs and hardness.

2.3.4. Lake Oswego/Tigard

Since 2017, the Lake Oswego Tigard Water Partnership completed a joint effort to upgrade existing water infrastructure, resulting in the Lake Oswego/Tigard Intake and Water Treatment Plant which has conventional filtration plus ozone. The new treatment facility has a capacity of up to 38 MGD and serves 90,000 in the cities of Lake Oswego and Tigard. Raw water from the Clackamas River intake in Gladstone (see **Figure 6** for intake location) is dosed with alum coagulant and sand to induce flocculation and sedimentation. Settled water is then filtered through coal and silica sand to remove fine particles and microbes. pH adjuster and chlorine are added before water undergoes an ozone disinfection process and is released to the distribution network (Lake Oswego-Tigard Water Partnership, 2021).

Annual water quality reports for the Lake Oswego Tigard Water Treatment Plant show that finished water consistently complies with state and federal MCLs for monitored contaminants and achieves MCLGs. A single exceedance of bromate occurred in February 2019.

2.3.5. City of Estacada

The City of Estacada is not located within the SWP Area, but accounts for a population of about 3,000 served by a public water system (CRWP, 2021).

2.4. <u>Other Water Users in the Watershed</u>

In addition to the five municipal water systems described above, the Timber Lake Job Corp, not located in the SWP Area, has a small drinking water system using surface water diverted at Lake Harriet as an emergency source (DEQ, 2001).

Furthermore, there are over 300 private wells within the SWP Area, and over 400 private wells within the entire watershed, that pump groundwater for drinking water, irrigation, community, livestock, and industrial purposes (Oregon Water Resources Department, 2020).

2.5. Challenges Related to Source Water Quality

Source water quality in the Clackamas River directly impacts drinking water treatment facility operations and finished drinking water quality.

The lower reaches of the watershed experience higher sediment and nutrient loads—including nitrates, ammonia, and phosphorus—than the upper reaches of the watershed due to agricultural practices associated with the land use in the lower watershed. Higher nutrient loads can contribute to algal growth and diminish the water quality at water intakes downstream. Similarly, pesticides associated with agricultural land use and urban landscaping are more prevalent in the lower reaches of the watershed and may affect raw drinking water quality. The Clackamas Basin Pesticide Stewardship Partnership (PSP), a voluntary, collaborative process to protect the river and its tributaries, carries out water quality monitoring. Since 2000, they have detected pesticides in Clackamas River tributaries that exceed benchmarks to protect fish and invertebrates (Kilders and Cloutier, 2021).

Turbidity spikes, especially in the winter months due to a higher frequency of storm events in winter, impact the types of treatment technologies used in the public water systems. In recent years, several treatment plants (e.g., Clackamas River Water and the City of Lake Oswego) have added flocculation and sedimentation to their treatment processes in order to reduce loading to filters, to lengthen filter run times, and to improve finished water quality. Agricultural practices within the SWP Area may exacerbate erosion and require water treatment facilities to use more coagulant and/or backwash filters more frequently in order to maintain high finished water quality.

Disinfection byproducts such as haloacetic acids and trihalomethanes are created during the water disinfection process when chlorine reacts with organic matter. The public water systems discussed in this Plan achieve drinking water standards associated with disinfection byproducts. However, improved source water quality with respect to organics may improve this finished water quality metric.

2.6. Partnership Opportunities with the NRCS

The NRCS is well suited to provide resources and expertise to help the CRWP protect its source water during both in this readiness phase and the implementation phase. Specifically, the NRCS may:

- provide local, on-the-ground expertise on land use practices, issues, and appropriate BMP strategies;

- provide technical assistance and resources to increase the capacity of local partners to provide education and outreach to agricultural producers;

- support the goal of reducing levels of nutrients, sediments, and pesticides, and increasing riparian buffers through identification, prioritization, and implementation of best management practices to address agricultural contribution to these water quality threats;

- support local partners to leverage funding from multiple sources across local, state, and federal sectors to address threats to source water quality;

- support increased efficiency and effectiveness of established programs and partnerships through increased collaboration, communication, and knowledge sharing; and

- provide funding avenues to implement on-the-ground practices, as discussed in **Section 6**.

3. CHARACTERIZATION OF THE SOURCE WATER PROTECTION AREA

3.1. Source Water Protection Area, SWP Area

This Source Water Assessment Plan (SWAP or Plan) focuses on the US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) and Clackamas River Water Providers (CRWP) designated source water protection area (SWP Area), which consists of the five key subbasins in the lower Clackamas River watershed (**Figure 2**). These subbasins drain nearly 140 square miles of public and private land. Key characteristics of each subbasin are defined in **Table 3**.

Table 3: Characteristics of key subbasins in the Clackamas River watershed.

Subbasin	Percent Impervious Surface	Primary Land Use	Population Centers
North Fork Eagle Creek	0.48%	Forested (71%) Open Space (21%)	
Tickle Creek – Deep Creek	5.29%	Forested (42%) Agricultural (36%)	Sandy
North Fork Deep Creek – Deep Creek	7.14%	Agricultural (70%) Forested (22%)	Boring
Lower Clear Creek	3.71%	Agricultural (59%) Forested (34%)	Redland
Rock Creek – Clackamas	15.95%	Agricultural (43%) Forested (27%)	Clackamas Damascus Gladstone Oregon City Happy Valley

3.2. Socioeconomic Conditions

3.2.1. Potential Impact to the Source Water Protection Plan

The human landscape of the SWP Area is an indirect, but important consideration during the source water protection planning process. Socioeconomic conditions, population distribution, and general demographics both within the SWP Area and outside the SWP Area that rely on the water provided by the Clackamas River can inform the plan's approach to stakeholder outreach and engagement.

3.2.2. Population Characteristics in the SWP Area

As noted in **Section 2.2.2**, most of the population served by the public water systems do not live within the Clackamas River watershed. Those living within the SWP Area rely on local wells for domestic water supply. This has the possible effect of disincentivizing the ready adoption of BMPs within the basin.

3.3. Landscape and Land Use

3.3.1. Potential Impacts to the Source Water Protection Plan

Land use can significantly affect the quality of water that runs off from it, which in turn may affect water quality at downstream drinking water intakes. Geospatial land use data provides essential information to support source water protection strategies. The impacts of land use on the Plan include but are not limited to:

- types of pollutants that need to be addressed. This stems from the relative prevalence of various nutrients, chemicals, and other contaminants that run off from different land uses, including pesticides that may be used for different types of crops;
- types of BMPs employed to address contaminants of concern. These may vary by pollutant type and/or functional effectiveness of specific BMP types in different landscapes; and
- different strategies or recommendations employed between SWP Area subbasins depending on predominant land uses.

3.3.2. Land Use in the SWP Area

The predominant land use in the SWP Area subbasins is agriculture (**Table 4**), which offers opportunities to improve source water quality through voluntary partnerships with local producers implementing BMPs to reduce pollutant loads to the Clackamas River. These opportunities are also influenced by land ownership patterns. In the SWP Area subbasins, five percent of the land is publicly owned, and 95 percent is privately owned.

Land use in the SWP Area is comprised mostly of agricultural (41 percent) and forested (39 percent) uses, with some residential (4.6 percent), commercial (2.0 percent), and open and public (8.8 percent) areas (**Table 4**, **Figure 5**). Agriculture in the SWP Area is dominated by pasture and hay, nurseries and greenhouses, Christmas trees, tree nuts, and seed and sod grasses. Many other crops, including flowers, landscaping vegetation, berries, and botanicals, belong to the keystone nursery and greenhouse component of agriculture in the region. The types of crops along with their percentage relative to the total agricultural acreage in the key subbasins are presented in **Table 5**. Near the Clackamas River Water Provider intakes, the primary land uses include commercial and residential.

Table 4. Land use by subbasins and overall SWP Area.

Land Use	Basin					
	North Fork Eagle Creek	**Tickle Creek – Deep Creek**	**North Fork Deep Creek – Deep Creek**	**Lower Clear Creek**	**Rock Creek – Clackamas**	**SWP Area**
Agriculture	7.0%	36.3%	70.2%	59.5%	42.8%	40.9%
Commercial	0.0%	1.4%	0.0%	0.0%	5.6%	2.0%
Forested	71.3%	41.7%	22.1%	34.2%	26.7%	39.0%
Open Space	20.8%	13.8%	3.5%	3.2%	2.7%	8.7%
Public Facilities	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
Residential	0.0%	3.8%	0.0%	0.0%	12.5%	4.6%
Transportation	0.8%	2.5%	2.5%	1.8%	4.4%	2.6%
Wetland	0.1%	0.6%	1.7%	1.3%	5.2%	2.2%

Table 5. Agriculture by crop type in the SWP Area.

Crop Type	Percent of Agricultural Acreage
Pasture and Hay	85.9
Christmas Trees	4.4
Nurseries and Greenhouses	3.8
Tree Nuts	1.7
Other Hay	1.7
Seed and Sod Grass	0.8
Grapes	0.3
Other	1.1
Total	**100**

Portions of the cities of Sandy, Gladstone, Oregon City, Happy Valley, and Damascus are located within the SWP Area, and the City of Estacada is located upstream of the SWP Area. In addition, important transportation routes pass through the five key subbasins in the lower watershed, including State Highways 212, 213, and 224; US Highway 26; Interstate Highway 205; and the north-south mainline of the Union Pacific Railroad. Each of these transportation routes runs adjacent to the Clackamas River for some length. These and other local roads comprise from about 1% (North Fork Eagle Creek subbasin) to up to 4.4% (Rock Creek – Clackamas subbasin) of the land area in each subbasin.

3.4. Surface and Sub-Surface Water Flow

3.4.1. Potential Impact to the Source Water Protection Plan

The hydrology, geology, geomorphology, and hydrogeology of the Clackamas Basin within the SWP Area are integral to ascertaining the impact of potential degradation factors on source water quality. Key aspects of surface and sub-surface water flow that may inform the Plan include:

- connectivity of potentially contaminated runoff and groundwater to local drinking water wells and supply intakes; and

- seasonality of connected potentially contaminated runoff and groundwater.

The following sections include fundamental information about the hydrology, geology, geomorphology, and hydrogeology of the SWP Area relevant to these investigations.

3.4.2. Hydrology

The Clackamas River begins at its headwaters above Timothy Lake in the Cascade Mountain Range, and generally flows northwest. It ends at its confluence with the Willamette River in Oregon City. The segment of the mainstem Clackamas River that flows through the SWP Area begins downstream of the confluence with Eagle Creek (below River Mill Dam and the City of Estacada) and is a little over 15 miles long. The topography of the SWP Area subbasins is provided in **Figure 7**. As can be seen from this topography, the highest elevation SWP Area subbasin (North Fork Eagle Creek) feeds into the Clackamas River via Eagle Creek. The peak elevation in the SWP Area is in the North Fork Eagle Creek subbasin at approximately 3,000 feet (NAVD88).

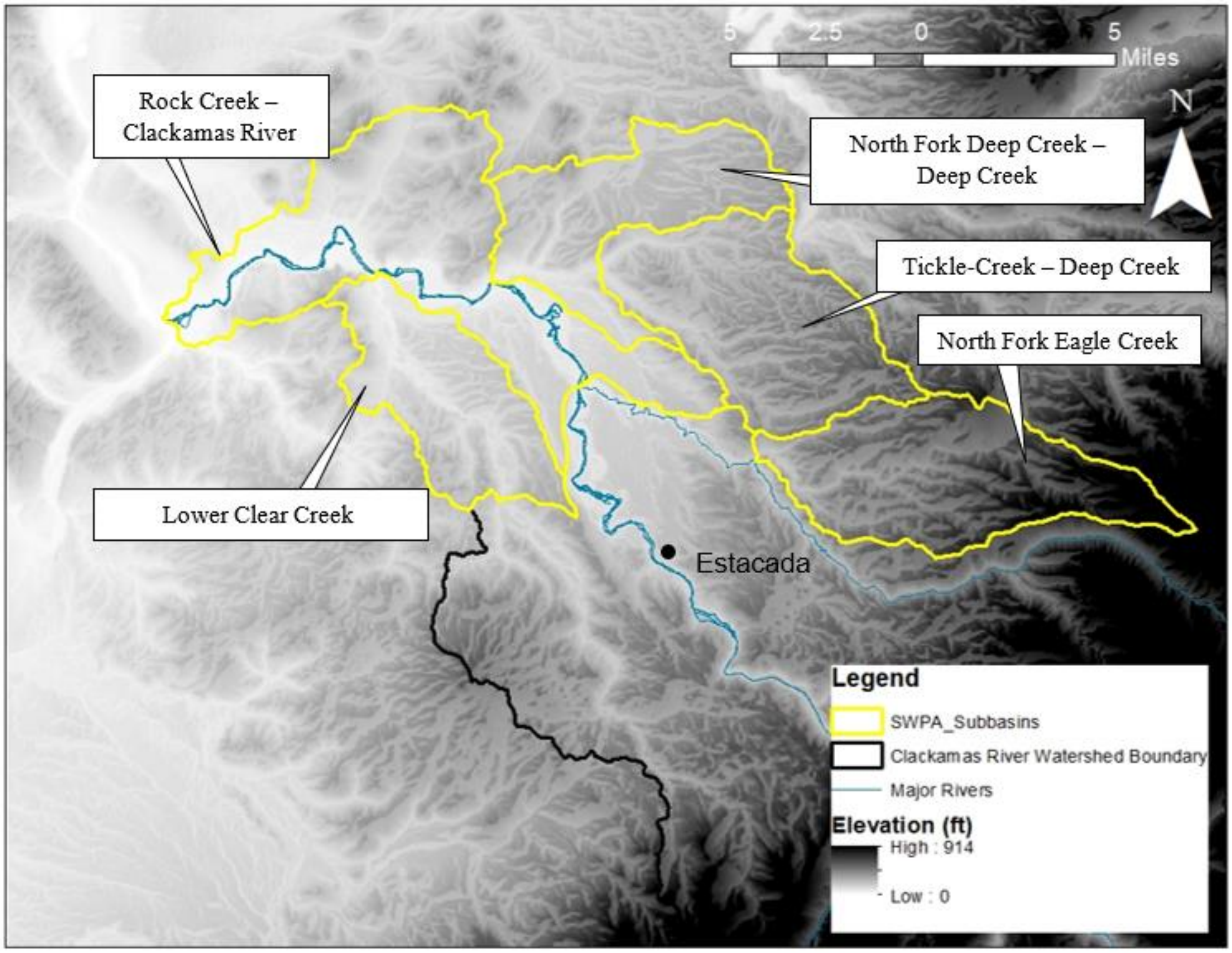

Figure 7. Elevation in feet (NAVD88).

The headwater region for the Clackamas River watershed, not shown in the figure above, is at approximately 6,000 feet (CRWP, 2021). The higher elevations accumulate snow in the winter, with monthly 30-year normals for snow water equivalent (SWE) peaking in February and March at around 11-12 inches (USDA and NRCS, 2021). Thus, the source of water for the Clackamas River downstream in the SWP Area are snowmelt and rain that reach the streams by way of surface runoff or discharge from the groundwater system after percolating through soils and fractured rock (Piper, 1942; Lee and Risley, 2002). Seasonal streamflow patterns in the lower Clackamas River are characterized by high flows from winter precipitation and spring snow melt, and low flows during the late summer (**Figure 8**). The winter and spring high flow periods average around 4,000 cfs at USGS gauge 14210000 near Estacada, with summer baseflows near 1,000 cfs (SNOFLO, 2021).

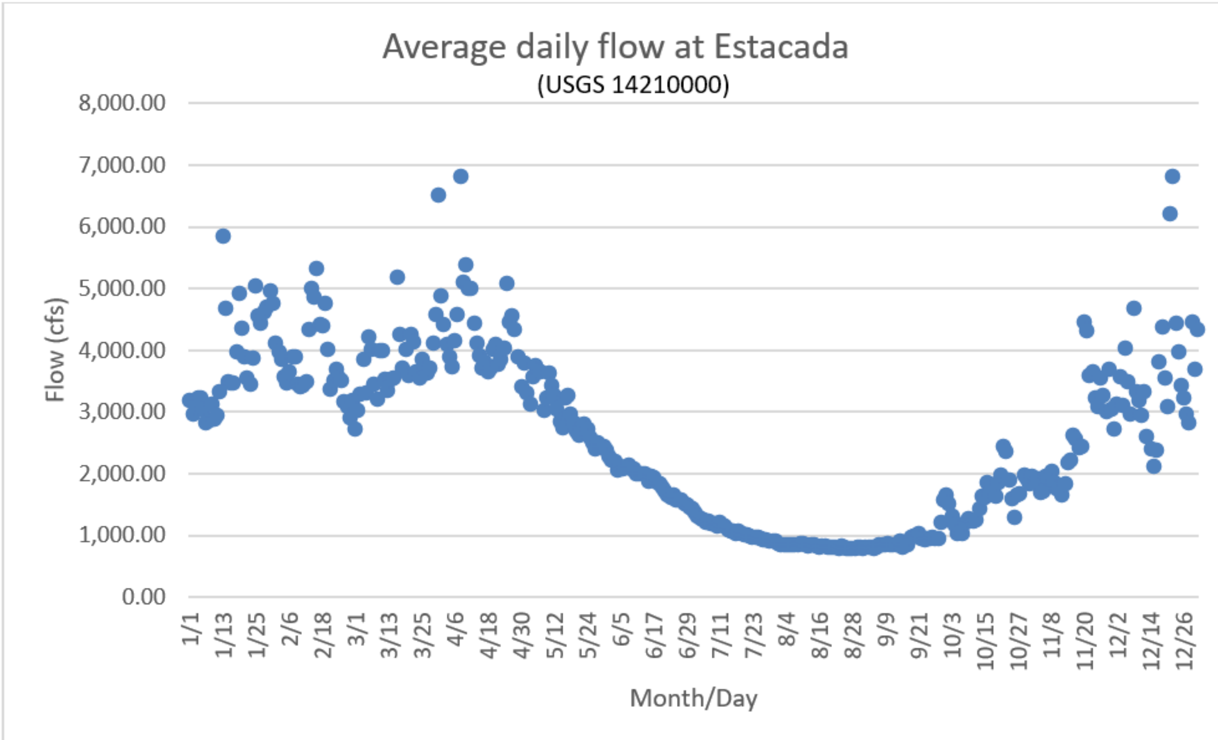

Figure 8: Daily average flow in the Clackamas River at Estacada, averaged over the last 10 years.

During the summer low flow season, flow in the Clackamas River through the SWP Area reflects natural flow from snowmelt and precipitation since the River Mill Dam operates as a "run of river" project per the Federal Energy Regulatory Commission (FERC) license issued to PGE, as discussed in **Section 3.6.2**. Additionally, a USGS seepage study in 2011 characterized individual sections of the lower Clackamas River in the SWP Area as gaining or losing streamflow as shown in **Figure 9** (Lee, 2011); a gain in streamflow indicates groundwater is flowing into the stream through the streambed or bankside, whereas a loss indicates stream water is flowing into the groundwater system through the streambed.

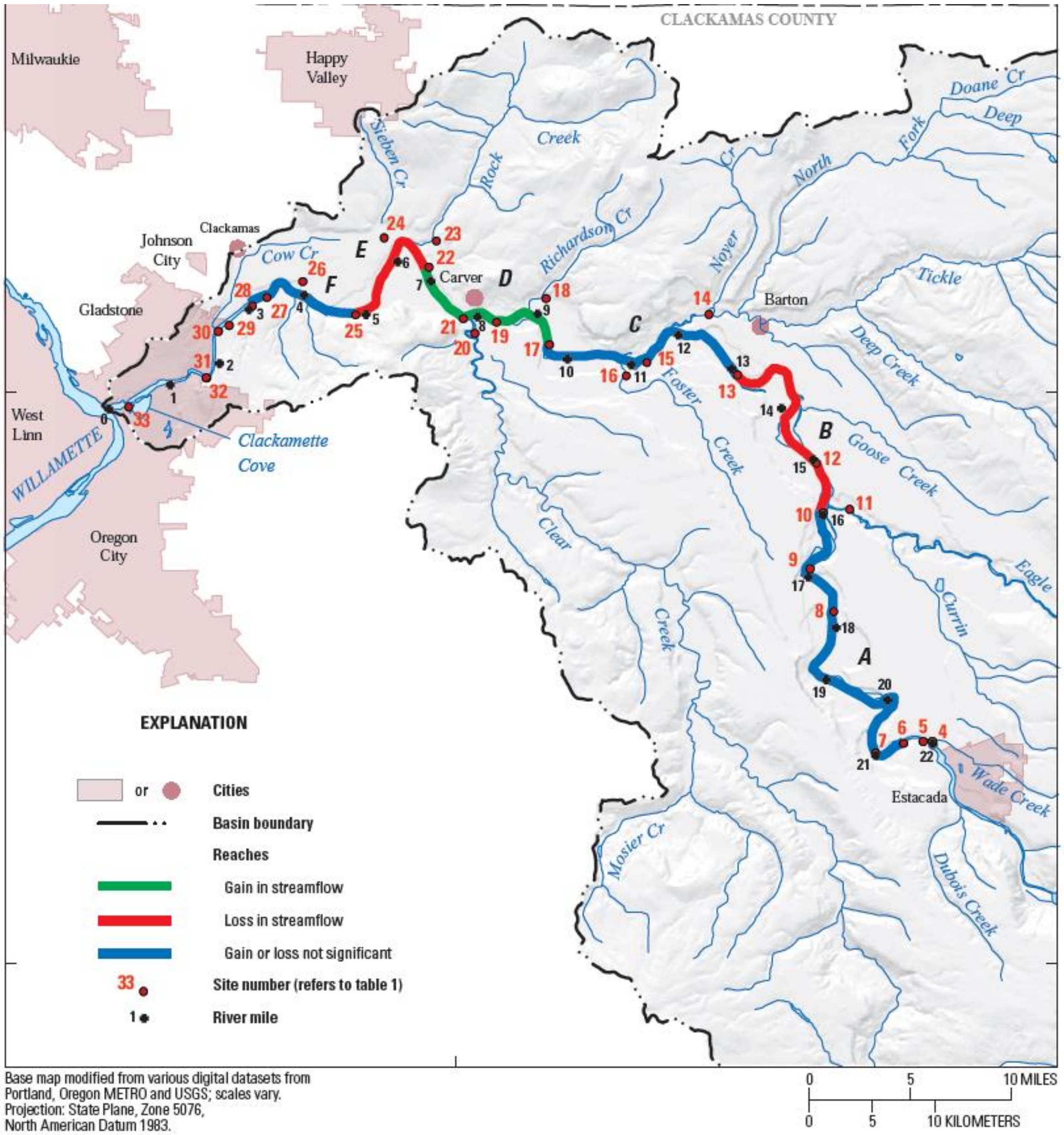

Figure 9: Volumetric streamflow segment gains and losses of the lower Clackamas River, differences greater +/- 5% deemed significant (Lee, 2011).

3.4.3. Geology, Geomorphology, and Hydrogeology

The underlying geologic feature in the region is lava flows (McFarland and Morgan, 1996). The region falls within the Columbia River Basalt group, and much of the base rock is comprised of basalt (Conlon et al., 2005). The geologic layer above this volcanic rock in the lower Clackamas Basin is termed the lower sedimentary unit, which constitutes the bulk of the basin-fill sediments and is dominated by the fine-grained deposits of the Sandy River Mudstone. Above this, in most areas of the lower Clackamas Basin, lies the middle sedimentary unit. This unit largely consists of moderately consolidated sands and gravels predating the Missoula Floods. It also includes Boring Lavas debris and other products of volcanoes that erupted in the Portland Basin. This unit is commonly unconsolidated near its upper surface but typically becomes more compacted and cemented with depth, which likely limits hydrogeologic connectivity. The middle layer is overlain by the upper sedimentary unit, which can be found along the lower Clackamas River. This uppermost layer is entirely exposed at the land surface and is largely composed of coarse-grained Missoula Flood deposits. The young sands and gravels of this unit have high permeability and porosity. These geologic layers (namely the upper, middle, and lower sedimentary units) have been used to characterize and model groundwater hydrology of the basin (Conlon et al., 2005). Historic specific capacity and aquifer tests suggest that the upper sedimentary unit has a higher hydraulic conductivity than the middle and lower sedimentary units. The spatial extents of these units in the Clackamas River basin are shown in **Figure 10**. The implications of this geology suggest limited hydrogeologic connectivity and conductivity deep under the upland portions of the SWP Area, with increasing conductivity at lower elevations along the mainstem of the Clackamas River.

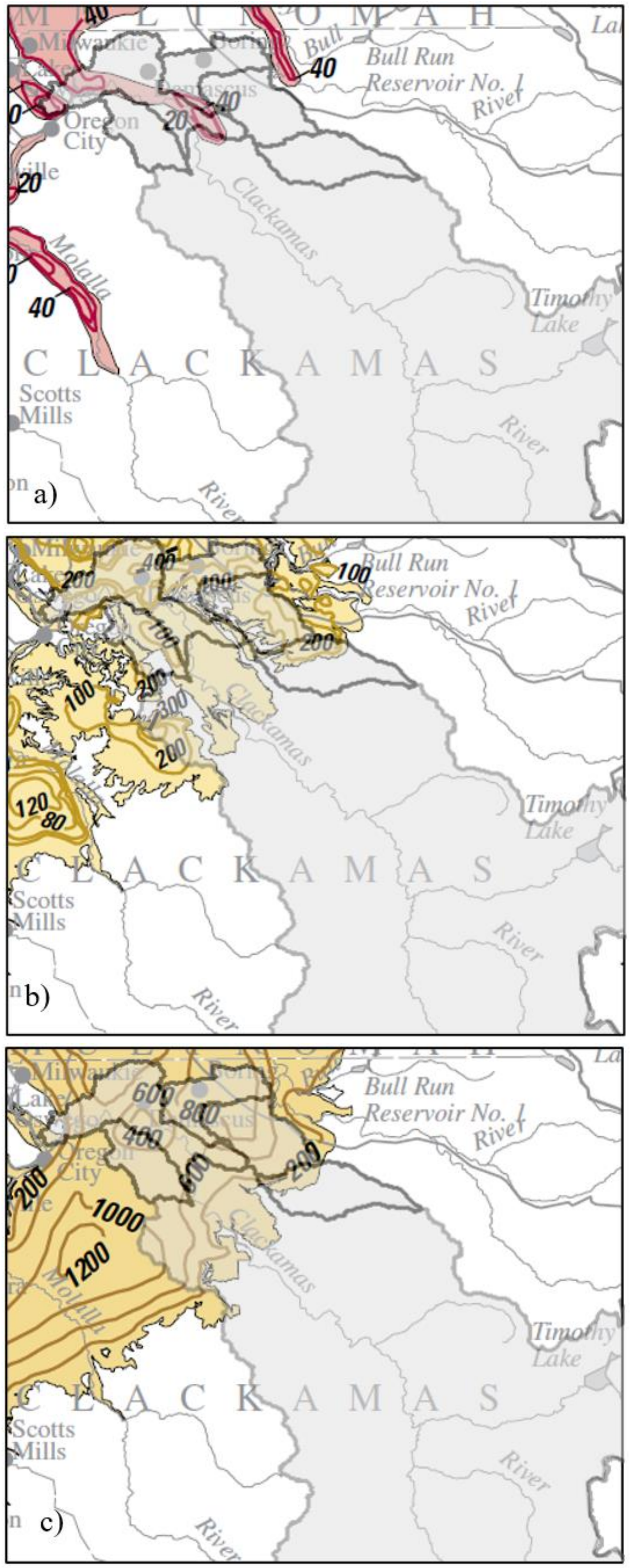

Figure 10: Spatial extents of the a) upper, b) middle, and c) lower sedimentary units (Conlon et al., 2005)

The hydrogeology of the broader Clackamas River Basin above the SWP Area is also of interest. While the SWP Area lies mostly within the Willamette Lowland hydrogeologic area, the upper Clackamas Basin is predominantly characterized by Western Cascade and High Cascade hydrogeology. The distributions of these hydrogeologic areas within the Clackamas River watershed are provided in **Figure 11** (Lee, 2011).

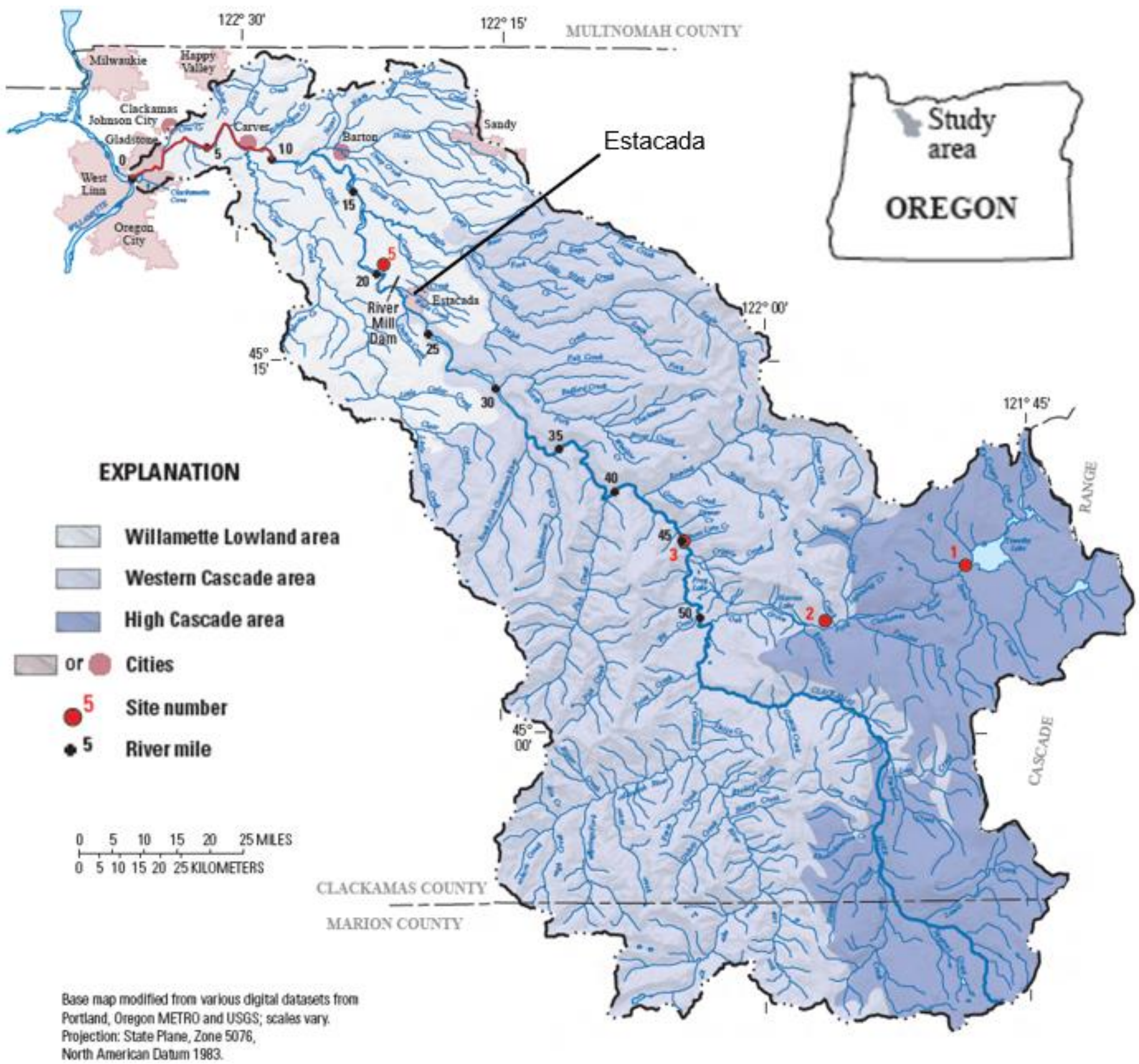

Figure 11: Hydrogeologic regions of Clackamas River Basin (Lee, 2011)

Previous studies and literature suggest the watershed's hydrogeology could cause snowmelt to infiltrate into the young, open lava rock characteristic of the High Cascades, which recharges the groundwater in the lower subbasins and may reappear in the streams after some extended residence time to boost late summer baseflow (Grant, 2013 and Tague et al., 2007). The USGS published a seepage study of the Clackamas River stating, "The relatively large gain in streamflow between sites in the upper basin [upstream of Estacada] was primarily attributable to the contribution of groundwater, which is a key source of basin-wide streamflow during the summer" (Lee, 2011). The theory explored in this and other studies is that young lava rock in the upper basin infiltrates water (rainwater and snow melt) more readily into the groundwater than the surface-flow dominated Western Cascades area, and this water is expected to affect streamflow both seasonally and over the course of many years.

3.4.4. Soils

The geology and hydrogeology underly the top soil units in the basin, which were detailed during a 1985 USDA survey. These soil units are broad areas that have distinctive drainage patterns. The spatial extents of these soil layers may line up with the geologic units, identified in **Section 3.4.3.,** where the sediment later is exposed at the land surface. For example, the Newberg-McBee-Cloquato-Chehalis soil unit along the lower Clackamas River corresponds to the upper sedimentary layer and is characterized by deep, well-draining soils (USDA, 1985). The soil units in the SWP Area and a portion of the upper Clackamas Basin are presented in **Figure 12**. The overall soil groups may inform hydraulic connectivity in shallow groundwater.

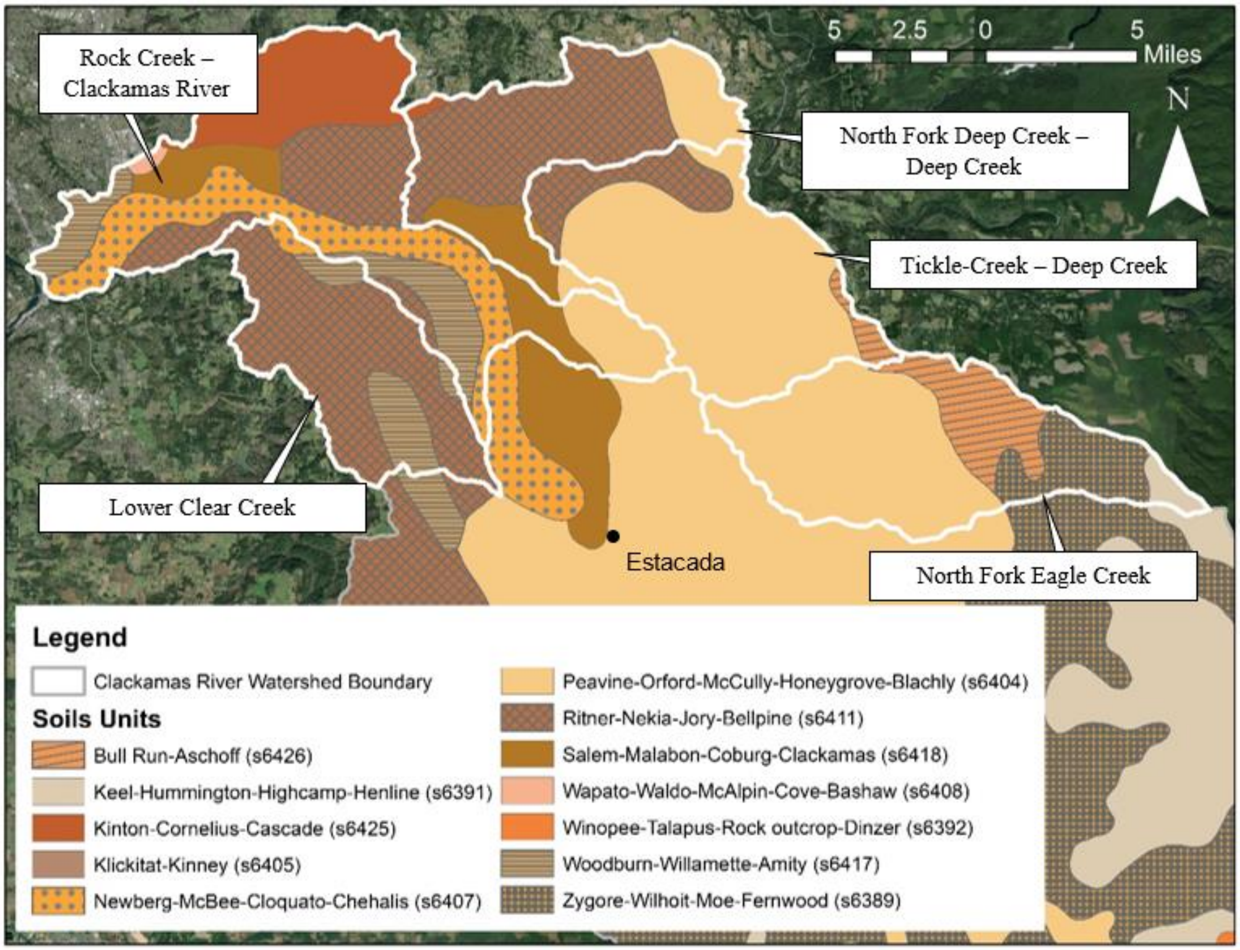

Figure 12: Soil classifications in the SPWA and lower Clackamas River Basin.

Soils can also be more directly characterized by their relative hydraulic conductivities, known as hydrologic soil groups. Soils belonging to Group A have high infiltration rates and low runoff potential, even when thoroughly wetted, and consist largely of sands and gravels (WSDOT, 2021). Group B has moderate infiltration rates and consists of moderately fine to moderately course particles. Comparatively, Group C soils have a relatively slow rate of water transmission, including moderately fine to fine-grained particles. Group D soils have very slow infiltration rates, high runoff potential, and very fine particle sizes, such as clay. Certain wet soils are placed in Group D based solely on the presence of a water table within 24 inches of the surface even though the saturated hydraulic conductivity may be favorable for water transmission. If these soils can be adequately drained, then they are assigned to dual hydrologic soil groups (A/D, B/D, and C/D) based on their saturated hydraulic conductivity and the water table depth when drained. The first letter applies to the drained condition and the second to the undrained condition (USDA and NRCS, 2021). The general drainage properties of soils in the SWP Area are presented in **Figure 13**.

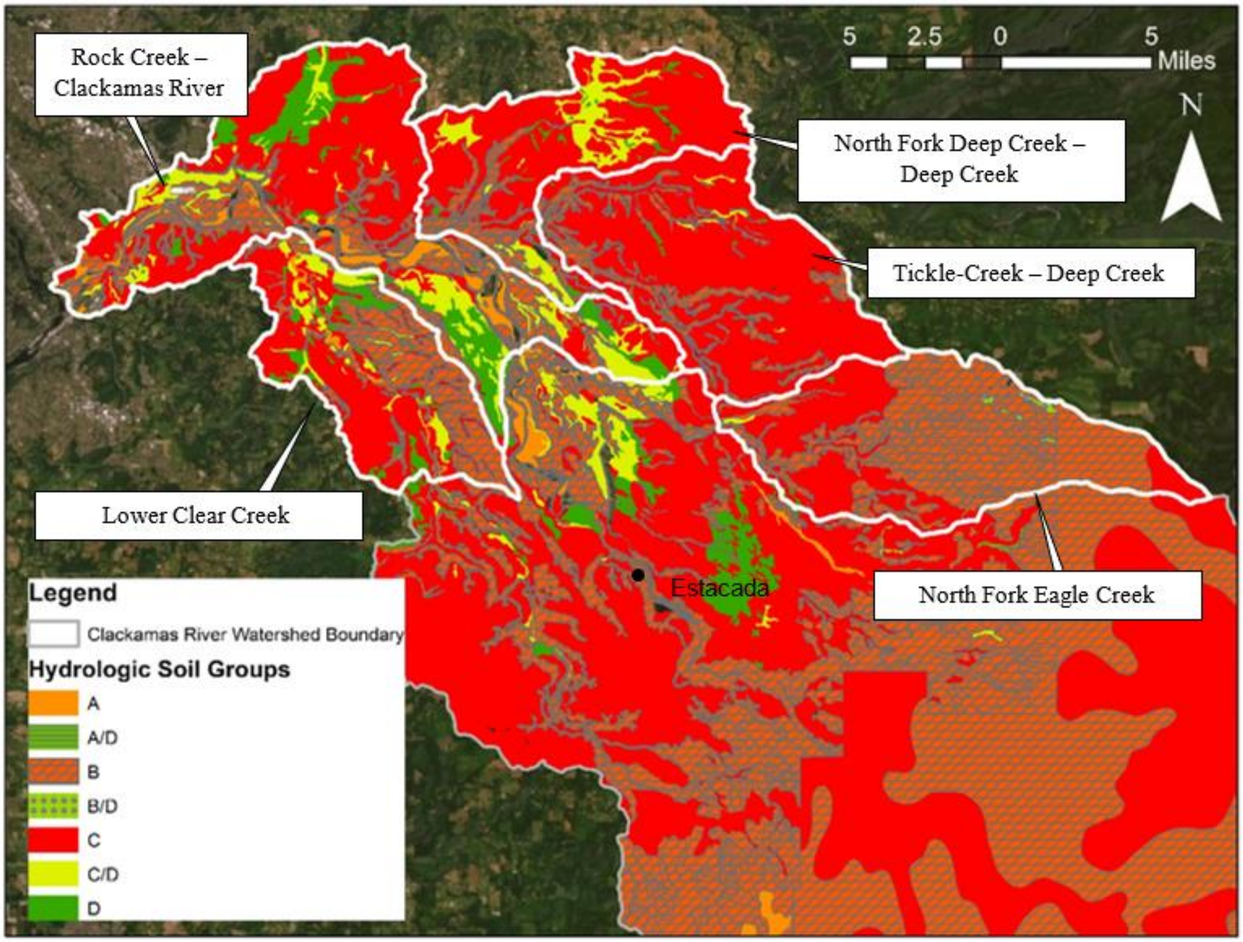

Figure 13: Hydrologic soil groups in the SWP Area and lower Clackamas River Basin.

Between the soil units and the hydrologic soil groups, there are several ways to assess infiltration and shallow subsurface flow patterns in the SWP Area. The soil units provide a categorization and delineation of broad areas with distinct drainage properties. These units generally follow the spatial trends outlined by the land-surface-exposed areas of the geologic sediment units. The hydrologic soil units provide more detailed estimates of these drainage properties. The area immediately along the Clackamas River is comprised of conducive A soils, however, the majority of the SWP Area has less infiltrative soil varieties including B, C, C/D, and D soils. This information taken together suggests overall higher infiltration and hydraulic connectivity in areas along the lower Clackamas River, with less conducive soils on the steeper slopes upland of the river banks.

3.5. Climate

3.5.1. Potential Climate Impacts to Drinking Water Systems

Shifting climate trends can cause changes in watershed hydrology that can impact drinking water quantity and potentially quality for public and private water systems. These impacts can include:

- changes in precipitation volume and timing, often leading to lower streamflows and lower groundwater recharge, which may cause lower base flows in dry weather with higher conductivity;

- increases in evapotranspiration rates, which may also cause lower base flows in dry weather; and

- increased storm intensity, potentially leading to flooding and instances of poor water quality at drinking water intakes due to runoff.

In recent years, CRWP has been investigating basin-wide hydrology and developing resiliency plans to accommodate changes in water availability throughout the year. Providers may need to adjust treatment plant operations in response to seasonal shifts in water quantity and/or water quality.

3.5.2. Climatic Trends in the SWP Area

Precipitation in the SWP Area falls predominantly as rain. A period of primary interest for CRWP is the summer base-flow period, when precipitation is minimal, and streamflow is sustained primarily by groundwater discharge. For the combined months of August and September, the average precipitation at Estacada during 1971–2000 was 3.4 in., about 6 percent of the average annual total of 57 inches (PRISM Group, 2008). Annual total precipitation varies across the SWP Area, as indicated by the 30-year precipitation normals in **Figure 14** (Oregon State University [OSU], 2021). Within the SWP Area, annual total precipitation normals vary from 40 to 60 inches per year, with the higher values at relatively higher elevations.

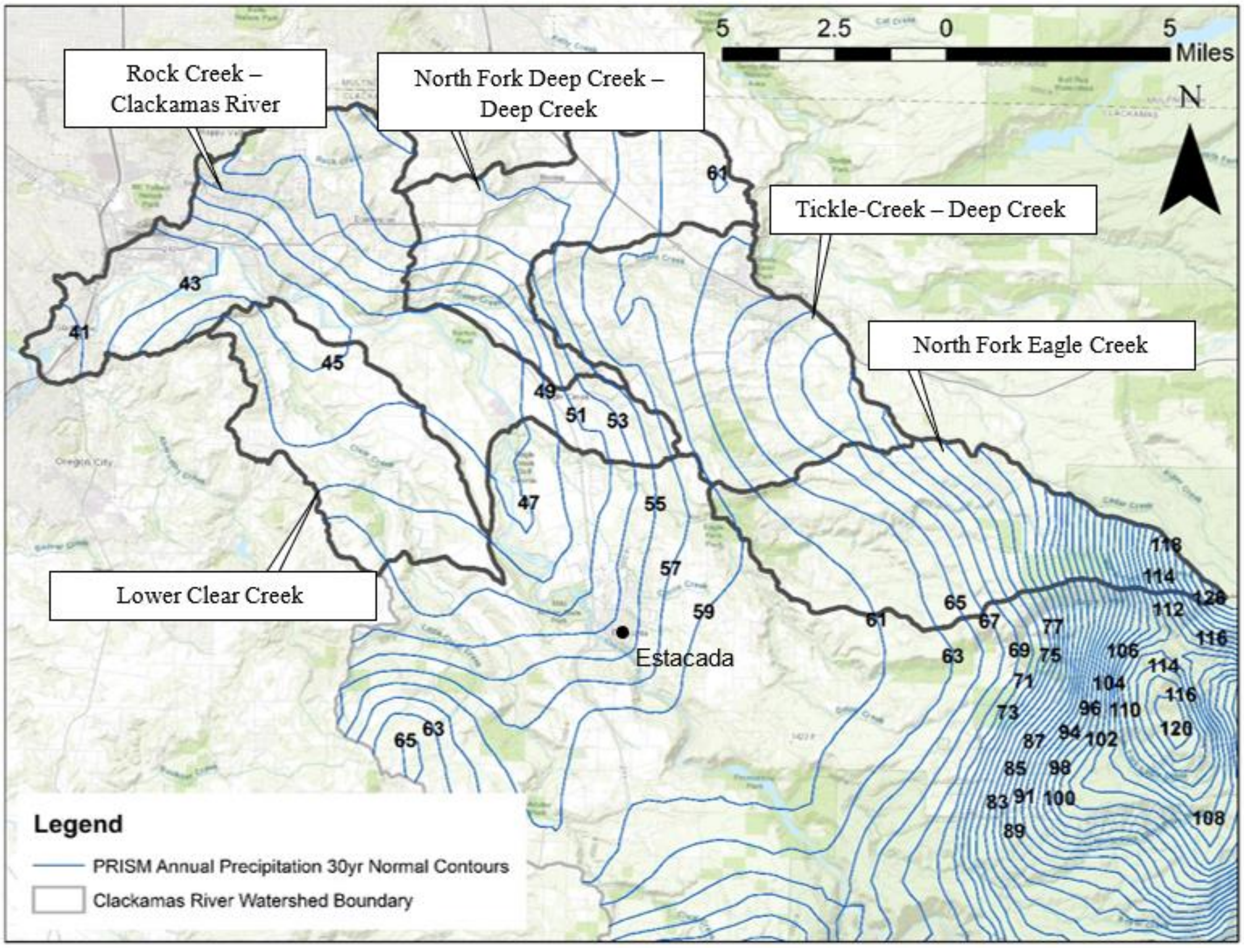

Figure 14: 30-year annual precipitation normals in inches for the Clackamas Basin region.

The projected impacts of climate change vary in severity and timing depending on the particular General Circulation Model and emissions scenario analyzed. One study found that average air temperatures in the Northwest United States are expected to increase by 5-8.5°F by the late 21st century (Vose et al., 2017). While projections for precipitation are not as certain as for air temperature, generally, the warming trends associated with climate change are expected to bring drier summers but more extreme precipitation events to the region, resulting in flashier winter storm hydrographs (Halofsky et al., 2020). Winter storms are expected to be more frequent, with higher intensities. Climate models generally agree that SWE (i.e., snowpack) is expected to decrease in the upper basin (Santelmann et al., 2012). Both factors will result in earlier snowpack melt and decreased summer flows in the Clackamas River (Chen and Chang, 2019), although the severity of decreased summer flows varies. While snowpack is predicted to decrease and melt earlier in the spring, studies generally reject that the Willamette basin may be vulnerable to water shortages, even in the late summer.

This decrease in snowpack and drier summers are expected to increase the amount of land area affected by wildfires by two- to nine-times (Turner and Gilles, 2016). Wildfires cause immediate damage and water quality concerns in the basin (**Section 3.7**). Additionally, changes in forest composition as a result of wildfire may reduce the ability to cultivate and harvest timber (**Section 3.3**) and change the local hydrology of the region (**Section 3.4**), affecting long-term water quantity for drinking water providers in the area.

3.6. Dam Operations

Dams can influence water quality and quantity both upstream and downstream of the infrastructure. **Section 3.6.1** briefly discusses potential impacts from dams in a general sense, and **Section 3.6.2** focuses on the dams operating in the Clackamas River and the potential impacts to water quality at the intakes in the SWP Area. It should be noted that the dams are upriver from the SWP Area and only have the potential to affect the Rock Creek – Clackamas River subbasin within the SWP Area.

3.6.1. Potential Impacts to Water Quantity and Quality from Dams

Dams and their operation can cause changes in watersheds that impact drinking water availability and quality downstream. Not all of the potential impacts of dams are expected to occur in the SWP Area due to dams on the Clackamas River, but in general impact of dams can include:

- changes to watershed hydrology, which have the potential to either restrict or increase water availability at intakes (not expected to affect the SWP Area);
- increased water temperatures due to long residence times in reservoirs;
- degraded water quality at intakes with respect to algal growth, which may lead to low dissolved oxygen (DO) concentration and/or the presence of cyanotoxins (not expected to affect the SWP Area); and
- increased settling of solids and other contaminants, resulting in improved water quality downstream.

In general, drinking water providers downstream of dams may need to modify treatment plant operation practices to accommodate changes in dam operations to ensure a sufficient quantity and quality of finished drinking water to meet community needs. However, this is not expected to be the case for the SWP Area, as discussed in **Section 3.6.2**.

3.6.2. Clackamas River Dams and Operation

PGE operates the Clackamas River Hydroelectric Project, a series of dams and powerhouses along the Clackamas from Timothy Lake to Estacada. Operations under PGE's FERC license include (PGE, 2021):

1. Timothy Lake and Timothy Dam
2. Lake Harriet and Harriet Dam
3. Frog Lake and Oak Grove Powerhouse
4. North Fork Reservoir and Dam
5. Faraday Powerhouse
6. Faraday Diversion Dam and Reservoir
7. Estacada Lake and River Mill Dam

The locations of these seven facilities are shown in **Figure 15**, and have been listed in order from upstream to downstream.

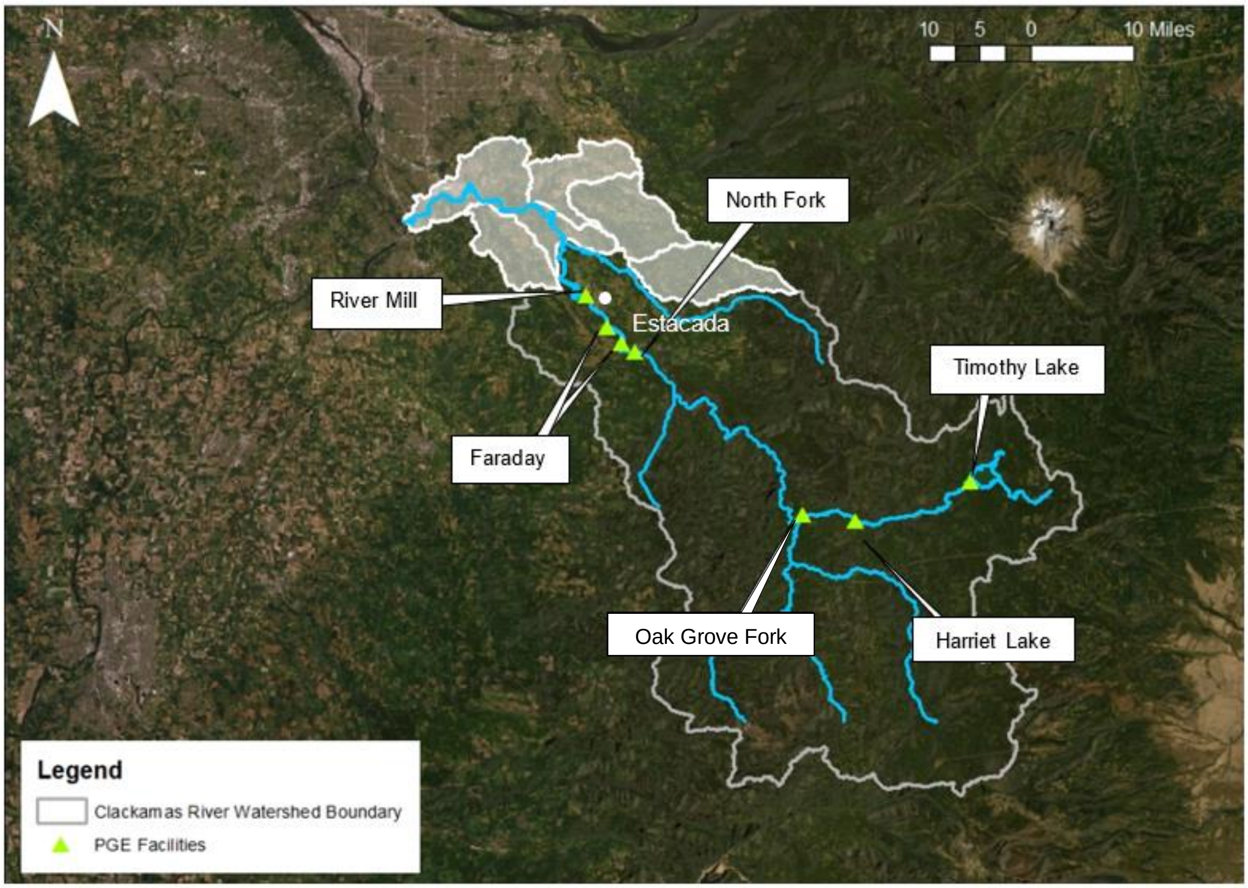

Figure 15: PGE facilities including dams and powerhouses along the Clackamas River.

The River Mill Dam is the furthest downstream PGE facility, and it is located outside of the SWP Area, upstream of the Rock Creek-Clackamas River subbasin. Flows released from River Mill Dam minimize flow-related impacts from the Clackamas River Hydroelectric Project. As stated in the Revised Project Operating Plan, "the River Mill Dam and powerhouse are operated to release flows from Estacada Lake that are as close as possible to the flows that would occur if the Clackamas Project facilities from North Fork Dam through River Mill Dam did not exist" (PGE

2021). This is achieved by estimating the River Mill Unregulated (RMU) Inflow as if the Harriet, North Fork, Faraday, and River Mill dams did not exist, then regulating flow release from River Mill Dam and powerhouse to within 10% or 100 cfs of the RMU Inflow, whichever is greater. This operations scheme classifies the River Mill Dam as “run of the river.”

Monitoring programs are in place to ensure the River Mill Dam preserves water quality downstream. PGE conducts annual monitoring for temperature, DO, inter-gravel dissolved oxygen (IGDO), total dissolved gas (TGD), and blue-green algae (visible bloom formation); when blooms are visible, water samples are tested for cyanotoxins[1] (PGE, 2019). Five years of temperature monitoring were conducted to ensure compliance and temperature management activities were implemented to address potential compliance issues downstream of River Mill Dam (PGE, 2019). DO and IGDO were primarily assessed in the priority area of Oak Grove Fork below the Harriet Powerhouse, and results indicated that the powerhouse does not cause DO to drop below DEQ’s reach standard (PGE, 2019). TGD monitoring near the River Mill dam occurred from 2011-2015, and primarily characterized exceedance trends in the River Mill Dam forebay, rather than downstream of the Dam, due to difficult sampling location configuration (PGE, 2019). TGD in the forebay was found to exceed DEQ’s standard of 110% saturation for flows greater than 5 kcfs. Blue-green algae (visible blooms) is monitored at Timothy Lake and North Fork Reservoir (PGE, 2019b). Ongoing water quality monitoring is planned in accordance with PGE’s license for the Project (PGE, 2013).

3.7. Wildfires

The Clackamas River watershed has experienced several wildfires in recent years, which pose acute risks to human health, life, and property. Risks can persist long after the fires are extinguished due to continued flooding, contamination, and landslide hazards. This section describes potential impacts from wildfires to drinking water systems and discusses the impacts of the 2020 wildfire season to water providers within the SWP Area.

3.7.1. Potential Wildfire Impacts to Drinking Water Systems

Wildfires can cause changes in watersheds that impact source water quality. These impacts can include:

- increased susceptibility to flooding and erosion due to loss of vegetation;
- increased risk of landslides and debris flows;
- decreased reservoir capacity from sedimentation;

[1] Cyanotoxins sampled include Anitoxin-a, Cylindrospermospin, Microcystin, and Saxitoxin

- elevated risk of harmful algal blooms due to elevated nutrient loading, especially to reservoirs;

- decreased infiltration of precipitation into groundwater systems, leading to lower base flows in dry weather; and

- degraded water quality at intakes, including increased turbidity, nutrients, organic matter, metals, and other chemicals from fire suppressants (such as per- and polyfluoroalkyl substances [PFAS]), and byproducts from any fires in more urban areas (e.g., due to burning of building materials and pipes).

After a wildfire, impacted drinking water providers may need to increase water quality monitoring in the river, modify, protect, or relocate intake structures and/or modify treatment plant operation practices to accommodate these changes in the watershed. In extreme cases of prolonged poor water quality, drinking water providers may need to switch to alternate water sources, if available, or shut down treatment until source conditions improve. Both alternatives could lead to an insufficient volume of finished drinking water to meet community needs, or an inability to meet Safe Drinking Water Act contaminant limits.

3.7.2. Regional Wildfire Hazard

The Oregon Wildfire Risk Explorer categorizes much of the lower Clackamas River watershed (outlined in red) as either non-burnable or low probability of wildfire (**Figure 16**). The southern-most portion of the lower watershed is categorized as a moderate wildfire risk, where the hazard to potential structures is categorized as high or very high (Federal Emergency Management Agency [FEMA], 2020). Much of the middle and upper watershed are categorized as a moderate or high probability of wildfire.

Likewise, the much of the lower watershed is expected to have low burn intensity, which is correlated to an increased ability to control a fire. The southern-most portion of the lower watershed is expected to have a higher burn intensity, where ember travel, tree torching, and spotting may increase the difficulty to control the fire (FEMA, 2020). Burn intensity in the upper reaches of the watershed is also high in many places (**Figure 17**).

Overall wildfire risk is shown in **Figure 18**. This risk accounts for both the likelihood and consequences of a wildfire. Much of the lower watershed has a low wildfire risk, while the middle and upper watershed reaches are mostly moderate to high risk.

The housing density in the watershed ranges from greater than three houses per acre (3/acre) in the lower basin (posing the greatest challenge for wildfirez management and greater susceptibility for widespread damage in the event of a wildfire) to about one house per 40 acres (1/40 acres). Areas where developed areas mix with undeveloped natural areas with a close proximity of infrastructure to flammable wildland vegetation are known as the Wildland Urban Interface (WUI), which poses greater challenges to wildfire management and put more homes and structures at risk of wildfire (Oregon Wildfire Risk Explorer, 2020).

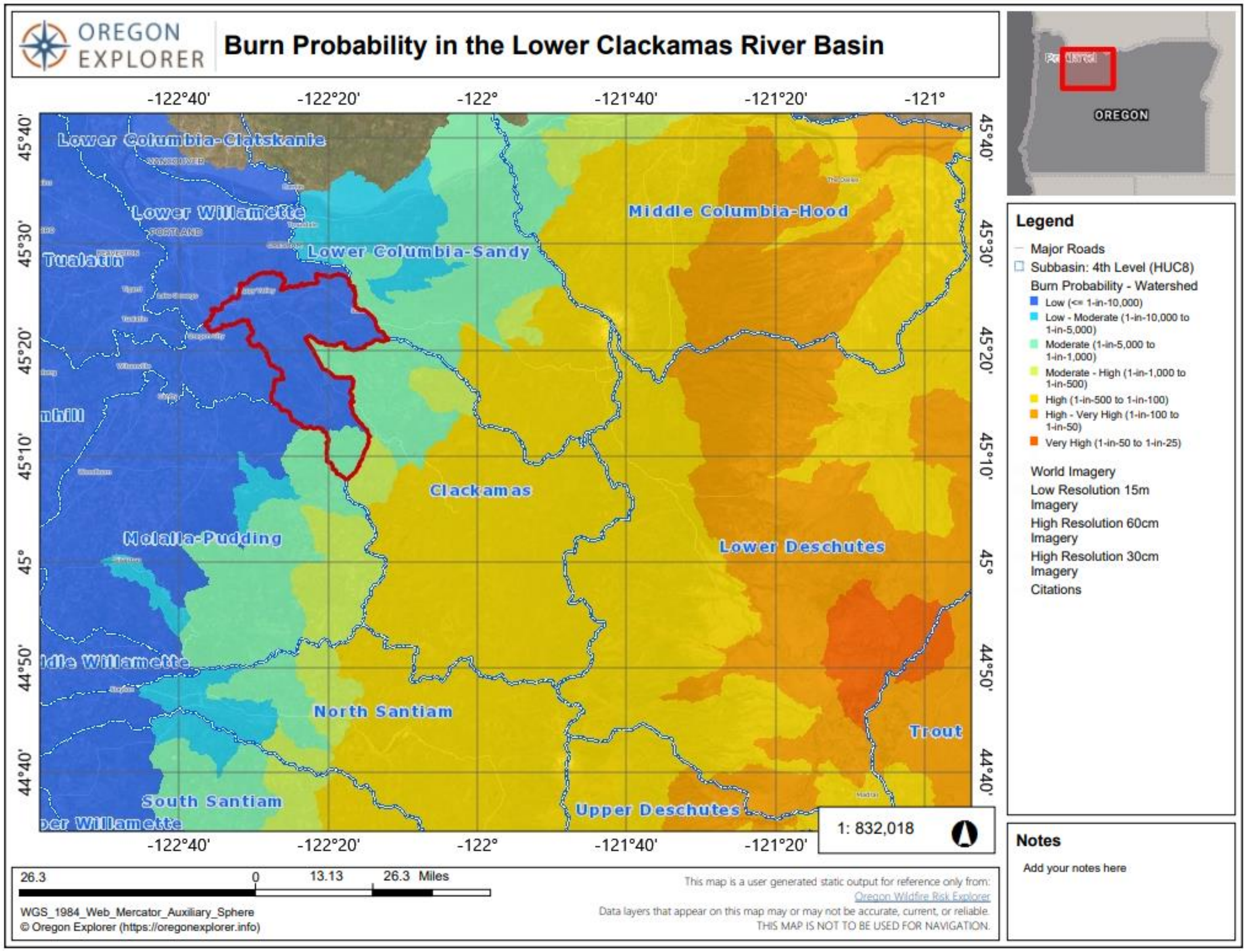

Figure 16. Burn Probability in the Lower Clackamas River Basin.

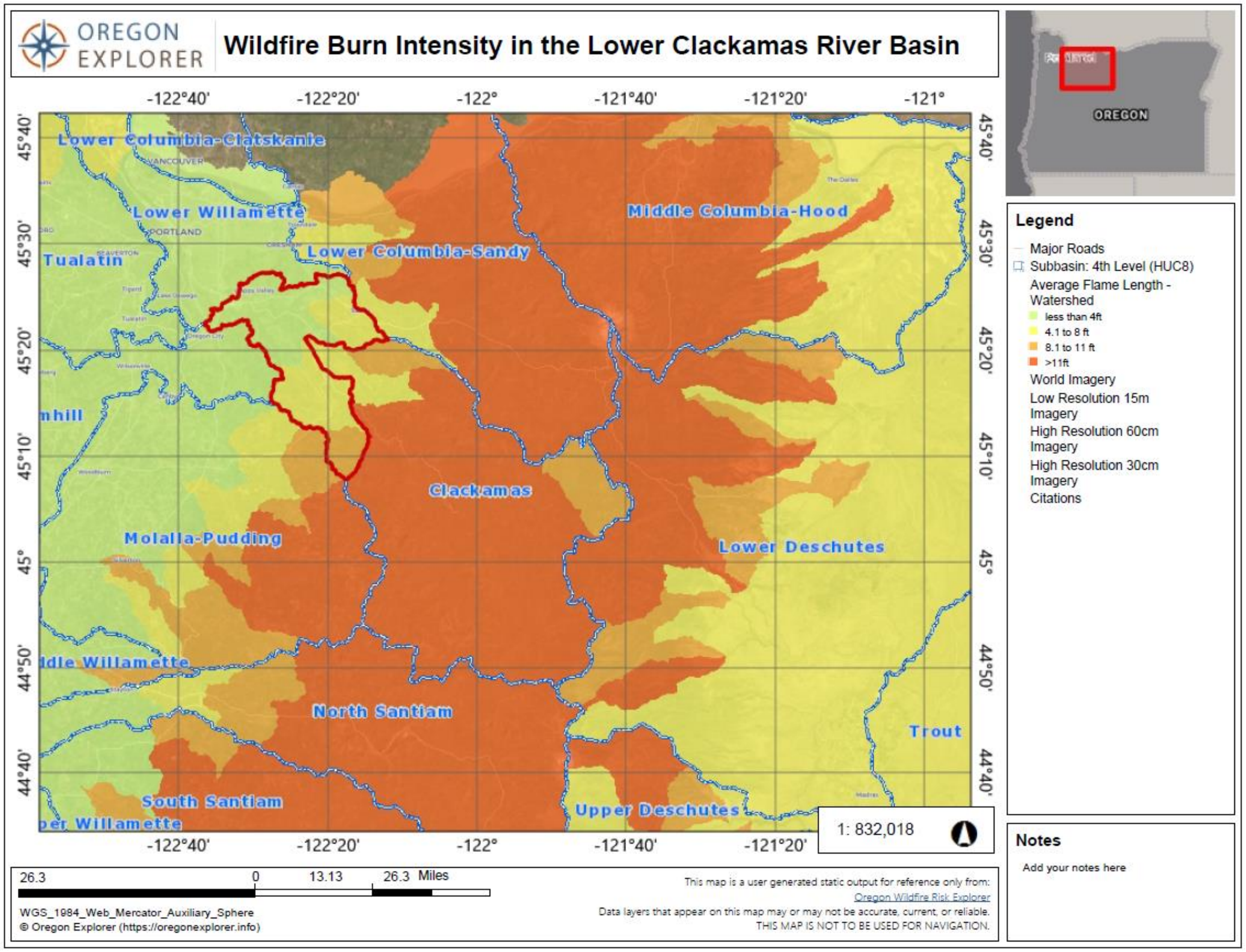

Figure 17. Wildfire Burn Intensity in the Lower Clackamas River Basin.

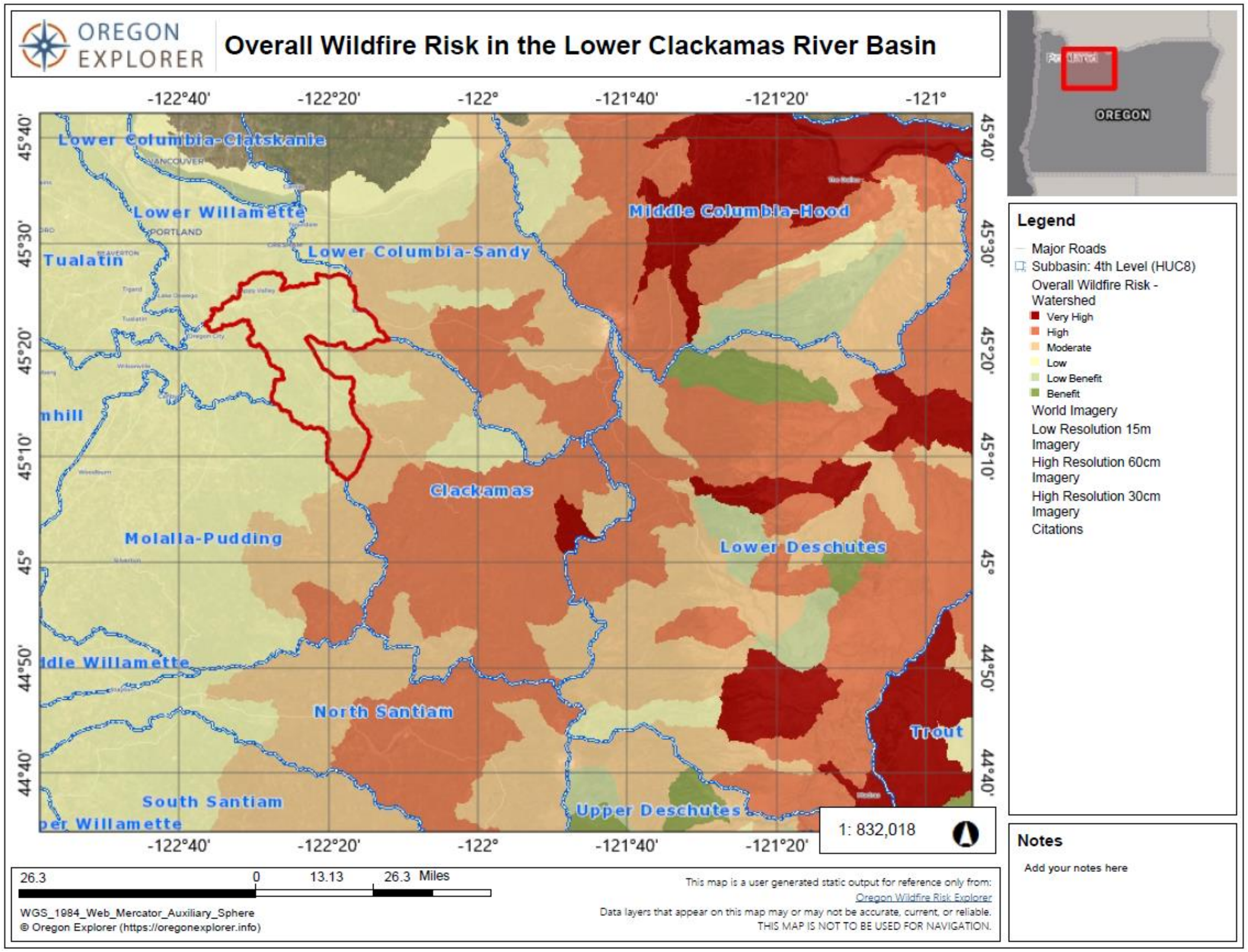

Figure 18. Overall Wildfire Risk in the Lower Clackamas River Basin.

3.7.3. Recent Wildfires

In 2020, the Clackamas River Watershed basin was impacted largely by the Riverside fire in the middle watershed, and to a lesser extent by the Lionshead fire in the upper watershed and the Dowty Road fire in the lower watershed. In 2021, the upper basin was affected by the Bull Complex fire in the Mt. Hood National Forest (**Figure 19**).

The Riverside fire originated just southeast of Estacada, Oregon and burned from early September through late October 2020. The fire burned approximately 138,000 acres of private and federal land in Clackamas County, mostly in the Clackamas River watershed. The fire left high- and moderately severe soil burn on steep slopes, which increases soil erosion potential and could potentially degrade water quality in the river. Loss of vegetation and soil burns are expected to increase runoff and increase peak flow rates in the Clackamas River, increasing the risk of damage to municipal intake systems. Ground cover in clear-cut areas may take longer than 2-5 years to re-establish (depending on burn severity) in order to decrease longer term erosion, leaving downstream water quality in question meanwhile (FEMA, 2020). It should be noted that the extents of the Riverside fire are upstream of the River Mill dam (see **Section 3.6**), and it is expected that the River Mill Reservoir will mitigate some of the impacts from this fire.

The Dowty Road fire burned more than 2,000 acres near Estacada. Though much smaller than the Riverside and Lionshead fires, the Dowty Road fire extents are downstream of River Mill dam, and thus have a higher potential to impact drinking water intakes lower in the SWP Area.

3.7.4. Recent Wildfire Impacts to Drinking Water Providers

No municipal drinking water intake structures within the SWP Area were damaged in the 2020 or 2021 wildfire seasons. After the 2020 wildfire season, drinking water intakes within the SWP Area were scored by the Erosion Threat Assessment and Reduction Team (ETART) as having low post-fire drinking water source area vulnerability. The City of Estacada was scored as having a high post-fire drinking water source area vulnerability, noted to not have an alternate water source available (Seeds et al., 2020).

About half of the subwatersheds within the Clackamas River watershed were categorized as having significant debris flow hazards, which indicates a potential water quality risk due to shallow landslides and debris flows. These risks will be elevated for a few years until these slopes regain vegetation and stabilize. Debris flows and associated higher turbidity are most problematic for slow sand and direct filtration systems; Clackamas River Water and North Clackamas County utilize direct and slow sand filtration systems, respectively (Seeds et al., 2020). Other water providers, which have conventional treatment systems, were considered of lower concern for turbidity since they use coagulants; adjustment of coagulant dosing will be necessary in response to increased turbidity. Note that the most severe fires occurred upstream of the River Mill dam, and thus the impacts to drinking water intakes downstream of the dam associated with turbidity will be somewhat mitigated by the River Mill Reservoir.

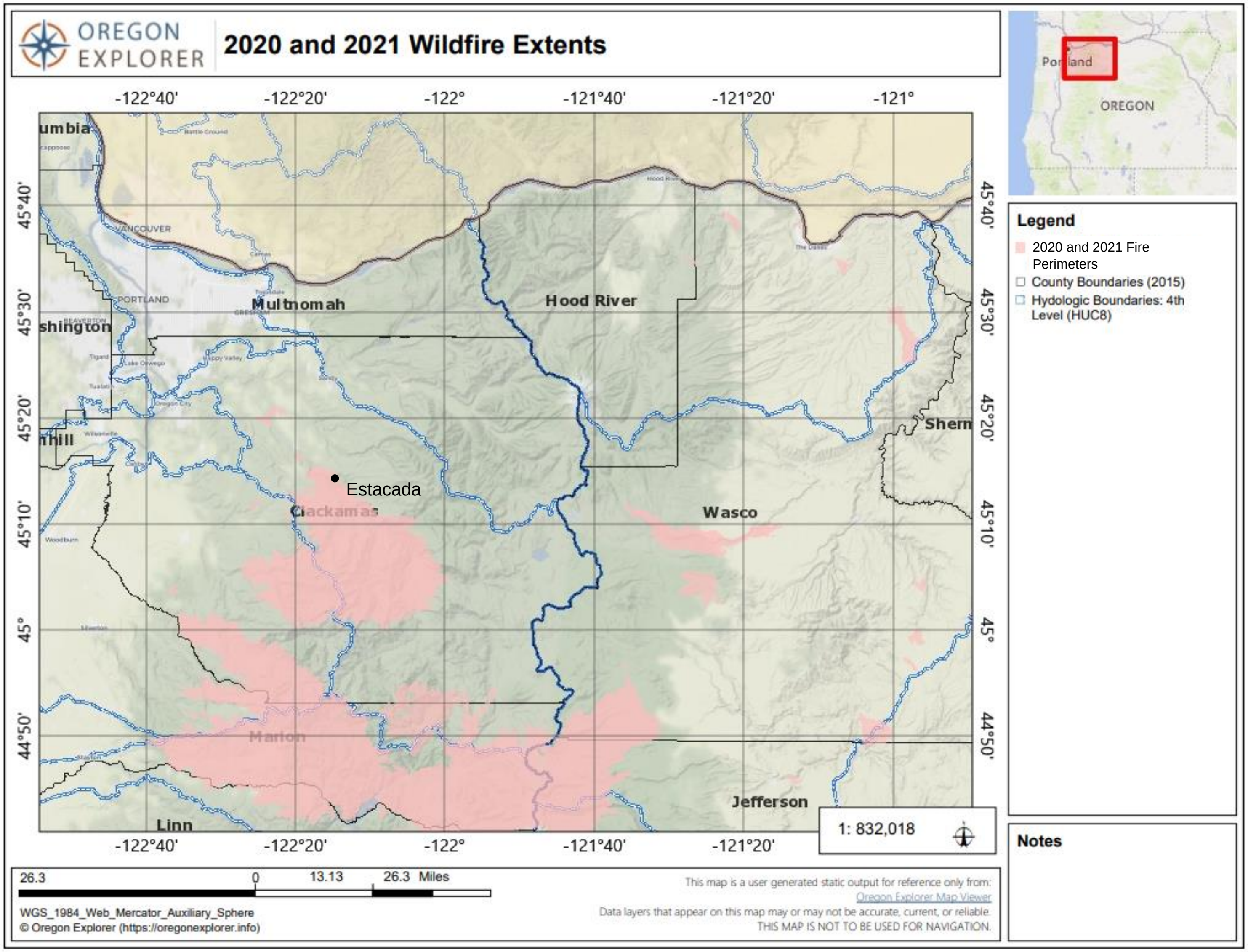

Figure 19. 2020 and 2021 Wildfire Extents.

3.8. Summary

The natural and anthropogenic characteristics of the watershed impact the quantity and quality of water available to the drinking water providers in the SWP Area. As described above, key characteristics and their impacts include:

- Most of the people served by the public water systems are not in the Clackamas River watershed. Furthermore, those living in the SWP Area are generally not served by the drinking water providers, relying instead mostly on private wells and septic systems. This could disincentivize the ready adoption of BMPs;

- Land in the SWP Area is dominated by privately owned agricultural operations or forest. This presents an opportunity to work with landowners to implement BMPs that would improve water quality at downstream intakes. The types of crops grown in the region contribute to some impairments or potential impairments to downstream water quality, but are amenable to the adoption of BMPs which would improve downstream water quality;

- Baseflow in the Clackamas River originates primarily from infiltrated snowmelt in the Cascade Mountains. Winter and spring months experience much higher flows than summer months due to storms and snow melt;

- Climate trends indicate the basin may experience more frequent, more intense winter storms and reduced summer baseflow due to decreased snowpack. While this effect may be somewhat alleviated by increased infiltration to groundwater during winter months, there is significant uncertainty in the overall impact on summer baseflow. This may pose challenges for drinking water quality as well as fish flow and temperature requirements in the Clackamas River. Drinking water providers may need to develop modifications to their water management and conservation plans or their drinking water source protection plan to accommodate changes in water availability and water quality throughout the year;

- The lowest dam on the Clackamas River generally maintains a run-of-river operation scheme to minimize the impacts of PGE dam operations. PGE monitors the potential effects of its operations on water quality, but water providers are still responsible for maintaining water quality in their supply network should it be impacted by dam operation;

- Increased wildfire frequency in the region will continue to pose a threat to both drinking water infrastructure and water quality in the basin. The risks associated with wildfires are different for each water provider in the SWP Area based on facility treatment systems and operation. The location of wildfires in the watershed is critical for protecting source water quality. The impacts of wildfires occurring above Rivermill Dam can by significantly mitigated by the reservoir(s) settling out sediments, ash, and other materials, preventing them from passing downstream. Wildfires below Rivermill Dam pose a more immediate and significant risk to the river water quality at the intakes, especially fires that occur within the SWP Area.

4. HYDROLOGY AND WATER QUALITY CHARACTERIZATION

4.1. Hydrology

Surface water hydrology in the SWP Area provides the key transport mechanism for pollutants coming off the land into local creeks and entering the lower Clackamas River. As a result, having a clear understanding of the surface water hydrology is important.

4.1.1. Surface Water

Runoff from the land surface is a primary driver of streamflow generation in the SWP Area on an annual, seasonal, and storm-event-by-storm-event basis. The land surface factors that determine runoff volume include imperviousness, slope, and hydrologic soil type. The dominant factor is imperviousness, which varies across the subbasins of the SWP Area as indicated by the 2019 National Land Cover Dataset (NLCD, 2019) shown in **Figure 20**. The subbasin with greatest impervious area is the highly urbanized Rock Creek – Clackamas River subbasin, and the least is the more rural North Fork Eagle Creek. Based on 2006 NLCD impervious data (NLCD, 2006), imperviousness in each subbasin has been trending upward since 2000, as shown in **Table 6**. Impervious area in North Fork Eagle Creek has more than quadrupled, but still amounts to less than 1% of the total land area. For the other subbasins, approximate increases of 2-3% have been recorded from 2006 to present day.

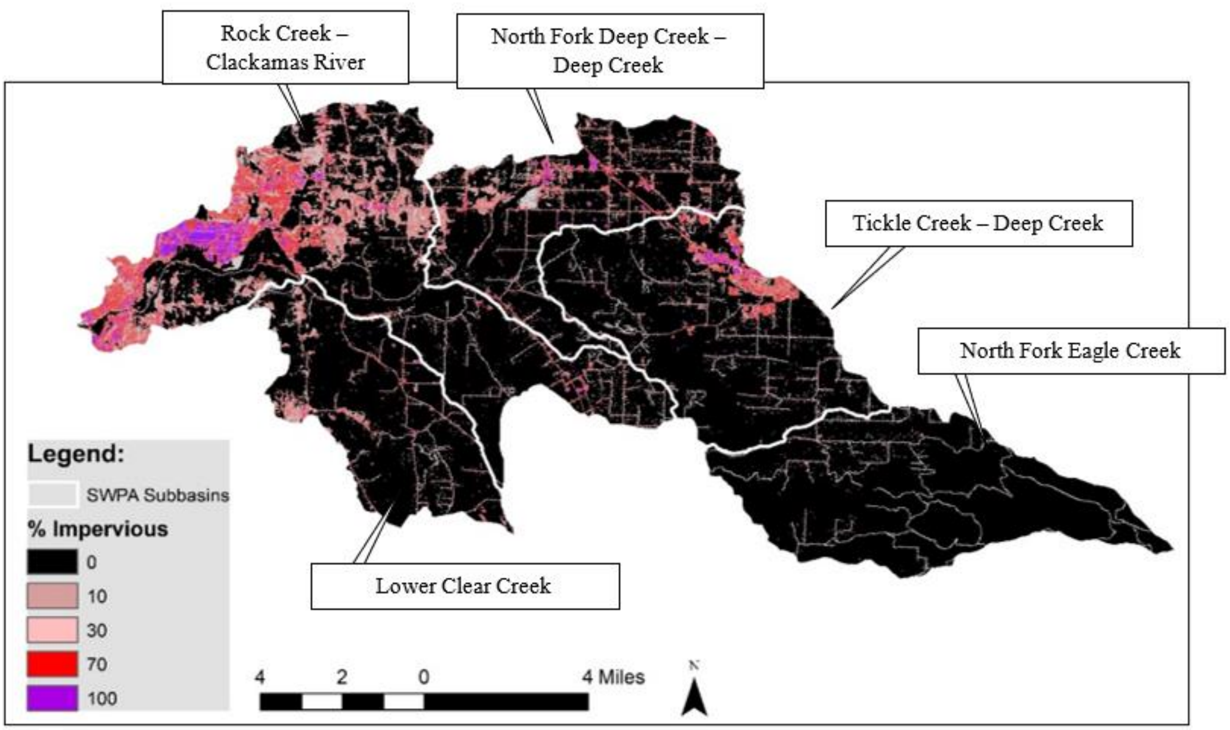

Figure 20: Land cover imperviousness in the SWP Area.

Table 6: Change in average imperviousness in the SWP Area by subbasin.

Subbasin	Total Area (ac)	Impervious Area		Percent Imperviousness	
		2006	2019	2006	2019
Lower Clear Creek	~12,500	326	464	2.61%	3.71%
North Fork Deep Creek-Deep	~13,750	648	981	4.72%	7.14%
North Fork Eagle Creek	~17,850	14	86	0.08%	0.48%
Rock Creek-Clackamas River	~27,350	3,648	4,366	13.34%	15.95%
Tickle Creek-Deep Creek	~17,850	526	945	2.94%	5.29%

The hydrologic properties of the land surface in the Clackamas Basin were originally characterized during development of the Pollutant Load Model (PLM) for the Clackamas River Water Providers (Geosyntec, 2014). To simulate total annual runoff, the model was updated[2], then the model applied local precipitation and climate records to characterize land surfaces for each subbasin (based on 2006 NLCD imperviousness). The modeled annual runoff volumes for the SWP Area subbasins are provided in **Table 7** based on the PLM.

Table 7: Estimated annual runoff from the Pollutant Load Model, 2014.

Subbasin	PLM Subcatchment #	Modeled Annual Runoff (mgal)
Lower Clear Creek	606	3,167
North Fork Deep Creek-Deep	605	3,473
North Fork Eagle Creek	502	1,374
Rock Creek-Clackamas River	607	8,728
Tickle Creek-Deep Creek	604	2,950

These estimated runoff values largely reflect trends in impervious area: Rock Creek – Clackamas River has the greatest total runoff and North Fork Eagle Creek has the least. Lower Clear Creek and Tickle Creek – Deep Creek were modeled as similarly impervious and had similar runoff volumes as a result. North Fork Deep Creek – Deep Creek was slightly more impervious than the latter two and thus produced slightly more runoff. While these are annual runoff values, it would be expected that these subbasins would have similar seasonal patterns with higher runoff in winter into spring with lower runoff in the summer as rainfall ceases and baseflows dominate.

The land surface in the SWP Area runs off to various streams and creeks, ultimately flowing to the lower Clackamas River. This network of smaller tributary streams and creeks is provided for reference in **Figure 21** (ODF, 2020). Although there is little-to-no streamflow data for many of these tributary creeks, there is a long period of record for daily average flow at the downstream

[2] The Pollutant Load Model was originally developed in 2014, and then updated for the SWP Area in 2021 to re-calculate the relative pollutant loads from different land uses and different subbasins in the watershed. The changes made to the model during this update consisted of updating the land use composition for the subbasins in the SWP Area. No other changes were made.

end of the Clackamas River (USGS gauge near Oregon City), as well as one year of daily average flow records in lower Clear Creek. These can be assessed to gauge potential seasonal trends resulting from surface runoff.

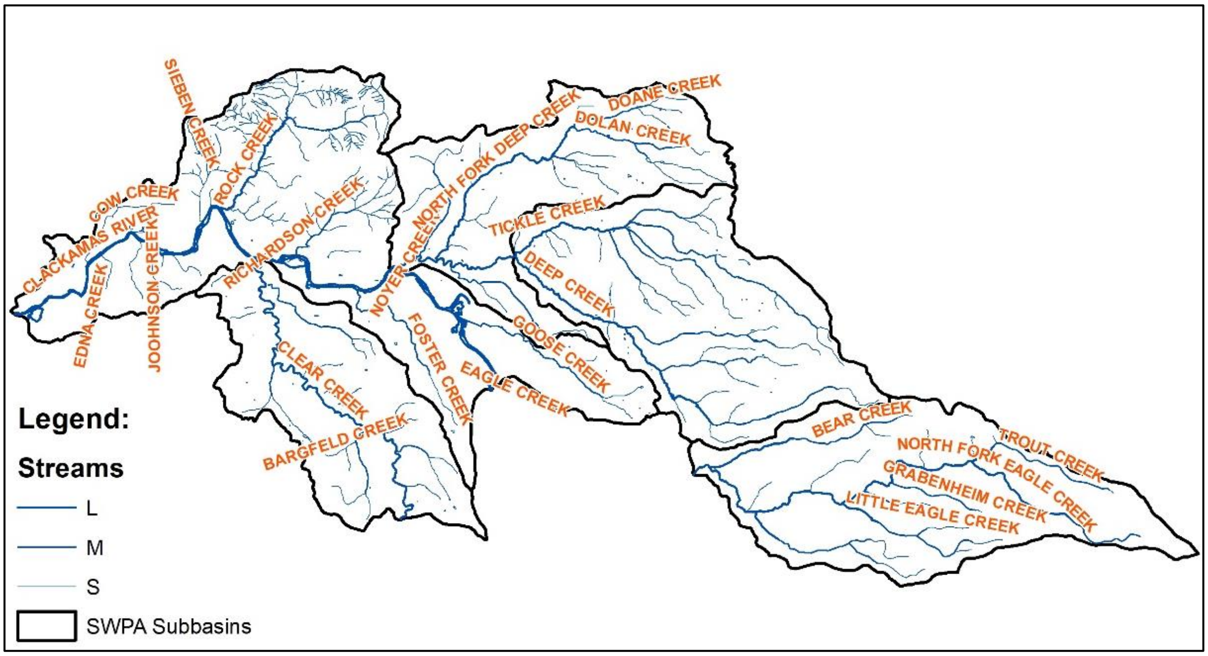

Figure 21: Large (average annual flow > 10 cfs), Medium (average annual flow between 2 cfs and 10 cfs), and Small (average annual flow < 2 cfs) streams in the SWP Area.

Flow in the lower Clackamas River is a product of both contributions from the upper basin as well as tributaries and groundwater seepage within the SWP Area. At the USGS gauge near Oregon City (Station ID #14211010), the double-humped trend observed is similar to previous studies of the Clackamas River (**Figure 22**). Daily mean flows, averaged over 20 years of streamflow data, reveal two peaks: one in the winter due to increased precipitation, and one in the spring influenced by snowmelt. Baseflow then gradually decreases throughout the summer. The seasonal hydrograph in Clear Creek, based on one year of data from 1936 to 1937, differs slightly (**Figure 23**). There, the daily average streamflow appears to decrease exponentially from winter to summer. This is to be expected as the basin receives significantly less snowfall than the upper basin, and therefore does not experience significant streamflow due to snowmelt in the spring. The Lower Clear Creek hydrograph also appears flashier during the winter, with conversely flatter baseflow throughout the summer. This could be due the lack of additional years of data compared to the Clackamas River streamflow gauge. It could also be the result of less buffering from groundwater compared to the seepage the Clackamas River receives from its largely undeveloped and relatively infiltrative upper basin. Due to similarities in modeled annual runoff, it can be expected that North Fork Deep Creek-Deep Creek and Tickle Creek-Deep Creek would experience annual hydrographs similar to Lower Clear Creek.

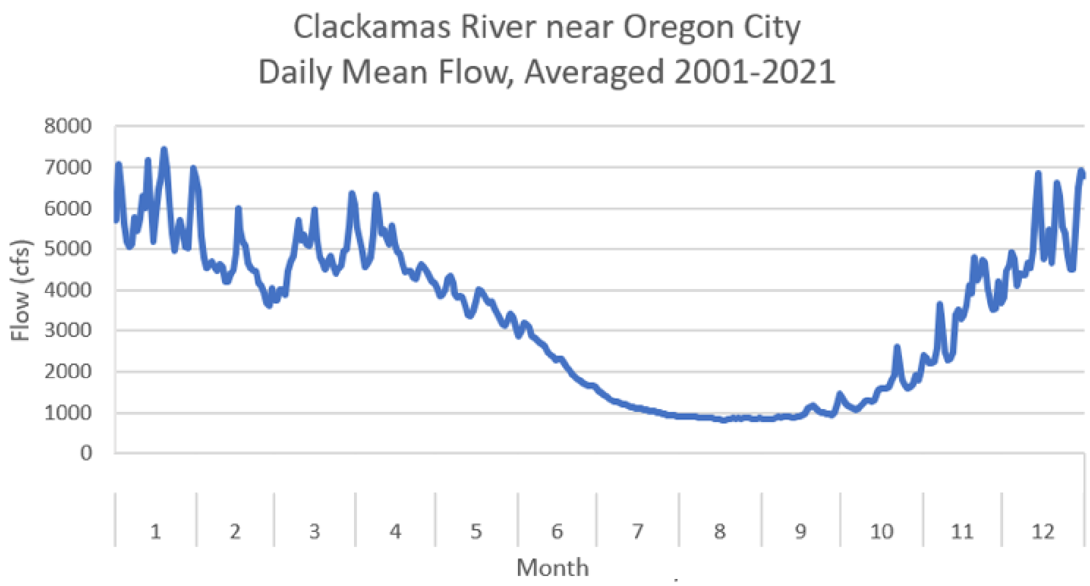

Figure 22: Average annual flow hydrograph for Rock Creek – Clackamas River.

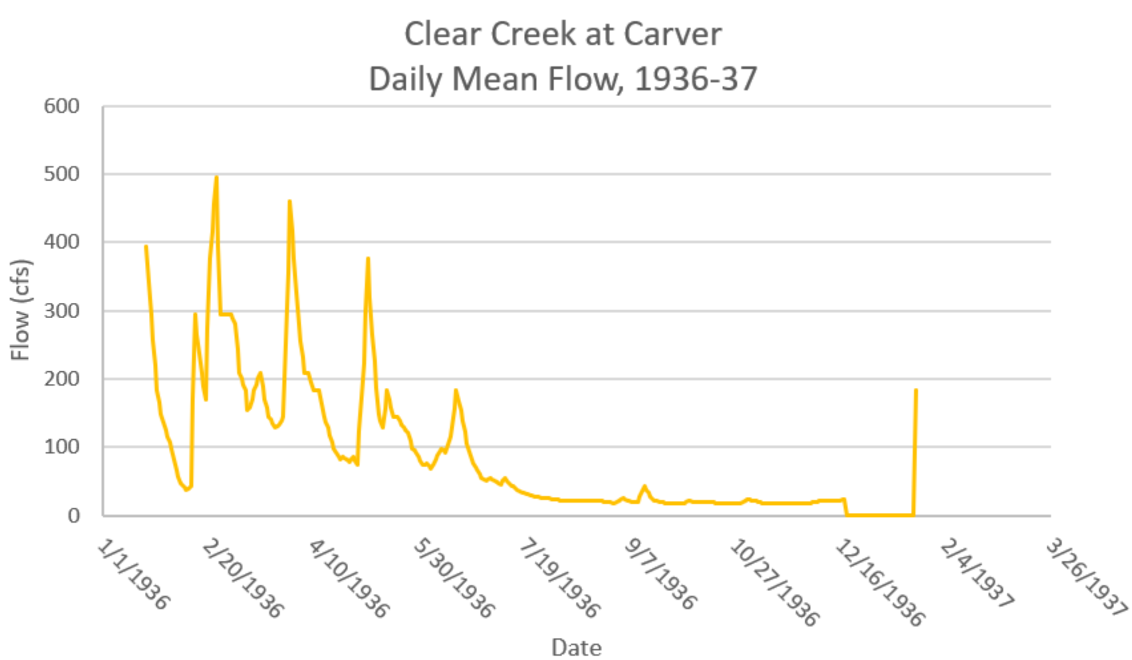

Figure 23: 1936-1937 annual flow hydrograph for Lower Clear Creek.

The above annual and seasonal trends are driven at a fundamental level by individual storm events. Large events can be especially conducive to pollutant transport in surface water. Basins with relatively steep topography and large amounts of impervious areas—Sieben, Rock, and Richardson Creek basins, for example — respond quickly to rainfall and are often highly turbid after storms (Carpenter, 2003). The types of events, and hydrologic responses increase the potential transport of dissolved and sediment-bound contaminants to tributaries and the Clackamas River from these basins.

As of 2019, the Clackamas subbasin had approximately 716 cfs of appropriated for consumptive use, 58 cfs of which are allocated for irrigation of approximately 14,800 acres of agricultural land (ODA, 2019). It is expected that withdraws for irrigation would be highest in the drier summer months, but the seasonality of these withdraws is unknown and would be an area of future work.

4.1.1.1. Potential Impact to the Source Water Protection Plan

Surface water hydrology in the SWP Area provides the primary transport mechanism for pollutants coming off the land into local creeks and entering the lower Clackamas River. Large events can be especially conducive to pollutant transport in surface water. Basins with relatively steep topography and large amounts of impervious areas—Sieben, Rock, and Richardson Creek basins within the Rock Creek – Clackamas River Subbasin, for example—respond quickly to rainfall and are often highly turbid after storms (Carpenter, 2003). The types of events, and hydrologic responses increase the potential transport of dissolved and sediment-bound contaminants to tributaries and the Clackamas River from these basins. Additionally, the Rock Creek – Clackamas River, Lower Clear Creek, and North Fork Deep Creek – Deep Creek subbasins have tributaries that flow directly into the Lower Clackamas River mainstem. Thus, water quality in the lower Clackamas may be more sensitive to runoff from these subbasins.

4.1.2. Geology and Hydrogeology

As introduced in **Section 3.4.3**., the majority of the SWP Area lies within the Willamette Lowland hydrogeologic region. It should also be noted that a small amount of land in the upland area of North Fork Eagle Creek resides in the Western Cascade region (see **Figure 11**). The geologic regions underlying the SWP Area (as defined by Herrera et al., 2014), consist primarily of the relatively permeable upper sedimentary and middle sedimentary units. Some patches of the less-permeable lower sedimentary and confining bedrock units are also distributed within the higher-elevation subbasins (**Figure 24**).

The specific hydrologic and geologic regions underlying the SWP Area are of interest because many studies have been done to characterize and understand the relative differences in groundwater flow and groundwater-surface water interactions. Although such studies are often inherently uncertain or qualitative, some numeric modeling has been done in the Willamette Basin, including the lower Clackamas Basin and the SWP Area (Conlon et al., 2005 and Herrera et al., 2014), to quantify approximate groundwater budgets and fluxes. Whether quantitative or qualitative, these models provide a helpful narrative for ascertaining the effect of different components of the groundwater system on potential pollutant transport from certain areas. Limited hydraulic connectivity of groundwater, as suggested by the geology and soils of upland areas of the SWP Area, may prevent groundwater that infiltrated in upland areas from reaching the mainstem of the Clackamas. It's also possible that relatively long residence time in the groundwater, where transport is inhibited by the low conductivity soils, could result in the degradation of pollutant compounds to more inert forms. Conversely, it is likely that infiltration that enters groundwater near the Clackamas River mainstem quickly makes its way into the river due to the high hydraulic conductivity of the soils along the lower Clackamas (where the reach is gaining, as discussed in **Section 4.1.2.2**.).

General components of the groundwater budget in the SWP Area include recharge and discharge. Each of these can be further broken down by the source of the water entering groundwater storage, or the destination of the water leaving. Sources of recharge include precipitation and seepage from stream beds. Discharges include pumping from wells and seepage into streams. The approximate magnitudes of each of these components of the surface-groundwater balance have been estimated by previous studies (Conlon et al., 2005). The sections below refer to these specific studies to illustrate the spatial variation in magnitude and direction of groundwater flow and possible implications for pollutant transport within the basin.

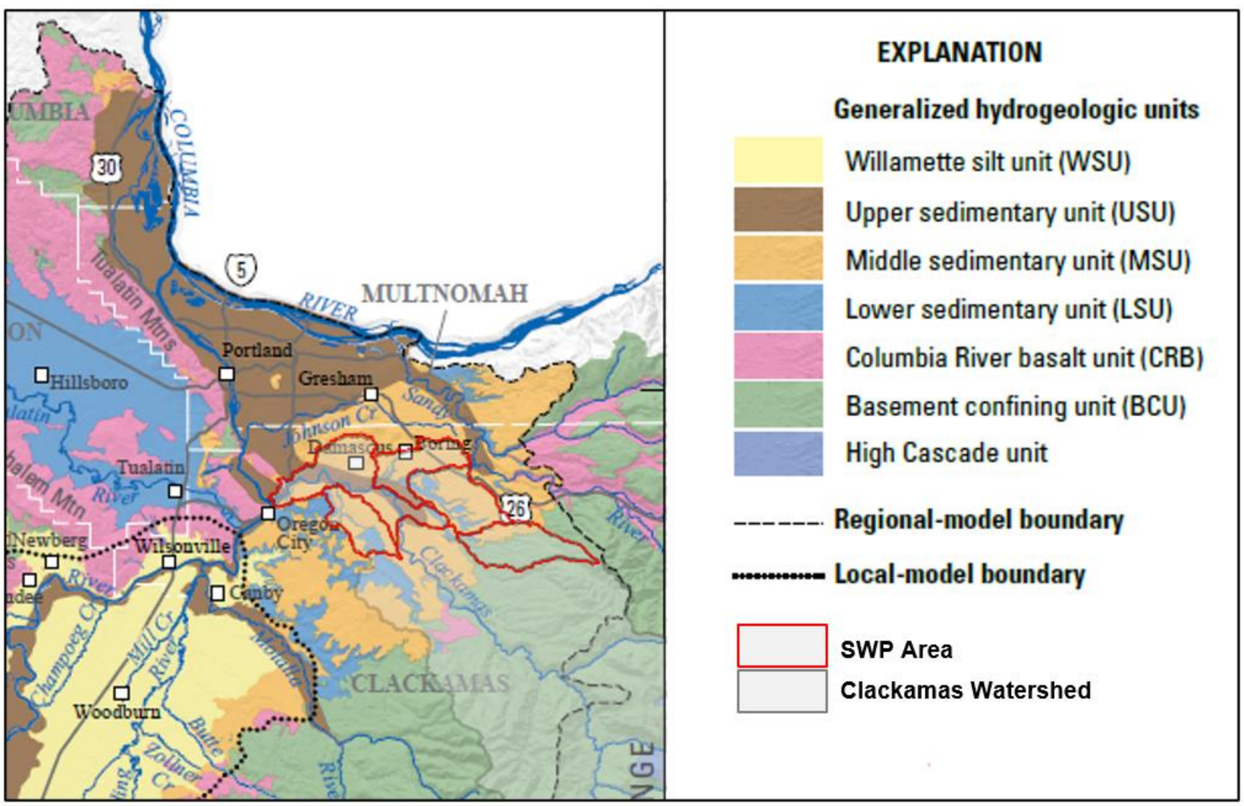

Figure 24: Geologic regions underlying the SWP Area and surrounding area.

4.1.2.1. Groundwater Recharge

A simulation of recharge rates in the Willamette Basin during water years 1995-1996 (Herrera et al., 2014) suggests that average recharge rates in the majority of the SWP Area could range from 15 to 25 inches per year (**Figure 25**). The spatial variability is closely tied to precipitation patterns

(**Section 3.5.2**.) such that lower-elevation areas in the basin, which receive less precipitation, also expect less recharge. According to a Precipitation Runoff Modeling System (PRMS) model that USGS developed for this study the SWP Area subbasin that receives the most recharge in inches per year is North Fork Eagle Creek, followed by Lower Clear Creek, Tickle Creek-Deep Creek, and North Fork Deep Creek-Deep Creek. Some areas of Rock Creek-Clackamas River are expected to receive the least amount of average annual recharge in the SWP Area, with a previous study indicating the precipitation rates could be as low as 7 inches per year (Conlon et al., 2005). One implication of the close correspondence of precipitation and recharge is that recharge varies seasonally; fall precipitation replenishes soil moisture in the unsaturated zone so winter precipitation is then available for recharge (and runoff), spring brings higher evapotranspiration and runoff and so less recharge, and finally summer evapotranspiration and low precipitation allow for little-to-no recharge.

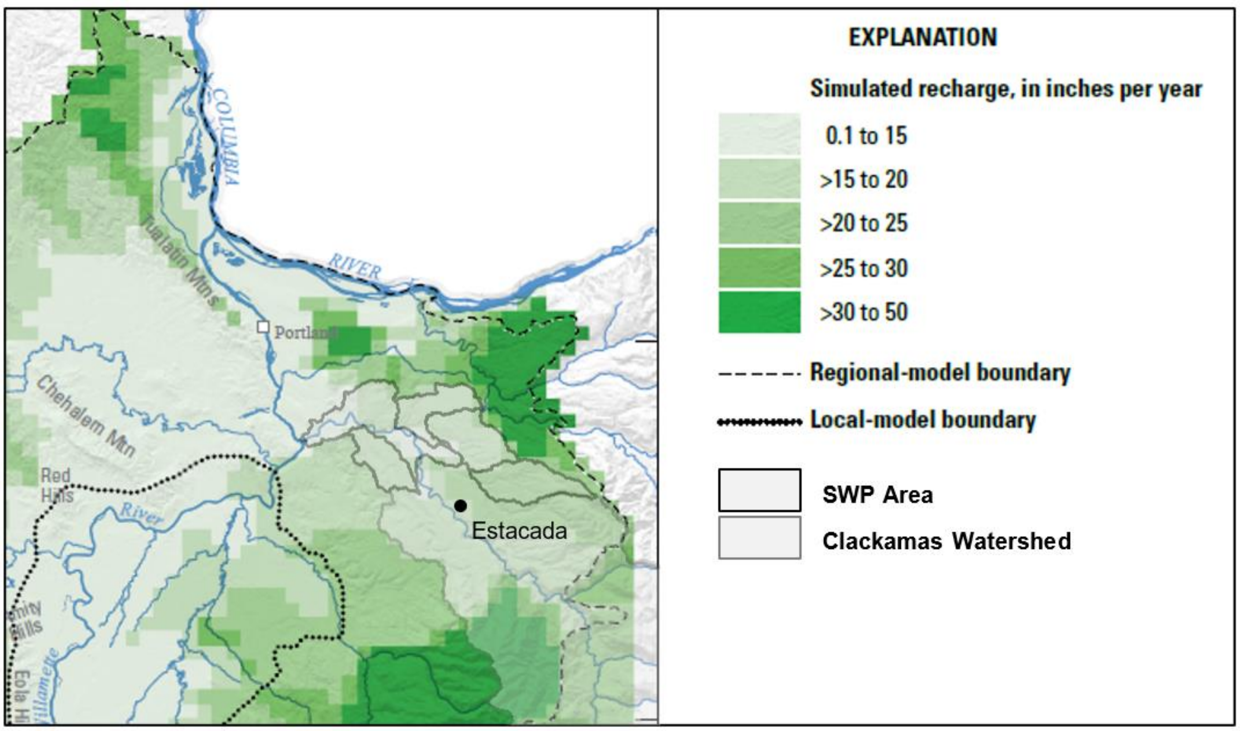

Figure 25: Simulated recharge rates in the SWP Area and surrounding area.

However, the PRMS model used for these recharge simulations does not capture the full effects of the hydrogeology of the region. The model simulation over-estimates the recharge in the Western Cascade area due to its inability to represent the way the steep slopes and low-permeability bedrock of this region cause infiltrated water to remain in the soil zone as shallow interflow before discharging to Western-Cascade streams (Conlon et al., 2005). Furthermore, studies suggest that much of the recharge infiltrating readily into the High Cascade area, from precipitation and snow melt in the upper-most part of the watershed, re-emerges as springs in the Western Cascade and discharges to streams in this region (Conlon et al., 2005). The implication is the groundwater recharge in regions above the SWP Area is largely unavailable as groundwater inflow to the Lowland area. Thus, it can be assumed that recharge to the Lowland areas of the SWP Area is due to local precipitation and is the source of most groundwater resources in the SWP Area.

4.1.2.2. Groundwater Discharge

One of the primary mechanisms of groundwater discharge is groundwater-surface water interactions at streams. In the Lowland area, including in the SWP Area, groundwater discharges to streams, but its contribution to annual streamflow is relatively small due to the dominance of wet-season runoff (Conlon et al., 2005). During the rainy winters, both runoff and groundwater discharge contribute to streamflow. In the dry summers, groundwater is the main component of streamflow and discharges at a low rate from local streams. As groundwater levels decline during summer, groundwater discharge to streams decreases. In fact, compared to the High Cascade and Western Cascade regions of the basin, late-summer gains in lower Clackamas River streamflow from groundwater are effectively negligible (Lee, 2011). On an average annual basis, the relative magnitudes of groundwater-surface water interactions in the SWP Area can be determined from seepage studies and analysis of the hydrogeologic setting of the streams in the SWP Area. This can be expressed by gaining and losing stream reaches, where gaining reaches receive more groundwater than infiltrates from the stream bed, and the reverse for losing reaches. A 2011 seepage study found gaining or losing trends in various river reaches of the Clackamas River itself that pass through the SWP Area (**Figure 26**). The loss in streamflow between Estacada and Barton is attributable to infiltration into recently reworked streambed sediments (Lee, 2011). The streamflow gain between Barton and Carver is attributable to a basin-scale constriction in the stream channel that forces subsurface flow to the active stream channel through shallow stream deposits overlying relatively impermeable sandstone. Downstream of Carver, the stream intersects permeable Pleistocene flood deposits and loses streamflow between Carver and USGS Gage 14211000 near Clackamas.

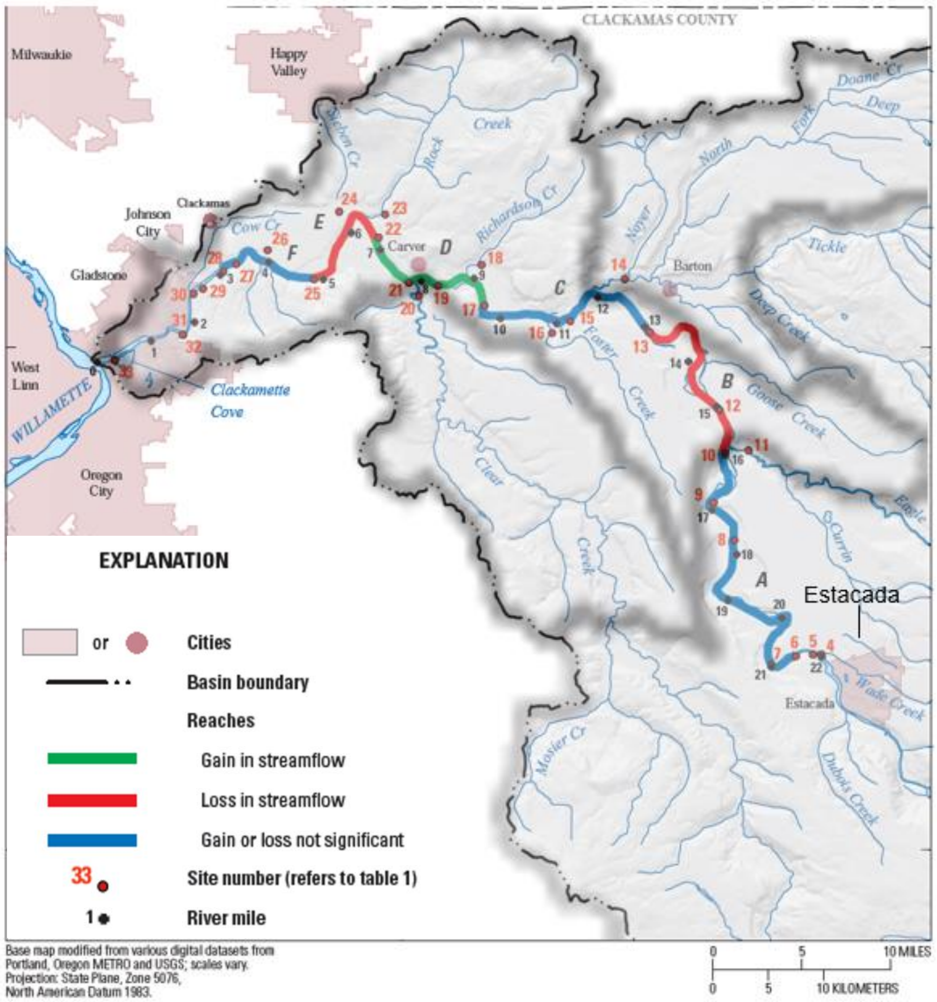

Figure 26: Gaining and losing reaches in the SWP Area, primarily through subbasin Rock Creek-Clackamas River.

Prior seepage studies from a 1996 report lend insight into groundwater-surface water interactions in tributaries to the Clackamas River within the SWP Area. Tickle Creek, Deep Creek, and Noyer Creek, which flow through subbasins Tickle Creek-Deep Creek and/or North Fork Deep Creek-Deep Creek, cut deeply through the Troutdale gravel aquifer (McFarland and Morgan, 1996). Thus, the groundwater flow directions within that area of the aquifer are controlled by these streams, causing a significant amount of seepage (1-2.5 cfs per stream mile) to discharge into them from groundwater. However, in a later modeling study (Herrera et al., 2014), the underlying geologic units along these stream channels led to the conclusion these tributaries are likely losing reaches (**Figure 27**). On the other side of the Clackamas River, the model suggests the portion of Clear Creek within the Lower Clear Creek subbasin is possibly a gaining reach.

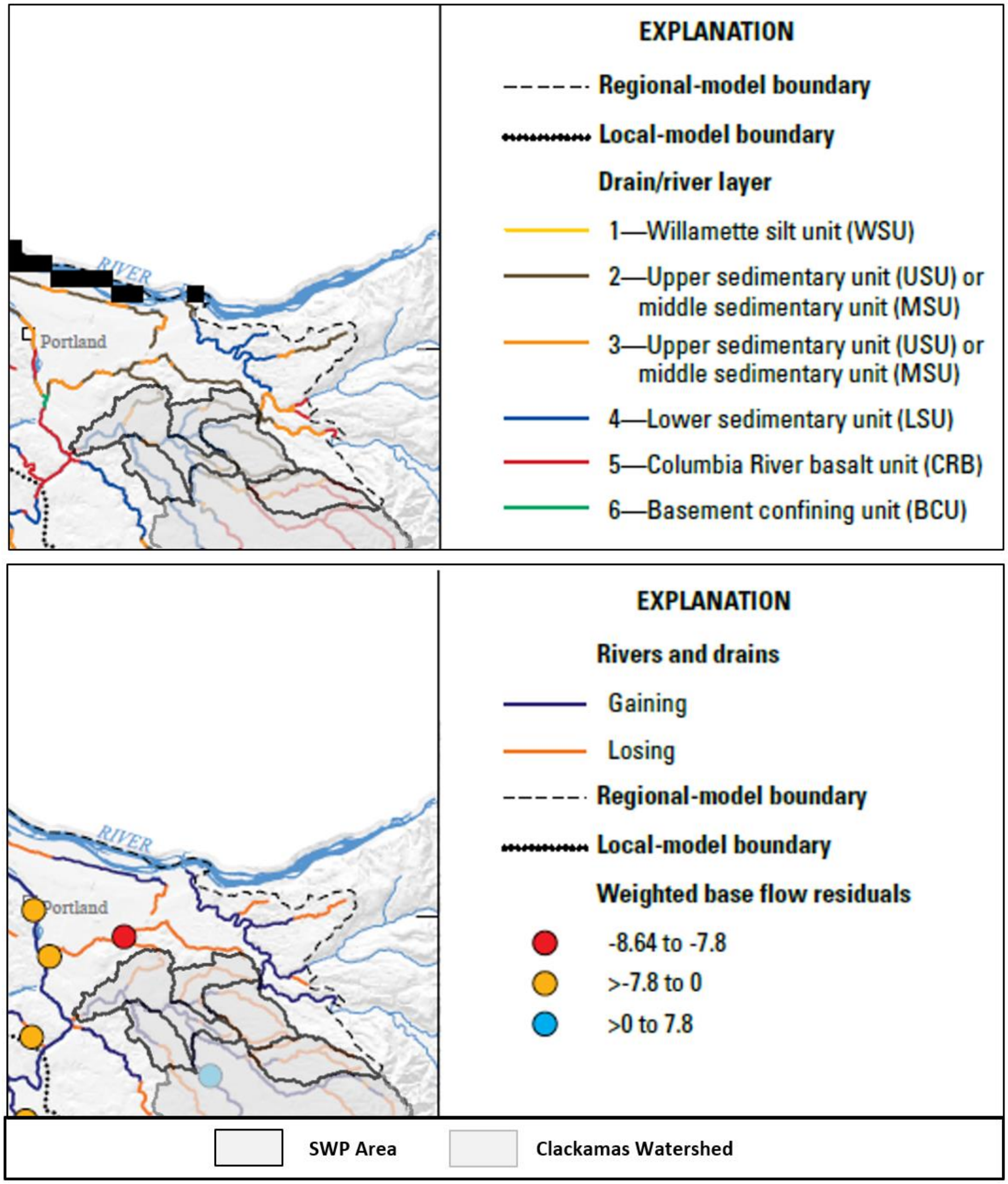

Figure 27: Stream channel geology (top) and simulated net groundwater-surface water interaction (bottom).

Another component of discharge from groundwater is pumping from wells. Although not much quantitative data is readily available with which to calculate pumping rates from distinct wells within the SWP Area, previous studies (Conlon et al., 2005) allow for generalizations about mean annual groundwater withdrawals in each subbasin based on water-years 1995-1996 (**Figure 28**). The primary use for pumped groundwater in the SWP Area at that time was irrigation, with a lesser amount of pumping for domestic supply. Average pump rates range from approximately 100 to 500 acre-feet per year in Rock Creek-Clackamas River, Lower Clear Creek, and North Fork Deep Creek-Deep Creek. Data suggests that the highest rate of pumping (up to 1,000 acre-feet per year) occurs near Damascus in the Rock Creek-Clackamas River subbasin, which depends on groundwater for its drinking water supply. Little pumping appears to occur in the Tickle Creek-Deep Creek and North Fork Eagle Creek subbasins.

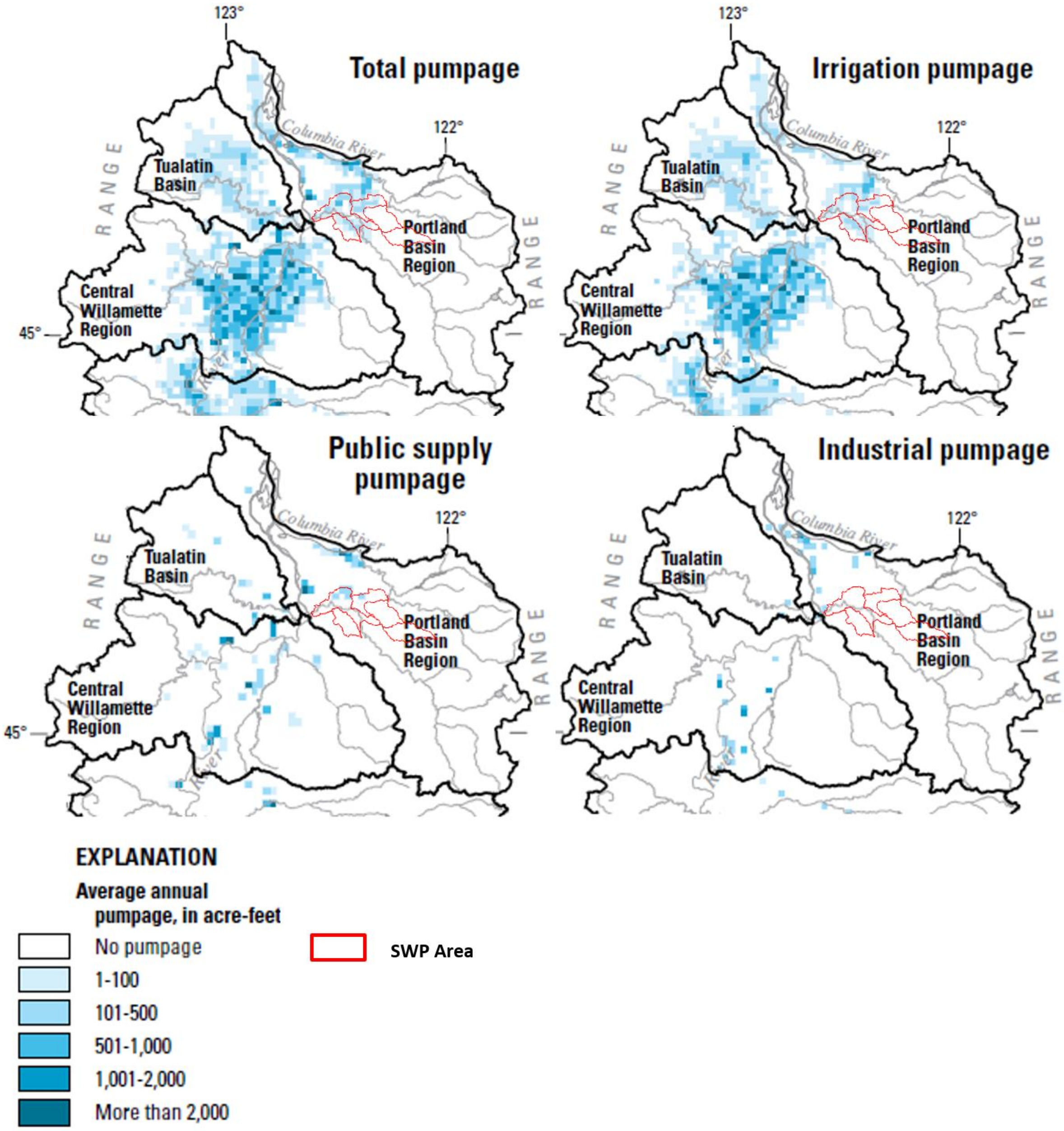

Figure 28: Average annual pumpage and use in the SWP Area and surrounding area (Conlon et al., 2005).

4.1.2.3. Potential Impact to the Source Water Protection Plan

Overall, there is insufficient data with which to draw quantitative conclusions about how groundwater flow affects the full path of potential pollutant transport, from initial infiltration to transport to streams. However, the local recharge and discharge patterns within subbasins provide anecdotal evidence for which regions have the greatest likelihood for potentially pollutant-laden infiltration to reach groundwater, and whether it is likely that this water will flow directly to a stream or rather experience a longer residence time. Generally, it can be expected that North Fork Eagle Creek, Lower Clear Creek, Tickle Creek-Deep Creek, and North Fork Deep Creek-Deep Creek experience the greatest amount of groundwater recharge from precipitation and, therefore, the highest potential for infiltration of pollutants. However, the soils and hydrogeology of these reaches are not as conducive to transport of groundwater as the lower Rock Creek-Clackamas River subbasin. Groundwater in these upper subbasins travels from upland to lowland areas, with potential interference from domestic supply and irrigation pumping. Groundwater from these subbasins may be viewed as unlikely to seep into tributary streams due to their losing characteristics. Although it is possible that it may enter the gaining portions of the Clackamas River mainstem during the wet season, it is likely that contaminated groundwater that has traveled this far from its source has experienced a longer residence time, resulting in potential attenuation and transformation. The potential overall effect of groundwater transport will depend on the pollutant characteristics and on the source. For example, Carpenter (2003) identified high nutrient contributions to the lower Clackamas River from shallow wells and seeps. However due to the limited scope and high uncertainty of this study and other studies (Conlon et al., 2005), the seepage volume and associated loads have not been quantified.

4.2. <u>Water Quality</u>

4.2.1. Ambient Water Quality

Over the last several decades, multiple studies of ambient water quality in the Lower Clackamas Basin have been conducted in response to concerns over drinking water quality and fish species endangerment. To continue providing clean water for drinking and supporting cold-water fish species, the Clackamas River must maintain high quality cold water that is well-oxygenated and low in chemical contaminants. The primary metrics of water quality that are tracked to support this effort include temperature, pH, DO, nutrients (nitrogen and phosphorous), bacteria (*E. coli*), gasoline hydrocarbons, and pesticides. Note that that some constituents lack comprehensive or recent data, which may impact conclusions that may be drawn either basin-wide or temporally.

4.2.1.1. Temperature, pH, DO, and E. Coli

A 2003 study of water quality and algal conditions found that water temperatures in the mainstem Clackamas River are generally cold, but between May and July may increase to levels that exceed the State water quality criteria of 12.8°C in July (Carpenter, 2003). This was consistent with the trend seen over the prior 15 years and was determined to be exacerbated by PGE reservoirs upstream of the SWP Area, as well as the inputs of relatively warm water from tributaries within the SWP Area. The DEQ has listed the lower 23 miles of the river (from River Mill Dam to the mouth) on the 303 (d) list of water bodies considered water-quality limited because of persistent high water temperatures during summer (DEQ, 2020). The Clackamas Basin is now governed by a temperature Total Maximum Daily Load (TMDL) (DEQ, 2006).

Carpenter (2003) also found the concentrations of DO and pH potentially exceed state water-quality criteria in the Lower Clackamas River during some seasons. Samples indicated that DO was closely controlled by temperature, except where algal photosynthesis caused DO concentrations to plummet at night. The lowest measurements of DO concentrations within tributaries occurred at sampling sites in Clear, Eagle, Deep, and Rock Creeks in August. Similarly, pH fluctuations leading to exceedances were also observed in the Lower Clackamas River during late summer. However, the only tributary that exhibited a pH exceedance was Deep Creek. Low DO may be considered a potential issue of concern as it is a strong indicator for the presence of organic pollution.

Additionally, the Clackamas River experiences high levels of *E. coli* bacteria during the summer. DEQ has listed the lower 15 miles of the Clackamas River for *E. coli* bacteria (DEQ, 2020). This portion of the mainstem Clackamas River, as well as many of the lower tributaries including Rock, Sieben, Deep, North Fork Deep, and Tickle Creeks, are governed by a bacteria TMDL (DEQ, 2006).

4.2.1.2. Nitrogen and Phosphorous

Ambient concentrations of nutrients are of particular concern, as nutrient enrichment can cause algal growth and, if left unchecked, eutrophication. Carpenter (2003) found the nitrate concentrations at sampling locations within in Clear Creek, Eagle Creek, and North Fork Clackamas River significantly exceeded the US Environmental Protection Agency (EPA) recommendation. Compounded by naturally high total phosphorous (TP) concentrations in the mainstem Clackamas River which is likely sourced from the young volcanic rocks in the upper basin, the nitrogen influx from the tributaries in the SWP Area may support algal growth, as well. Additionally, some lower tributaries including Deep, Richardson, Rock, and Sieben Creeks had much higher nutrient concentrations compared with other sites, likely reflecting anthropogenic activities. Due to the relatively low streamflow in Richardson, Rock, and Sieben Creeks, they contribute smaller loads of nutrients to the Lower Clackamas River despite their high nutrient concentrations. Deep Creek, however, has higher flow and contributed relatively large loads of both nitrogen and phosphorus to the Clackamas River.

Table *8* presents the USGS's study findings for temperature, pH, DO, and nutrients (Carpenter, 2003). It may be useful to note how the metrics from this table can be interpretated in terms of concentration, load, and yield. By examining nutrient concentration data, it can be observed that, in most streams, NO_3^- (nitrate) was the dominant form of nitrogen, although NH_4^+ (indicating both ammonia and ammonium regardless of pH) was also occasionally detected at low concentrations. Furthermore, nitrate concentrations at tributary sites in the lower Clackamas River basin (Sieben, Rock, Richardson, and Deep Creeks) were 10 to 20 times higher than at sites in the middle Clackamas River basin (Clear and Eagle Creeks), which were in turn 10 to 20 times higher than sites in the upper Clackamas River basin. Nutrient load, on the other hand, considers the streamflow to estimate total nutrient discharge from tributaries to the Clackamas River mainstem.

For example, Sieben Creek, with its exceptionally high nitrogen concentration (7,500 μg/L) contributed four times as much nitrogen as Rock Creek, even though the Sieben Creek Basin is four times smaller by volumetric flow rate. Finally, nutrient yield considers basin area, to represent the runoff potency from the land surface draining to each tributary. It can be determined that, for instance, the highest dissolved inorganic nitrogen (DIN, including NO_3^- + NH_4^+) yields (loads per unit basin area) were observed from lower Clackamas River basin and the middle Clackamas River basin tributary sites.

One other metric of interest in **Table *8*** is the nitrogen-to-phosphorus ratio. The DIN:SRP (soluble reactive phosphorous) ratio (in other words, the relative availability of dissolved inorganic forms of nitrogen [N] and phosphorus [P]) is often used to indicate which nutrient might be regulating algal growth (Carpenter, 2003). Under certain conditions, this may be used to focus nutrient mitigation efforts on sources of either P or N. A ratio of roughly seven indicates balanced nutrient availability, whereas higher ratios may indicate P limitation, and lower ratios may indicate N limitation. DIN:SRP ratios were less than seven at the main-stem sites, owing to the low N concentrations at sites in the upper basin, suggesting limitation by N. In contrast, DIN:SRP ratios were greater than seven at the tributary sites in the middle and lower Clackamas River basin, owing to the relative abundance of NO_3- at both the middle and lower Clackamas River basin sites. This suggests that P could potentially be limiting algal growth in middle Clackamas River basin tributary sites. However, the high P concentrations at lower Clackamas River basin tributary sites suggest P is probably not limiting algal growth in those parts of the SWP Area, despite the high DIN:SRP ratios.

Table 8: Basin characteristics and environmental conditions at sites sampled in the Clackamas River Basin, July 1998 (Carpenter 2003).

	Main-stem Clackamas River sites								Upper- and middle-basin tributary sites											Lower-basin tributary sites				
	CR_UPPER	CR_3LYNX	CR_ABNFK	CR_BLNFK	CR_MCIVER	CR_BARTON	CR_CARVER	CR_99E	COLLA	OAK_BLTLK	OAK_RAIN	ROARING	FISH	SFCLACK	WINSLOW	FALL	NFCLACK	EAGLE_W	EAGLE_M	CLEAR	DEEP	RICHARDSON	ROCK	SIEBEN
BASIN CHARACTERISTICS																								
Basin area (mi^2)	157	489	602	668	680	785	920	942	150	55	141	43	45	28	7	3	32	15	90	72	49	4	9	1.8
Stream density (mi/mi^2)	3.1	3.5	3.8	3.9	3.9	4.0	4.0	3.9	4.4	1.6	2.5	5.1	5.4	4.0	4.8	3.0	4.7	6.6	5.5	4.3	3.3	2.9	3.1	2.3
Road density (mi/mi^2)	3.6	3.5	3.4	3.5	3.6	3.6	3.7	3.8	3.1	3.5	3.9	1.4	4.0	4.3	5.3	8.3	4.5	1.4	4.1	4.5	4.3	7.4	6.4	9.5
Urban land (%)	0	0	0	0	1	1	2	3	0	1	1	0	0	0	0	1	0	0	4	4	17	35	24	10
Agricultural land (%)	0	0	0	0	0	1	3	3	0	0	0	0	0	0	0	0	0	0	3	8	11	22	38	27
Mature forest (%)	61	62	63	62	61	59	52	51	67	53	57	77	56	54	80	40	65	91	47	22	6	2	2	3
Nonforest upland (%)	26	23	21	20	20	19	19	19	15	39	32	14	11	11	3	8	5	2	11	18	30	23	17	28
Regrowth forest (%)	13	14	16	17	18	19	22	22	17	3	9	8	32	34	16	51	30	7	34	45	31	11	12	15
WATER QUALITY																								
Streamflow (ft^3/s)	342	900	1,230	1,100	1,180	1,620	1,760	1,870	176	100	22	128	48	48	9	7	48	41	125	54	26	1	2	1
Streamflow yield (ft^3/s per mi^2)	2.2	1.8	2.0	1.6	1.7	2.1	1.9	2.0	1.2	1.8	0.2	3.0	1.1	1.7	1.3	2.3	1.5	2.7	1.4	0.8	0.5	0.3	0.2	0.6
Water temperature (°C)	12.7	14.2	14.5	14	14.9	15.1	15.3	16.7	14.1	8.4	15.3	13.5	18.3	15.2	11.8	12.8	na	12.4	15.3	17.1	18.7	16.2	18.3	17.4
Specific conductance (µS/cm)	74	61	57	56	54	52	53	54	47	52	77	37	44	40	31	26	37	35	36	54	81	82	164	256
Dissolved oxygen (mg/L)	9.5	9.4	9.8	9.7	9.8	10.3	9.8	na	9.6	9.6	9.4	9.9	9.6	9.5	9.8	9.5	na	10.2	9.5	9.9	10.1	9.3	9.3	10.2
Dissolved oxygen (% saturation)	94	96	99	96	98	103	98	na	98	91	98	99	106	97	97	94	na	99	95	103	109	96	100	108
pH (standard units)	8	7.9	8	7.7	7.7	7.7	7.6	7.4	7.6	7.9	7.8	7.8	7.9	7.8	7	7.3	7.2	7.5	7.5	7.6	8.8	7.8	7.9	8.4
NH_4^+ (µg/L)	<2	<2	2	<2	<2	<2	2	<2	<2	<2	<2	<2	<2	<2	7	<2	4	<2	6	6	3	9	12	433
NO_3^- (µg/L)	<5	<5	<5	6	<5	8	32	20	<5	<5	5	<5	7	8	43	116	81	9	142	206	1,045	849	810	7,077
SRP (µg/L)	22	11	10	8	7	7	8	7	7	2	24	8	7	7	3	<1	3	<1	2	6	68	26	65	121
TP (µg/L)	21	18	17	13	15	16	20	41	10	13	26	12	12	8	7	6	9	4	10	15	78	32	75	144
DIN:SRP	<0.3	<0.6	<0.7	<1.0	<1.0	1.1	4.3	2.9	<1	3.5	0.3	0.9	1	1	17	>116	28	>9	74	35	15	33	13	62
SiO_2 (mg/L)	25.3	20.0	19.9	19.4	18.8	17.6	18.0	18.7	15.3	na	24.3	17.8	17.6	18.3	18.2	15.2	18.4	14.7	17.5	22.2	18.7	24.3	31.7	32.0
DIN load (kg/d)[a]	<(6)	<(15.4)	6.0	16.2	<(20.2)	31.7	146.4	91.5	<(3.0)	<(1.7)	0.3	<(2.2)	0.8	0.9	1.1	1.9	10	0.9	45.3	28.1	65.4	1.4	4	13.7
SRP load (kg/d)[a]	18.4	24.1	30.1	21.5	20.2	27.7	34.5	32	3	0.5	1.3	2.5	0.8	0.8	0.1	<(.01)	0.4	<(0.1)	0.6	0.8	4.2	0.1	0.3	0.2
TP load (kg/d)	17.6	39.6	51.2	35	43.3	63.4	86.1	187.6	4.3	3.2	1.4	3.8	1.4	0.9	0.2	0.1	1.1	0.4	3.1	2	4.9	0.1	0.4	0.3
ALGAL BIOMASS / CANOPY CONDITIONS																								
Chlorophyll *a* (mg/m^2)	72	226	24	332	276	60	194	55	54	130	95	20	98	137	14	23	48	11	62	235	143	51	186	371
AFDM (g/m^2)	25	218	7	127	65	38	70	25	11	61	20	10	21	23	3	8	18	4	13	27	18	8	29	41
Canopy closure (%)	15	10	16	11	10	2	15	2	16	10	71	81	32	62	97	92	44	98	61	55	74	43	60	85

[a] Values in parentheses represent the nutrient load with concentrations set to the minimum laboratory reporting levels, and therefore represent theoretical maximum values.

4.2.1.3. Organic Compounds

Organic compounds detected in the Lower Clackamas River include different types of gasoline hydrocarbons and pesticides. These compounds are anthropogenic and therefore derive primarily from developed areas or agricultural land. The most commonly detected hydrocarbons include benzene, toluene, ethylbenzene, and xylene, while the most commonly detected pesticides are herbicides such as simazine and atrazine (Carpenter and McGhee, 2009). Detection alone does not necessarily indicate a hazard to human or aquatic health; chemical concentration and load must also be considered.

Both the detection frequency and concentrations of gasoline hydrocarbons cause concern about these compounds. Compared to eight other community water systems across the country sampled as part of a 2008 USGS study, concentrations of several different hydrocarbons, including benzene, toluene, and xylene, were highest in the Clackamas River (Kingsbury et al., 2008). The frequent occurrence of these compounds also indicated a persistent source during much of the year, possibly including vehicle emissions and fumes from fueling stations, runoff from roads and parking lots, leaky underground gasoline storage tanks, and exhaust from watercraft (Carpenter and McGhee, 2009). It should be noted that the frequent occurrence of benzene was likely related to the naturally high concentrations in crude oil from Alaska, which is the primary oil source for gasoline refineries in the Pacific Northwest (DEQ, 2007). Subsequent US EPA legislation required most refineries to reduce benzene levels by 2012, which should help reduce the amount of benzene from gasoline that enters the Clackamas River. However, a follow-up study has not been done to confirm this result.

63 different pesticides compounds have been detected in the Clackamas River and tributaries since 2000. Pesticide compounds include herbicides, insecticides, fungicides, and pesticide degradation products (degradates). Potential uses of pesticides in the Clackamas River basin include applications to Christmas trees, nursery stock and other agricultural crops, landscaping and lawns, roads and other right-of-ways, golf courses, and forestland.

In 2008, a study found that several pesticide concentrations in lower Clackamas River basin tributaries exceeded US EPA aquatic-life benchmarks (ALBs), while several more pesticides exceeded Federal and State of Oregon benchmarks for the protection of fish and benthic invertebrates or other, non-US EPA benchmarks (Carpenter et al, 2008). The tributaries with ALB exceedances for different pesticides compounds are summarized in **Table 9**. The largest pesticide loads were from Rock Creek and two tributaries of Deep Creek (North Fork Deep and Noyer Creeks). The Deep Creek tributaries also contained the largest number of individual pesticides per sample (17-18). These tributaries drain nursery, pasture, and rural residential land. While only a few different pesticide compounds were detected in Clear and Eagle Creeks, which were comparatively undeveloped at the time, the high streamflows resulted in these reaches together contributing over 30% of the total measured atrazine load to the lower Clackamas River in May of

2000 (Carpenter, 2004). Pesticide yields (loads per unit area) were highest in Cow and Carli Creeks – small streams draining urban and industrial areas. Other areas with relatively high pesticide yields included middle Rock Creek and upper Noyer Creek.

Table 9: Exceedances of US EPA and other ALBs for pesticide compounds in the Lower Clackamas Basin.

Pesticide or degradate	Sites and sample dates of aquatic-life benchmark exceedance	Maximum concentrations	Benchmark quotient (BQ)		Aquatic-life benchmark derived from USEPA Office of Water		Aquatic-life benchmark derived from USEPA OPP reregistration eligibility decisions and ecological risk assessments						Aquatic-life benchmark from other agencies				USEPA OPP references
							Fish		Benthic invertebrates		Non-vascular plants (algae) acute-each sample	Vascular plants acute-each sample	Oregon DEQ		NAS/NAE (Maximum concentration-each sample)	Canada (Maximum concentration-each sample)	
			USEPA	Other agency	Acute-each sample	Chronic-4-day average	Acute-each sample	Chronic-60-day average	Acute-each sample	Chronic-21-day average			Acute	Chronic			
Azinphos-methyl	Doane Creek ds Hwy 212 (Sept. 2005)	0.21	21	214		0.01	0.18	[2]0.36	0.08	[2]0.16				0.01	0.001		USEPA (2005b)
Chlorpyrifos	NF Deep Creek at Boring (Sept. 2005)	.17	3.4	167	.083	.041	.9	.57	.05	.04	140		0.083	.041	.001	0.004	USEPA (2000a, 2002)
	Noyer Creek ds Hwy 212 (May/ Sept. 2005)	.14	2.8	140													
	Rock Creek near mouth (Oct. 2000)	.056	1.1	56													
Diazinon	Carli Creek near mouth (Sept. 2005)	.25	2.5	28	.17	.17	45	[3].55	[4,5]0.1	[4].17	3,700		[10].08	[10].05	.009		USEPA (2000b, 2004c)
	Rock Creek at 172nd Ave (Sept. 2005)	.17	1.7	19													
	Sieben Creek at Hwy 224 (May 2000)	.16	1.6	18													
p,p'-DDE[8]	Deep Creek at Hwy 224 (Oct. 2000)	.002	2.4		1.1	0.001							1.1	.001			–
2,4-D	NF Deep C trib at 312th Ave (Sept. 2005)	6.1	0.02	2.0			[6]50,500	[6]14,200	[6]12,500	[6]16,400	[6]3,880	[6]299			3	4	USEPA (2004a)
Carbaryl[9]	Noyer Creek ds Hwy 212 (Sept. 2005)	.15	.1	7.7			[4]125	[4]210	2.55	1.5	1,100				.02	.2	USEPA (2003a)
	Sieben Creek at Hwy 224 (May 2005)	.094	.06	4.7													
	Rock Creek at 172nd Ave (Sept. 2005)	.052	.03	2.6													
	Sieben Creek ds Sunnyside Rd (Sept. 2005)	.026	.02	1.3													
Chlorpyrifos	Clackamas River (source water) (Nov 2002/ May2005)	.006	.12	6.0	0.83	0.41	.9	.57	.05	.04	140		0.083	0.41	.001	.004	USEPA (2002a, 2002)
Chloro-thalonil	Noyer Creek at mouth (May 2005)	.26	.09	1.4			11.5	3	34	39	190					.18	USEPA (1999a)
Dieldrin	Noyer Creek ds Hwy 212 (May/ Sept. 2005)	.024	.43	4.8	0.24	0.056							0.24	0.019	.005		–
	NF Deep C trib at 312th Ave (Sept. 2005)	.01	.04	2													
	Rock Creek near mouth (Oct. 2000)	.008	.03	1.6													
Diuron	Doane Creek at Hwy 212 (Sept. 2005)	2.3	0.94	1.4			355	26	80	[2]160	2.4				1.6		USEPA (2003d)
	NF Deep Creek at Boring (Sept 2005)	1.9	.8	1.2													
Endosulfan[1]	Tickle Creek near Boring (Sept. 2005)	.11	.51	35.2									0.22	0.056	0.003	0.02	
Malathion	Rock Creek near mouth (Sept. 2005)	.05	.79	5.9		0.1	2	[3]4	0.25	0.06				.1	.008		USEPA (2000c)
	Sieben Creek at Hwy 224 (May 2000)	.025	.1	3.1													

One way to interpret the relative severity of these high concentrations of various pesticides is via the Pesticide Toxicity Index (PTI) values for each sample. These values were calculated for both benthic invertebrates and fish. Samples with the highest PTI values, representing the greatest relative risk to aquatic species, are provided in **Figure 29**. The sample with the highest PTI occurred in Tickle Creek near Boring, and was due to the insecticide endosulfan (Carpenter et al., 2008). For the other samples, the PTI values were higher for benthic invertebrates. The greatest risk to these organisms occurred in North Fork Deep, Noyer, Doane, and Rock Creek, followed by Sieben Creek.

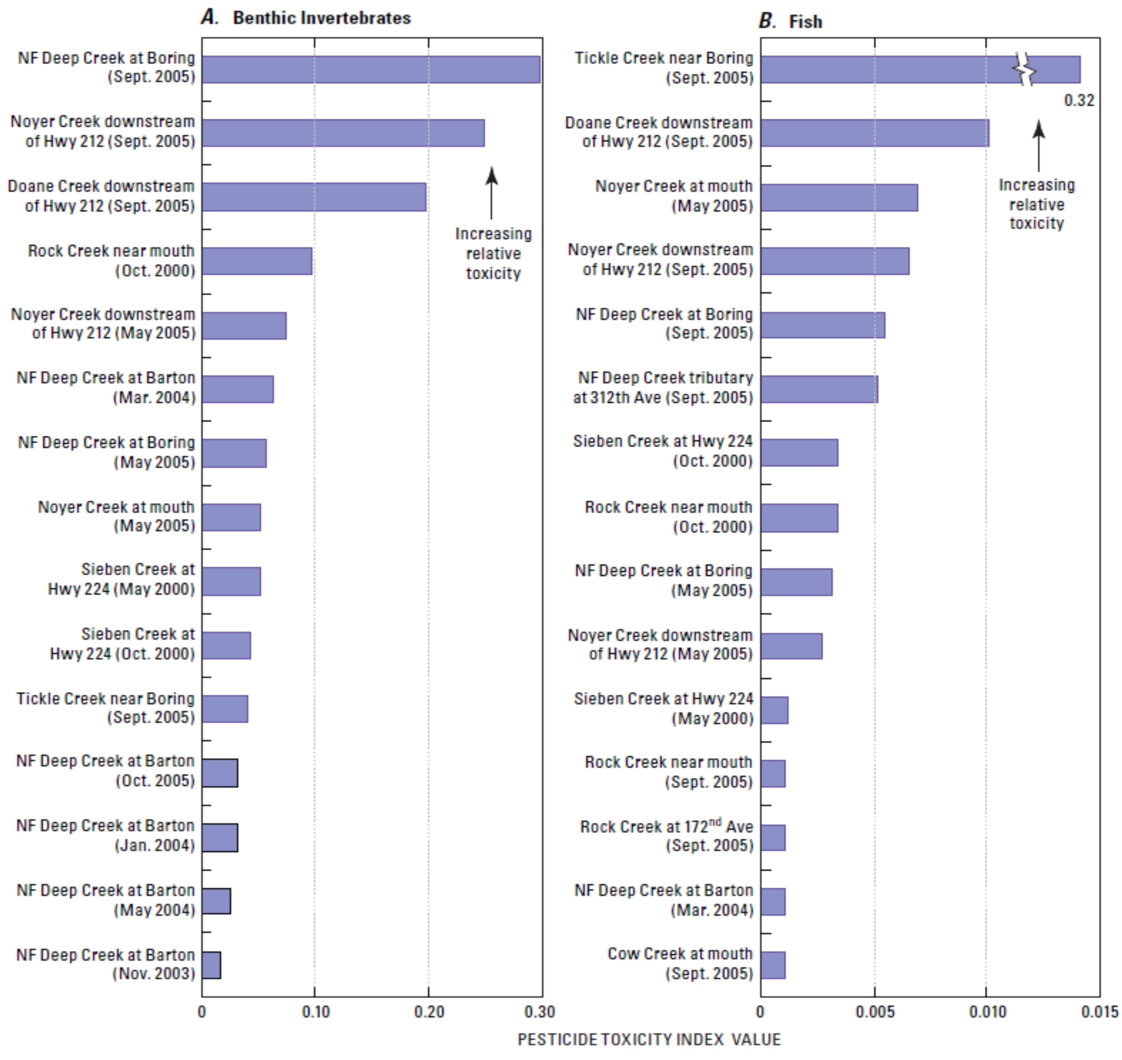

Figure 29: Highest Pesticide Toxicity Index Values for samples from the lower Clackamas River basin, 2000-2005.

Several other patterns of pesticide occurrence were also observed in the 2008 study. First, the two most commonly detected pesticides overall were the herbicides simazine and atrazine, which occurred in about one-half of the samples. Deethylatrazine (a degradate of Atrazine) was detected along with atrazine in about 30 percent of the samples. The active ingredients in the common household herbicides RoundUP™ (Glyphosate) and Crossbow™ (Triclopyr and 2,4-D) were frequently detected together; these three herbicides, especially Glyphosate and Triclopyr, are also strongly associated with pasture and hay (**Section 5.2**) These three herbicides together often made up most of the total pesticide concentration in samples from tributaries throughout the study area (Carpenter et al., 2008).

Since 2005, annual sampling has been performed in North Fork Deep, Noyer, and Sieben Creeks (Kilders and Cloutier, 2021) through the State of Oregon's Pesticide Stewardship Partner program and pesticides continue to be detected each year. In 2021 the Clackamas Pesticide stewardship Partnership Strategic Plan was completed and the result was a framework for ranking certain pesticides into levels of higher or lower concern based on detection frequency and concentration compared to ALBs (**Table 10**). This table does not represent an exhaustive categorization of all pesticide compounds found in the Clackamas River basin. Rather, it is a product of preliminary sampling to inform management efforts. It should also be noted that the table does not include two legacy pesticides: Dieldrin and Silvex.

Table 10: Clackamas Pesticide Strategic Plan Matrix used to rank local pesticides of high, medium, and low concern.

Clackamas PSP Reference Level Criteria (2018-2020)

Frequency of Detection in % Last 3 Years	≥ 1 detection at or above 50% of an acute ALB	≥ 3 detections at or above 50% of a chronic ALB	1 to 2 detections at or above 50% of a chronic ALB	No detections over 50% of any ALB
100 to 65.1	High Level of Concern	High Level of Concern	High Level of Concern	Moderate Level of Concern 2,6-dichlorobenzamide, AMPA, Diuron,
65 to 35.1	High Level of Concern	High Level of Concern	Moderate Level of Concern	Moderate Level of Concern Glyphosate, Simazine
35 to 0	High Level of Concern Chlorpyrifos, Diazinon, Dimethenamid, Imidacloprid, Metsulfuron-methyl, Oxyfluorfen,	High Level of Concern	Moderate Level of Concern Bifenthrin, Carbaryl,	Low Level of Concern See List Below

Pesticides of Low Concern: 2,4-D, Acephate, Acetamiprid, Azoxystrobin, Bromacil, Deisopropylatrazine, Dichlobenil, Dieldrin, Dinoseb, Ethoprop, Hexazinone, Malathion, Metolachlor, Metribuzin, Napropamide, Pendimethalin, Pentachlorophenol, Prometon, Propiconazole, Pyraclostrobin, Sulfometuron-methyl, Tebuthiuron, Triadimefon, Triclopyr

4.2.2. Potential Contaminants of Concern and Sources

The latest Drinking Water Projection Plan for the region (CRWP, 2010) identified potential pathways for pollutant export from the Clackamas River basin. Activities at high-risk of pollutant export included septic systems, agriculture, forestry, vulnerable soils, urban development, and point-source pollutants. Potential pollutants of concern from several of the high-risk activities have been identified as part of previous studies (Schmidt, 2012 and Kilders and Cloutier, 2021). At a general level, the potential contaminants of concern fall into the following categories: sediment, nutrients, heavy metals, pathogens, organic matter, pesticides, and hydrocarbons. The pollutants in each of these categories that have been identified as potential contaminants of concern within the basin are summarized in **Table 11**. The literature sources supporting the inclusion of each pollutant are also indicated.

Table 11: Potential contaminants of concern.

Category	Pollutant	Description
Sediment	Total Suspended Solids (TSS)*	Soil particles that transport pollutants (via adsorption), must be filtered out of drinking water
Nutrient	Total Phosphorous (TP) *	A commonly occurring nutrient, representative of contaminants that are transported with sediments
Nutrient	Nitrate (NO3) *	A commonly occurring nutrient, representative of contaminants that are transported with sediments
Nutrient	Ammonia (NH3) *	Common base for fertilizers used within the watershed
Heavy Metal	Lead (Pb) *	A commonly occurring metal, poses a significant threat to aquatic resources
Heavy Metal	Copper (Cu) *	A commonly occurring metal, poses a significant threat to aquatic resources
Heavy Metal	Zinc (Zn) *	A commonly occurring metal, poses a significant threat to aquatic resources
Pathogen	*E. Coli**	Common pathogen
Hydrocarbon	Oil and Grease*	A common issue where roadways are proximal to watercourses
Organics	Biological Oxygen Demand (BOD) *	Indicates degree of organic pollution
Pesticide	Glyphosphate*,†	Herbicide applied widely within the watershed; water soluble and strongly adsorptive, attaches itself to suspended solids and organic matter
Pesticide	2,4-D*,†	Herbicide; water soluble and, although it has a low soil persistence, it is one of the most commonly detected pesticides due to the high level of application. Full name: 2,4-Dichlorophenoxyacetic acid (2,4-Dichloro)
Pesticide	Carbaryl*,†	Insecticide applied widely to crops, pasture, and home landscapes; adsorbs to organic matter and can be transported in soil runoff. Trade names: Sevin, Drexel
Pesticide	2,6-dichlorobenzamide†	Commonly detected; transported primarily via surface runoff. Trade name: Dichlobenil
Pesticide	AMPA†	Herbicide used in right-of-ways; commonly detected; transported primarily via surface runoff. Full name: Aminomethylphosphonic acid.
Pesticide	Diuron†	Herbicide; commonly detected; transported via drift and runoff. Trade name: Karmex

Category	Pollutant	Description
Pesticide	Simazine†	Herbicide; commonly detected; transported via drift and runoff. Trade name: Princep
Pesticide	Bifenthrin†	Commonly detected; applied to crops and home landscapes; transported via drift and runoff. Trade names: Allectus, Brigade, Talstar
Pesticide	Chlorpyrifos†	Insecticide applied to crops, pasture, and home landscapes; detected in high concentrations; transported via drift and runoff. Trade names: Drexel, Dursban, 50W, Hatchet, Lorsban, Nufos, Vulcan, Yuma
Pesticide	Diazinon†	Insecticide applied to crops and home landscapes; detected in high concentrations; transported via drift and runoff
Pesticide	Dimethenamid†	Herbicide used in agriculture; detected in high concentrations; transported via drift and runoff. Trade names: Outlook, Tower, Frontier
Pesticide	Imidacloprid†	Insecticide applied to crops and home landscapes; detected in high concentrations; transported via drift and runoff. Trade names: Admire, Allectus, Avatar, Adonis, Lesco Bandit, Malice, Marathon, Merit, Midash
Pesticide	Metsulfuron-methyl†	Herbicide used in forestry; detected in high concentrations; transported via drift and runoff. Trade name: Escort
Pesticide	Oxyfluorfen†	Herbicide used in agriculture; detected in high concentrations; transported via drift and runoff. Trade name: Goal
Other	Pharmaceuticals*	Drugs including medication, hormones, and antibiotics

* Schmidt, 2012

† Kilders and Cloutier, 2021

The above pollutants have been identified as potential contaminants of concern for a number of reasons. For some, such as sediment, nutrients, and bacteria, their prevalence is so universal and their detrimental effect on receiving water quality so well understood that mitigative measures are encouraged wherever there’s uncovered soil, fertilizer application, or animal waste. These characteristics apply to many areas within the SWP Area. Of the pesticides listed, some are potentially concerning due to their wide use and/or heavy application rates, some are easily transported due to their solubility and absorptivity, and some take so long to degrade into inert forms they may persist in soils long after the chemicals themselves have been applied. Finally, there is growing concern, but little data, about the potential effects of pharmaceuticals on aquatic species. Of the pollutants listed, nutrients and pesticides were considered the highest threat to drinking water providers; other contaminants such as pathogens, hydrocarbons, and metals can also be mitigated through treatment processes. Suspended solids is considered as a threat as it is closely associated with other pollutant concentrations.

For these pollutants, previous studies suggest the receiving water quality is tied to land use. For example, the highest concentrations of both nitrogen and phosphorus during a past study (Carpenter, 2003), and the highest algal biomass for a lower basin tributary, occurred in Sieben Creek, which drains a watershed undergoing rapid urbanization. The excessively high concentration of nitrate in Sieben Creek (>7,000 μg/L) may have resulted from applications of fertilizer on urban or agricultural land in the basin, or from leaky septic systems by comparison, overall fewer pesticide compounds have been detected in storm-runoff samples collected from largely undeveloped Eagle and Clear Creeks in May and October 2000 (2 and 5 pesticides each, respectively) compared with streams draining agricultural or urban land.

Land uses in the SWP Area include different types of crops, animal activities including CAFOs, fish hatcheries, developed land, and septic systems (Schmidt, 2012). It has been estimated that as much as one-half of agricultural pesticide use in the Clackamas River basin could be on nursery, floriculture, and greenhouse crops, with lesser amounts applied to pastureland, Christmas trees, alfalfa and hay fields, hazelnut orchards, and grass seed fields (Carpenter et al., 2008). The extent of pesticide use on the six golf courses in the Clackamas River basin is unknown, although about 50 percent of the pesticides detected in the Clackamas River basin have reported use on golf courses (Barbash, 1998). Several subbasins in the SWP Area also receive urban discharge. North Fork Deep and Tickle Creeks receive treated wastewater effluent from the community of Boring and the City of Sandy, respectively. In addition, 194 areas with septic systems and 27 large capacity septic systems in the Clackamas River basin have potential to release wastewater to ground water flowing into the Clackamas River (DEQ, 2003). A matrix of pollutants and their corresponding uses/potential sources is provided in **Table 12**.

For the purposes of this SWAP, agricultural practices will be the focus of primary sources of contaminants, as opposed to urban activities, forestry, or other sources associated with development.

Table 12: Sources of potential contaminants of concern.

Source / Pollutant	Berry Growers	Christmas Tree Farms	Hazelnut Growers	Nursery & Greenhouse	Pasture/Hay	Vegetable Growers	Veg Seed Growers	CAFOs/Stables/Kennels	Fish Hatcheries	Forestry	Home Landscapes	Turfgrass	Right of Way/Roads	Urban Development	Chem/Mech Facilities	Septic Systems
TSS[*]	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
Nitrogen[*]	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
Phosphorous[*]	X	X	X	X	X	X	X		X	X	X	X	X	X		X
Ammonia[*]	X	X	X	X	X	X	X		X		X	X				X
E. Coli[*]								X	X							X
BOD[*]								X	X							X
Lead[*]													X	X	X	X
Copper[*]													X	X	X	X
Zinc[*]													X	X	X	X
Oil and Grease[*]													X	X	X	
2,4-D[*,†]	X	X	X		X	X										
AMPA													X			
Bifenthrin	X	X	X			X	X				X	X				
Carbaryl[*,†]	X	X	X	X	X	X	X				X	X				
Chlorpyrifos[†]		X	X	X	X	X					X	X				
Diazinon[†]	X		X	X		X					X					
Dimethenamid[†]				X		X										
Diuron[†]	X		X	X		X										
Glyphosphate[*,†]	X	X	X	X	X	X										
Imidacloprid[†]	X	X	X	X		X					X	X				
Metsulfuron-methyl[†]										X						
Oxyfluorfen[†]				X												
Simazine[†]	X	X	X	X		X										
Pharmaceuticals[*]								X	X							X

[*] Schmidt, 2012
[†] Kilders and Cloutier, 2021

Any approach to mitigating contaminants of concern in the SWP Area will be closely dependent on relative distributions of pollutant sources within the subbasins. As discussed in **Section 3.3.2.**, the subbasins are composed of broad land use categories (also shown in **Figure 30**).

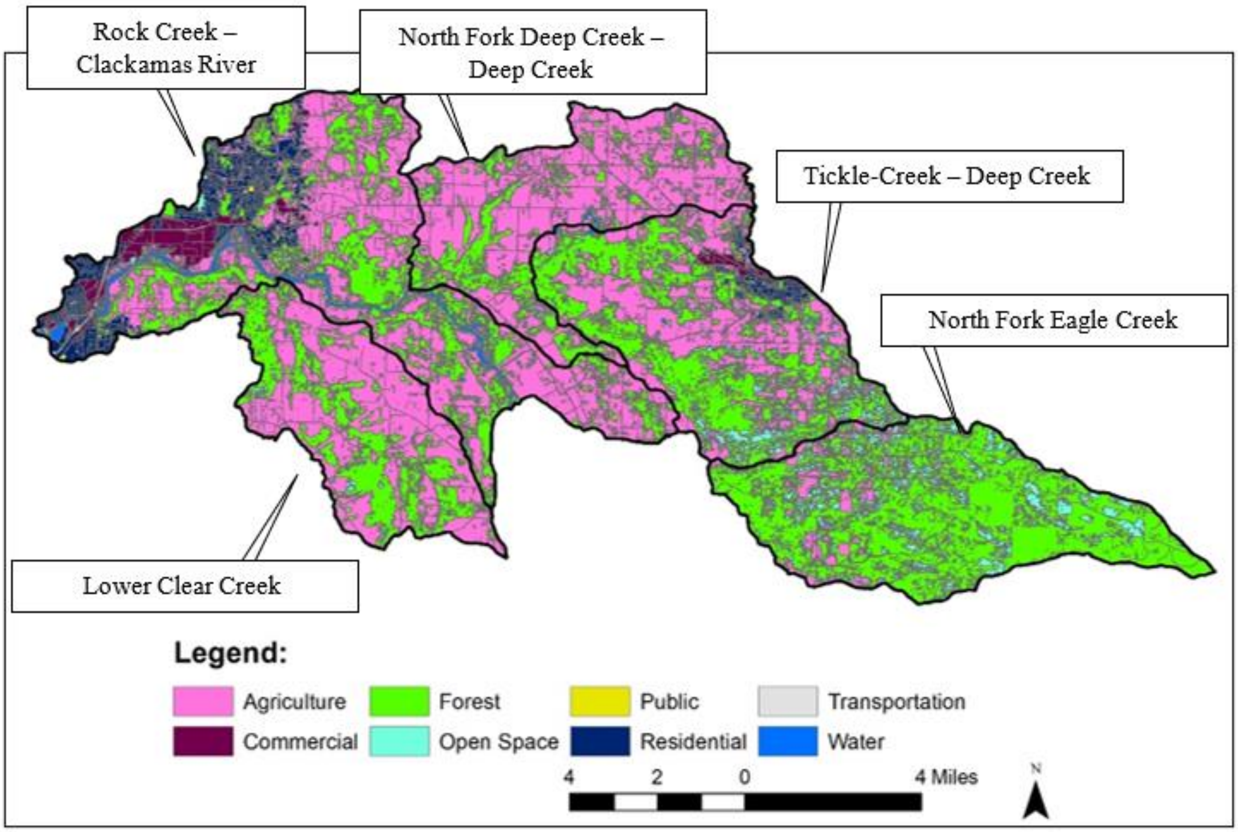

Figure 30: Land use in the SWP Area subbasins.

The land use distributions are broken down by subbasin in **Table 13**. Orange highlighted entries identify the primary land use category, yellow highlighted - the secondary, and green highlighted the tertiary. For most subbasins (Lower Clear Creek, North Fork Deep Creek – Deep Creek, and Rock Creek – Clackamas River), the primary land use is agriculture, accounting for at least 40% and up to 70% of the land area within the subbasins. For the other two subbasins (North Fork Eagle Creek and Tickle Creek – Deep Creek), forest is the primary land use, with approximately the same percent area range represented (40-70%). For most subbasins (again, Lower Clear Creek, North Fork Deep Creek – Deep Creek, and Rock Creek – Clackamas River, in particular), the secondary land use is forest, at 20-30%. Agriculture is secondary in Tickle Creek – Deep Creek, and open space (including shrubland) is secondary in North Fork Eagle Creek.

Finally, open space is the tertiary land use in Lower Clear Creek, North Fork Deep Creek – Deep Creek, and Tickle Creek – Deep Creek, while it's agriculture in North Fork Eagle Creek. The Rock Creek – Clackamas River subbasin differs in that its tertiary land uses are commercial and residential. This subbasin drains significant urbanized land, which altogether accounts for almost

20% of the area in the subbasin. It should also be noted that Rock Creek – Clackamas River is the largest overall subbasin, also accounting for the largest total acreage of agricultural land.

Table 13: Land use cover in the SWP Area by subbasin.

Land Use	Lower Clear Creek		North Fork Deep Creek-Deep Creek		North Fork Eagle Creek		Rock Creek-Clackamas River		Tickle Creek-Deep Creek	
	Area (ac)	% of Total	Area (ac)	% of Total	Area (ac)	% of Total	Area (ac)	% of Total	Area (ac)	% of Total
AGR	7,435	59%	9,639	70%	1,241	7%	11,725	43%	6,484	36%
COM	-	-	-	-	-	-	1,545	6%	255	1%
FOR	4,281	34%	3,034	22%	12,728	71%	7,316	27%	7,439	42%
OPS	404	3%	484	4%	3,711	21%	745	3%	2,461	14%
PUB	-	-	-	-	-	-	31	0%	-	-
RES	-	-	5	0%	-	-	3,413	12%	673	4%
TRA	219	2%	350	3%	151	1%	1,192	4%	442	2%
WET	163	1%	228	2%	19	0%	1,413	5%	101	1%
Total (ac)	12,501		13,740		17,851		27,379		17,856	

Many of these land use categories can be further divided into the specific pollutant sources identified in **Table 12**. As aforementioned, agricultural land uses in the SWP Area include hay, pasture, Christmas Trees farms, nurseries, greenhouses, and blueberry growers. The overall distribution of these and other primary crop types are displayed in **Figure 31** (Schmidt, 2021).

The primary crop type in the SWP Area subbasins is grassland/pasture, accounting for more than 60% to almost 90% of total agricultural land. Christmas tree farms and nurseries are typical secondary and tertiary agricultural uses, although the actual percentage of these crops out of total agriculture varies widely from 2% for nurseries in Rock Creek-Clackamas River to more than 17% for Christmas trees in North Fork Eagle Creek. Hay is a common tertiary crop as well, accounting for approximately 1-2% of agricultural land in the subbasins except North Fork Eagle Creek, which is dominated instead by both Christmas tree farms and nurseries.

A complete summary of potential sources of specific pollutants within each subbasin is provided in **Table 14**. The same highlighting color scheme used in **Table 13** above is also applied to **Table 14** below.

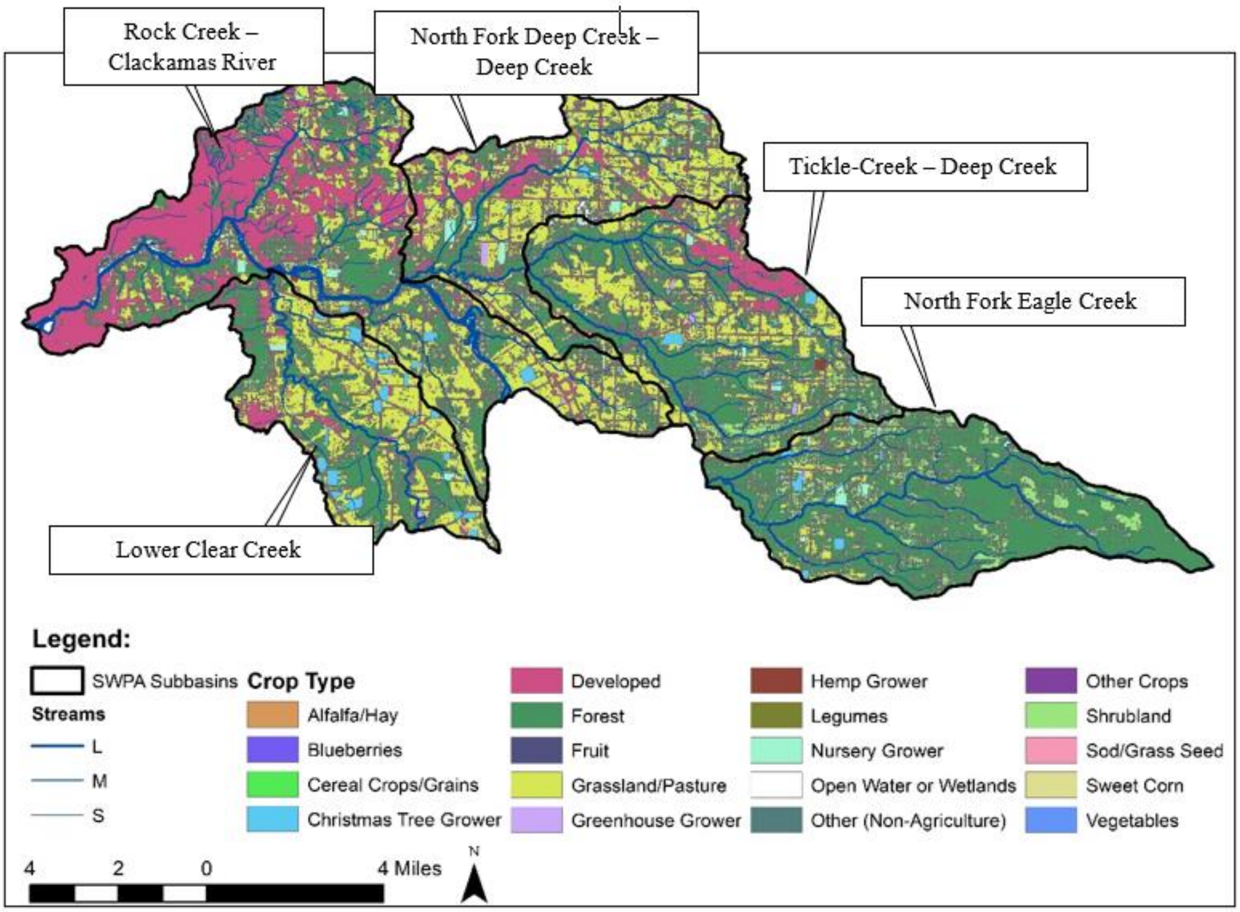

Figure 31: Crop types in the SWP Area.

Table 14: Summary of crop type distribution in the SWP Area by subbasin.

Crop Type	**Lower Clear Creek**	**North Fork Deep Creek-Deep Creek**	**North Fork Eagle Creek**	**Rock Creek-Clackamas River**	**Tickle Creek-Deep Creek**
	% of Total Ag.	% of Total Ag.	% of Total Ag.	% of Total Ag.	% of Total Ag.
Alfalfa/Hay	2.42%	1.15%	0.35%	1.26%	1.11%
Blueberries	0.06%	0.07%	0.02%	0.15%	0.23%
Cereal Crops/Grains	0.19%	0.27%	0.04%	0.31%	0.76%
Christmas Tree Farm	9.73%	0.99%	17.71%	1.97%	3.09%
Fruit	0.28%	0.83%	0.25%	0.37%	0.25%
Grassland/Pasture	83.07%	87.15%	66.62%	88.77%	87.68%
Greenhouse Grower	0.26%	0.66%	1.31%	0.34%	0.89%
Hemp Grower	0.00%	0.08%	0.00%	0.46%	0.68%
Legumes	0.27%	0.51%	0.00%	0.65%	0.61%
Nursery Grower	1.21%	5.23%	12.80%	2.16%	2.03%
Other Crops	1.69%	1.88%	0.56%	2.75%	1.48%

Crop Type	Lower Clear Creek	North Fork Deep Creek-Deep Creek	North Fork Eagle Creek	Rock Creek-Clackamas River	Tickle Creek-Deep Creek
	% of Total Ag.	% of Total Ag.	% of Total Ag.	% of Total Ag.	% of Total Ag.
Sod/Grass Seed	0.78%	0.97%	0.03%	0.66%	0.91%
Sweet Corn	0.04%	0.06%	0.00%	0.07%	0.02%
Vegetables	0.02%	0.13%	0.32%	0.07%	0.27%

Key finding: The most prominent pesticides identified in historical studies of the Clackamas River and tributaries were Atrazine, Simaizine, Glyphosate, Triclopyr, and 2,4-D (Carpenter et al., 2008). Several of these are applied to pasture and hay, which make up the vast majority of agricultural land in the SWP Area.

The quantity of different crops can be an indicator of the overall magnitude of potential pollutant sources. Although pasture and hay are associated with only a few pesticides (Carbaryl, Chlorpyrifos, and Glyphosphate), the dominance of these land uses in the SWP Area suggests that these are sources of potential significant load of those pollutants.

The likelihood of pollutant loading from specific agricultural sources is supported by the ambient water quality data. The most prominent pesticides identified in historical studies of the Clackamas River and tributaries were Atrazine, Simaizine, Glyphosate, Triclopyr, and 2,4-D (Carpenter et al., 2008). As will be discussed in **Section 5.2.1.,** several of these are applied to pasture and hay, which make up the vast majority of agricultural land in all five SWP Area subbasins (**Table 14**). While Atrazine is not commonly applied to pasture and hay crops, it is a prominent pesticide used for nurseries, greenhouses, and Christmas trees, which also occur throughout the SWP Area. Other pesticides of high concern such as Bifenthrin, Imidacloprid, and Simazine, which were observed during recent sampling efforts in North Fork Deep, Noyer, and Sieben Creeks (Kilders 2021), are also used on both Christmas trees and nurseries. These are prominent crop types in the North Fork Deep Creek-Deep Creek, Tickle Creek-Deep Creek, and Rock Creek-Clackamas River SWP Area subbasins (**Table 14**). Some other pesticides of concern identified in water quality samples, including Diuron and Diazinon, are not used on Christmas trees and so the largest source of these compounds in the SWP Area may be nurseries and greenhouses. Although many varieties of pesticides are used on blueberries and hazelnut trees, these land uses make up a relatively small portion of agricultural area in the SWP Area.

Key finding: Other pesticides of high concern such as Bifenthrin, Imidacloprid, and Simazine, which were observed during recent sampling efforts in North Fork Deep, Noyer, and Sieben Creeks (Kilders 2021), are also used on both Christmas trees and nurseries. These are prominent crop types in the North Fork Deep Creek-Deep Creek, Tickle Creek-Deep Creek, and Rock Creek-Clackamas River subbasins.

5. RESOURCE ANALYSIS AND SOURCE ASSESSMENT

The Clackamas River basin and SWP Area characteristics, river and tributary hydrology, and existing water quality conditions set the stage to discuss specific pollutants and their sources which could affect water providers in the SWP Area. This section discusses potential sources of contaminants, their relative risks, existing management strategies, and potential opportunities for pollutant source management.

5.1. Source Causes of Contamination

As discussed in **Section 4.2.2**. above, previous studies have identified primary source causes of contamination as agriculture, forestry, point-sources, urban development, and septic systems. Although documentation of specific occurrences and quantities of contaminants from any of these sources within the SWP Area entering the Clackamas River is lacking, data analysis, modeling, and literature from studies in other watersheds are valuable resources for identifying likely sources of contamination and the relative risk they pose to surface water. The resources most relevant to the Clackamas River for this purpose are the GIS Risk Analysis performed by Herrera Environmental Consultants (Schmidt 2012, updated Schmidt 2021), the PLM developed by Geosyntec (2014, updated 2021), and several USGS water quality studies in the Clackamas Basin (2003-2009).

Schmidt found the primary agricultural threats to source water are crop areas, plant nurseries, animal grazing areas, boarding stables, farm machinery repair shops, and chemical mixing/storing/handling areas. The relative risk posed by these areas is influenced by fertilizer and pesticide application rates by crop type for agricultural fields and nurseries, locations of CAFOs and other animal activities, proximity of agricultural activities to surface water, and vulnerable soils and irrigated land. Of the crops that make up the majority of the SWP Area subbasins, the highest average rates of herbicides recommended for use are for nurseries and greenhouses, Christmas trees, and blueberries; for insecticides, nurseries and greenhouses, and Christmas trees; for nitrogen, pastures and hay, and seed and sod grass; and for phosphorous, Christmas trees and pastures and hay (Schmidt, 2021). The spatial distribution of agricultural contaminant sources and their relative risk to surface water in the SWP Area are illustrated in

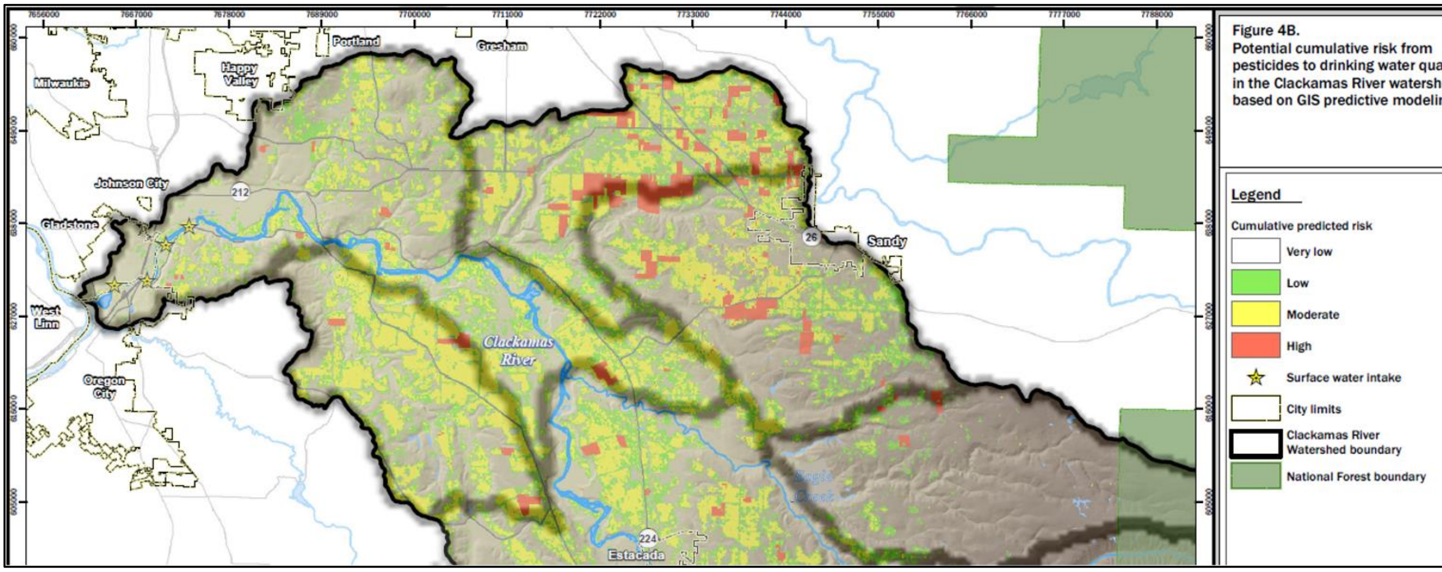

Figure ***32*** (a and b). The majority of the risk from pesticide application seems to fall within the North Fork Deep Creek – Deep Creek and Tickle Creek – Deep Creek subbasins, while the fertilizer risk seems more evenly distributed. The figures represent relative geospatial trends and not absolute values, and they identify only agricultural sources of nutrients and pesticides, respectively, and not sediment, bacteria, or heavy metals.

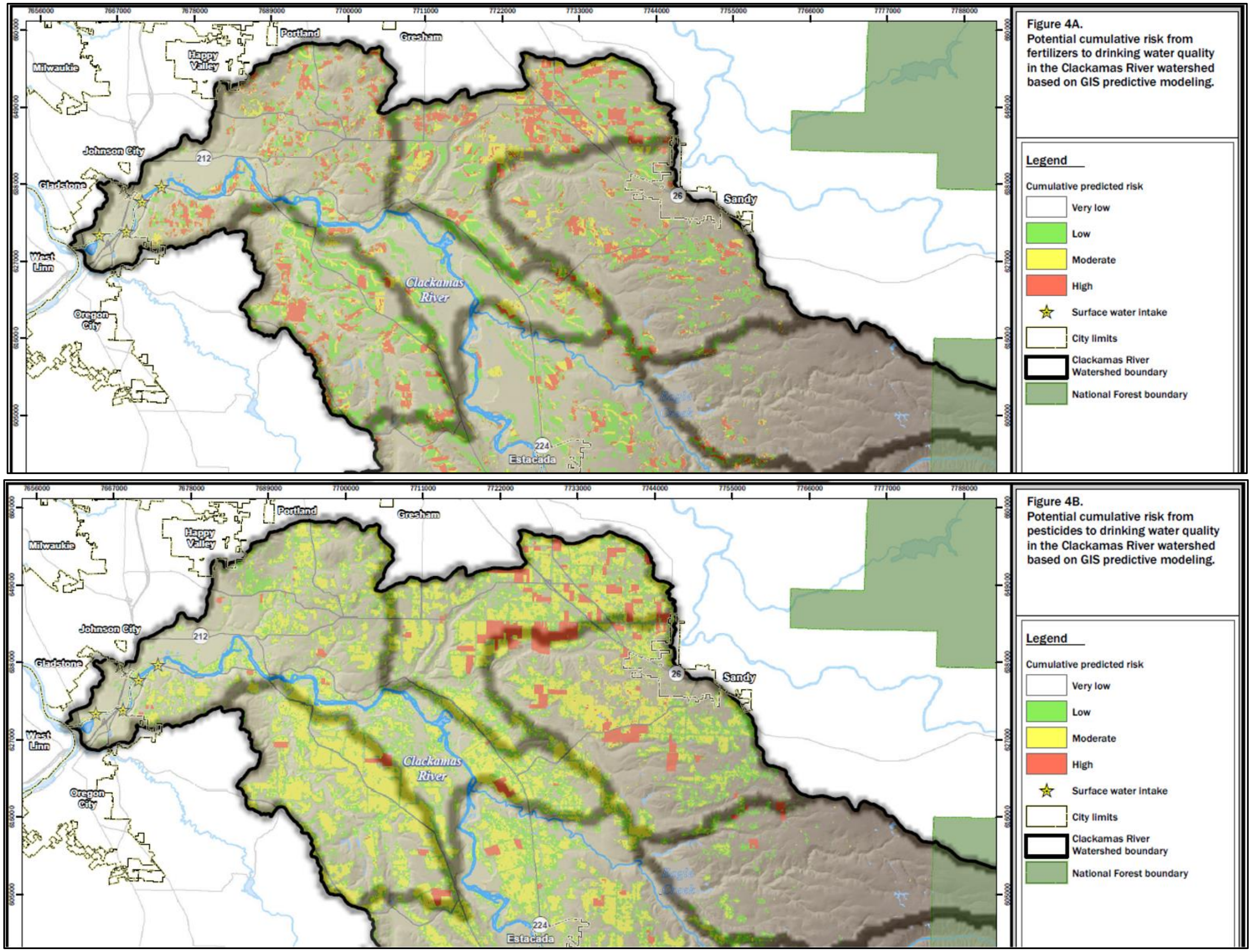

Figure 32: Potential risk from (a) fertilizers and (b) pesticides in the SWP Area (Schmidt, 2021).

Herrera Environmental Consultants' findings suggest relatively low risk of forestry-related contamination in the Lower Clackamas River basin (Schmidt, 2012).[3] The forestry activities evaluated included fertilizer and herbicide use, clearcutting, pre-commercial and commercial thinning, burning, road construction, site preparation, and other harvest activities. The risk associated with these activities can be influenced by the proximity of forestry activities to riparian stream buffers and surface water and soils that are highly sensitive to erosion and landslide areas. The only subbasin with parcels of high-risk area was North Fork Eagle Creek, and the activities posing these risks consisted primarily of sediment-generating activities rather than fertilizer or pesticide application.

Conversely, the risk from urban development at full build-out was centralized within urban growth boundaries that lie in the SWP Area subbasins (Schmidt, 2021). Predominantly, these urban areas are in Rock Creek – Clackamas River, North Fork Deep Creek – Deep Creek, and Tickle Creek – Deep Creek, as shown in **Figure 33**.

Additionally, Herrera Environmental Consultants identified regions with septic systems at relatively high risk of failure and subsequently impacting surface water quality. Factors that may influence the likelihood of contamination from septic systems include septic system age, septic system clusters, proximity to surface water and upstream distance from municipal surface water intakes, vulnerable soils, and parcel size. As indicated in **Figure 34**, the regions with the highest risk for septic system failure within the SWP Area are located Northeast of Oregon City and South of Highway 224 (Schmidt, 2021).

[3] This conclusion is based upon the 2012 forestry activities report by Herrera, rather than the 2021 update.

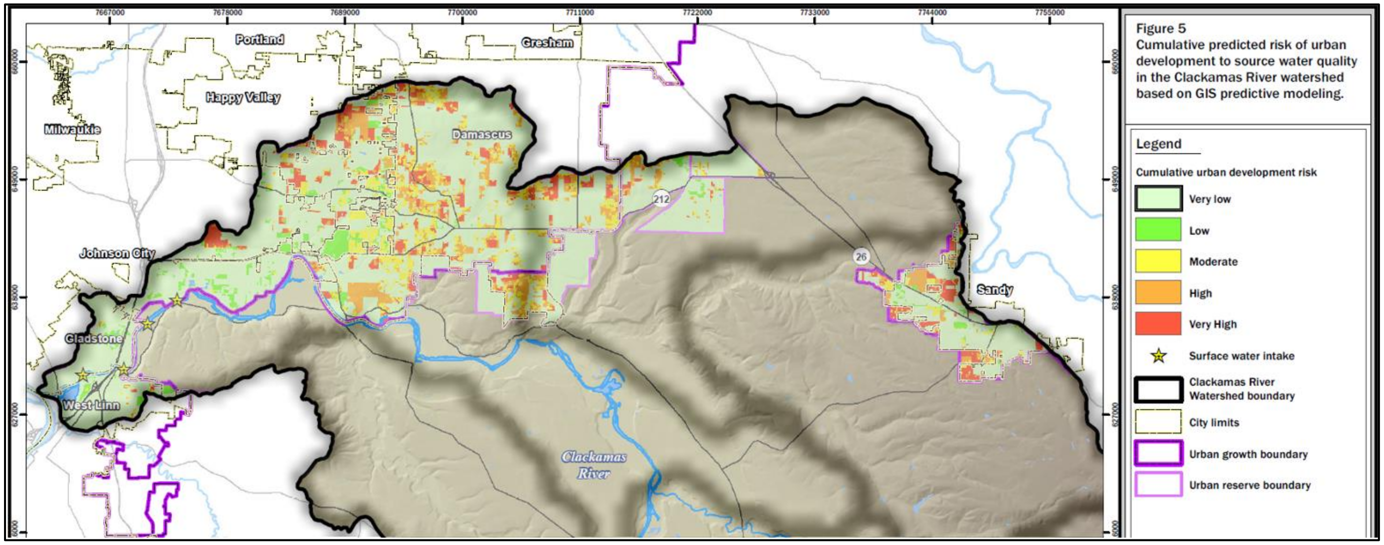

Figure 33: Potential risk from urban development in the SWP Area (Schmidt, 2021).

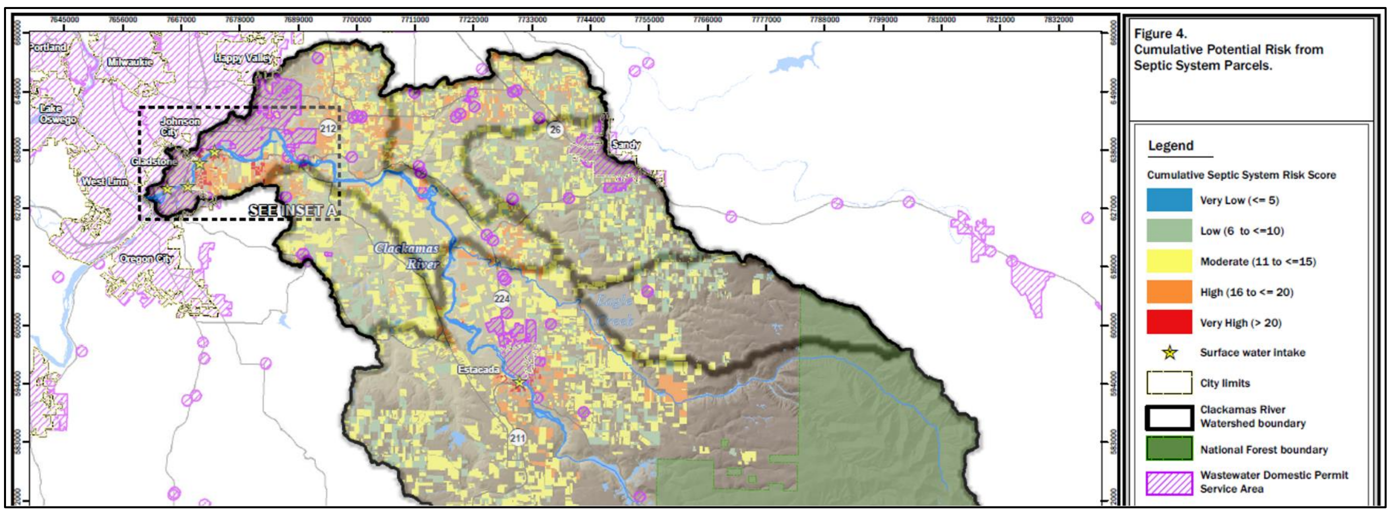

Figure 34: Potential risk from septic systems in the SWP Area (Schmidt, 2021).

Previous assessments that utilized the PLM (the specifics of which are discussed in greater detail in **Section 5.2**) indicated the highest loads of contaminants in the pollutant categories modeled (including sediment, nutrients, pesticides, metals, and bacteria) came from sources within the Rock Creek – Clackamas River subbasin (Geosyntec, 2014). A visual summary of these results is provided in **Figure 35**. This conclusion on loading from Rock Creek – Clackamas River subbasin makes sense given the high quantity of both developed and agricultural land, as well as the relative risks from point sources and septic systems identified by Herrera Environmental Consultants (Schmidt, 2021). The analyses performed by Geosyntec (2014), and Herrera (Schmidt, 2012 and Schmidt, 2021) have provided a foundation for further investigating the lower tributary subbasins in the SWP Area.

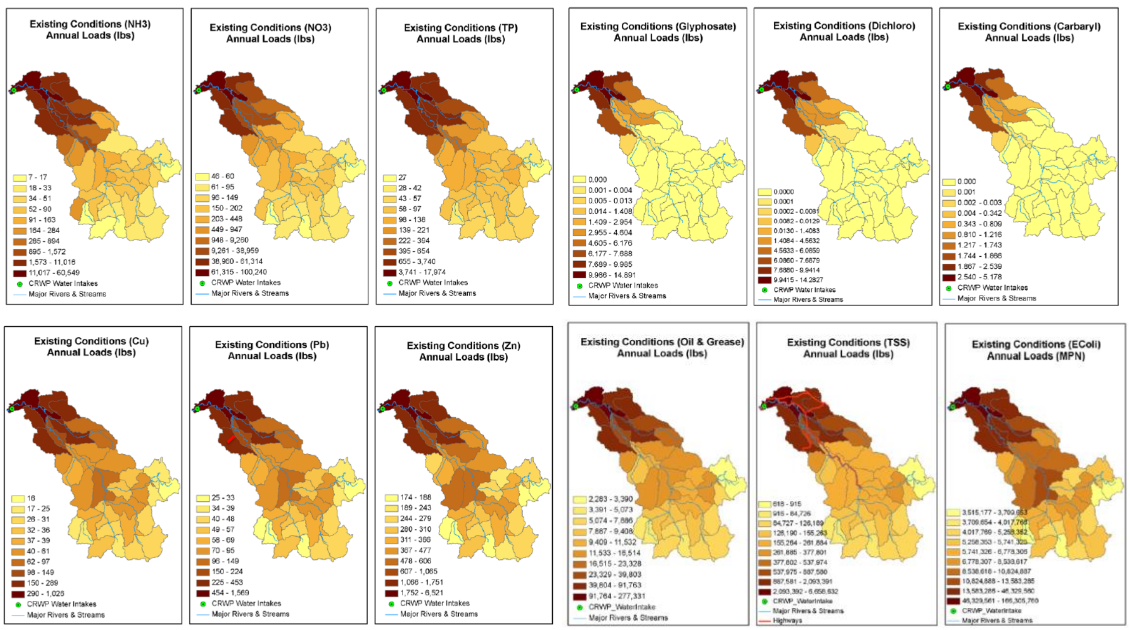

Figure 35: 2014 Pollutant Load Model baseline results.

5.2. Preliminary Analysis

5.2.1. Risks to Surface Water

As aforementioned, the PLM calculates approximate pollutant loads from land uses and sources within the Clackamas River subbasins, as well as potential treatment by various BMPs and classes of BMPs. To compute average annual pollutant loads, the model utilizes several key sets of data and assumptions. These include surface runoff coefficients (calculated using the EPA Stormwater Management Model [SWMM]), land use area by subbasin (as discussed in **Section 4.2.2.**), and Event Mean Concentrations (EMCs) for each pollutant from each land use type.

The EMCs used to represent the runoff concentrations of different pollutants from each land use type in the model are provided in **Table 15**. These EMCs reveal several trends. With respect to total suspended solids (TSS), metals, and oil & grease, the largest concentrations appear to run off from developed land uses such as transportation, commercial, residential, and public facilities. The same is true of ammonia (NH_3), phosphorous, biological oxygen demand (BOD), and *E. coli*. Nitrates and pesticides, on the other hand, run off in highest concentrations from agricultural land. To a lesser extent, pesticides are sourced from residential land uses, trailed by commercial and public facilities. The PLM does not report pesticides that may run off from forest, open space, or transportation land uses.

Table 15: Pollutant EMCs in the PLM.

	Land Use										
Pollutant	AGR	COM	FOR	OPS	PUB	RES	TRA1	TRA2	TRA3	TRA4	TRA5
TSS, mg/L	66.00	81.70	66.00	52.90	79.24	135.3	150.9	150.9	150.9	150.9	150.9
TP, mg/L	0.082	0.451	0.016	0.175	0.274	0.408	0.347	0.347	0.347	0.347	0.347
NO3, mg/L	2.445	0.681	0.023	0.400	0.503	0.677	1.530	1.530	1.530	1.530	1.530
NH3, mg/L	0.114	1.561	0.002	0.738	0.981	1.471	1.715	1.715	1.715	1.715	1.715
PB, mg/L	0.0134	0.040	0.0134	0.003	0.024	0.021	0.055	0.055	0.055	0.055	0.055
CU, mg/L	0.0085	0.026	0.0085	0.004	0.013	0.015	0.032	0.032	0.032	0.032	0.032
ZN, mg/L	0.05	0.165	0.05	0.025	0.075	0.101	0.211	0.211	0.211	0.211	0.211
BOD, mg/L	6.47	13.55	4.67	4.67	8.28	9.76	14.86	14.86	14.86	14.86	14.86
E. Coli, MPN/100 mL	1340	3247	1000	1000	1679	2926	6002	6002	6002	6002	6002
Glyphosate, mg/L	0.000412	0.000070			0.000070	0.000100					
2,4-D, mg/L	0.000412	0.000070			0.000070	0.000070					
Carbaryl, mg/L	0.000100	0.000070			0.000070	0.000070					
Oil & Grease, mg/L	2.886	5.738	2.886	0.833	4.938	3.678	9.664	9.664	9.664	9.664	9.664

- ACWA stormwater database (Kennedy/Jenks, 2009)
- ACWA stormwater database - average of 'Open Space' and 'Mixed' land uses
- USGS Report (Carpenter, 2003)
- White Paper (Herrera, 2007)
- ACWA stormwater database - set equal to the 'OpenSpace' land use
- USGS Report (Kelly et al., 2012)
- Set equal to TRA2 levels

The PLM and the data sources it relies on have remained largely unchanged since its development in 2014, save for the land use area, which was updated for the SWP Area with the 2021 land cover data provided in **Table 13**. The runoff coefficients were not updated due to negligible change in average imperviousness by subbasin (as discussed in **Section 4.1.1**.), and the EMCs were not updated due to lack of new supporting data.

The new land use cover data improves on the model's original 2012 land use layer in several ways. First and foremost, it is based primarily off of Herrera Environmental Consultants' refined 2021 crop type layer, rather than the Regional Land Information System (RLIS) Zoning dataset. This allows for better resolution and accuracy of the extent of agricultural and forested areas, as well as open water and wetlands. Where Herrera's layer identified developed land, the 2021 RLIS Zoning dataset was then used to classify area as residential, commercial, or public facilities. Transportation was then burned into the land use layer using the 2021 RLIS Streets layer and the buffering methodology described in the PLM (Geosyntec, 2014). This created the land use layer shown in

Figure 30 in **Section 4.2.2**. The relative land use composition of each subbasin is expressed in **Figure 36**.

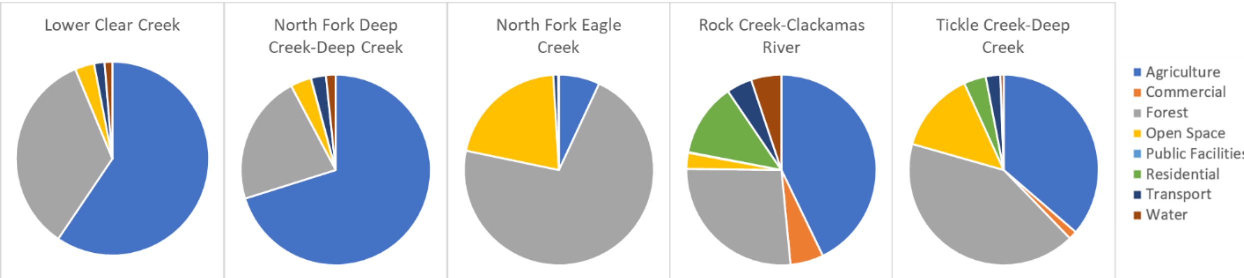

Figure 36: Land use composition in the SWP Area by subbasin.

After updating the land use cover data, new baseline pollutant load results were calculated. The updated PLM results indicate the Rock Creek – Clackamas River subbasin produces the highest loads of any of the SWP Area subbasins over the pollutant categories examined. A sample of the loads from each subbasin as a fraction of the total load for various pollutants is provided in **Figure 37**. The dominance of this subbasin is likely due to the large amount of drainage area in the Rock Creek – Clackamas River subbasin (almost twice that of the other subbasins), as well as the prevalence of developed land uses and agricultural land. In the legend, the number before the subbasin name corresponds to the HUC identifier for the subbasin in the PLM.

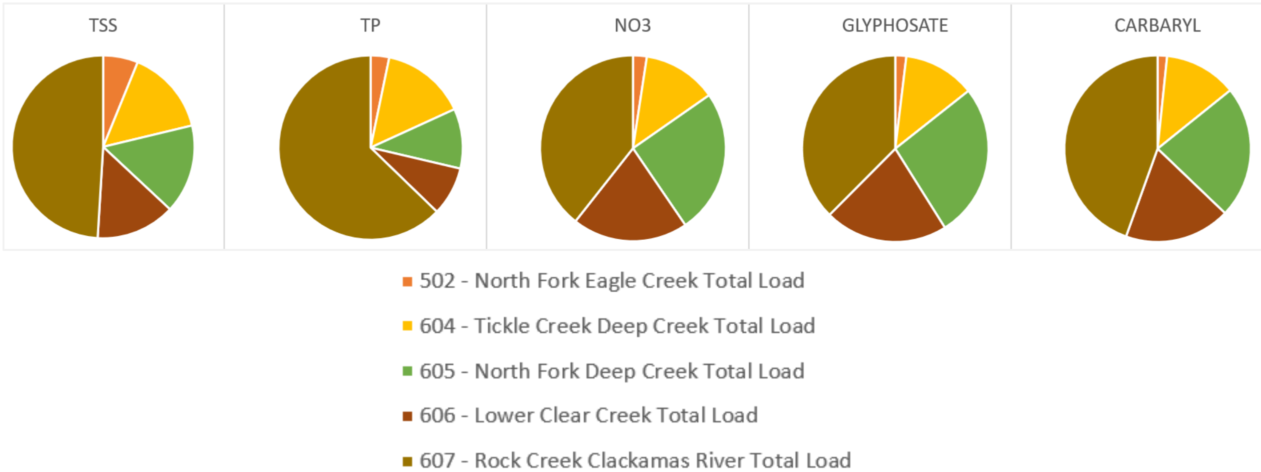

Figure 37: SWP Area subbasin contributions to total loads of select pollutants.

Normalizing for land area to calculate pollutant yield (load per acre) reveals the relative potency of runoff from an average acre in each subbasin. Charts symbolizing these results are provided in **Figure 38**. Yields of nitrogen and the pesticides Glyphosate and Carbaryl from North Fork Deep Creek and Lower Clear Creek are comparable to the Rock Creek - Clackamas River subbasin.

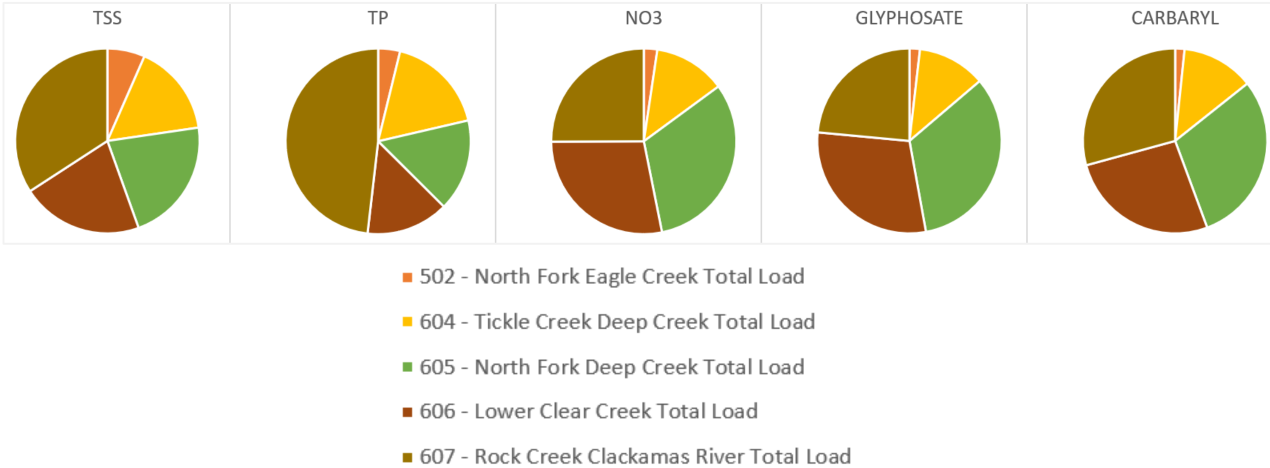

Figure 38: Relative magnitudes of pollutant yield (load/acre) by SPWA subbasin for select pollutants.

These two figures of PLM results help visualize the overall connections between land use and pollutant loads in the SWP Area. For example, the Rock Creek – Clackamas River subbasin contains proportionally (and outright) the most developed land, including commercial, residential and transportation land uses. Developed land uses are associated with higher TSS loading, which is reflected in the proportion of TSS in the SWP Area that is attributable to this subbasin. Similarly, developed land uses are associated with higher phosphorus loads, which is reflected in the proportion of phosphorus in the SWP Area that is attributable to the Rock Creek – Clackamas River subbasin. With respect to nutrients and pesticides, it can generally be concluded that the prevalence of agricultural lands in North Fork Deep Creek, Lower Clear Creek, Rock Creek Clackamas River, and Tickle Creek Deep Creek cause much more significant loads from these subbasins compared to North Fork Eagle Creek, which is overwhelmingly forested.

These nutrient and pesticide results generally agree with findings from previous water quality studies in the basin (Carpenter, 2003; Schmidt, 2021; Kilders and Cloutier, 2021). As discussed in **Section 4.2.1**., the highest nitrogen yields were from the lower tributaries. Tributaries with the highest yields of DIN included Sieben Creek (7.6 kg/d/mi^2) and Deep Creek (1.3 kg/d/mi^2). Sieben Creek is a small tributary to the Lower Clackamas in the Rock Creek - Clackamas River subbasin which drains urban and agriculture land uses, including a few large nurseries (Carpenter, 2003). North Fork Deep Creek and Tickle Creek, both tributaries of Deep Creek, drain primarily agricultural land, along with some commercial land in Tickle Creek. These land uses possibly explain why Sieben Creek and Deep Creek also exhibit the highest phosphorous yields (0.17 kg/d/mi^2 and 0.1 kg/d/m^2, respectively). It should be noted that point sources including septic systems and wastewater treatment plants have been identified as potential sources in these subbasins as well (Carpenter, 2003 and Schmidt, 2021). Additionally, large pesticide loads have been identified from Rock Creek and two tributaries of Deep Creek (North Fork Deep and Noyer Creeks). These tributaries all drain nursery, pasture, and rural residential land. Pesticide yields (loads per unit area) were highest in Cow and Carli Creeks – small streams draining urban and industrial areas in the Rock Creek - Clackamas River subbasin. Other areas with relatively high pesticide yields included middle Rock Creek and upper Noyer Creek. Further monitoring is being done for North Fork Deep, Noyer, and Sieben Creeks due to ongoing pesticide concerns (Kilders and Cloutier, 2021). These studies corroborate the conclusion that nutrient and pesticide loading are especially high from tributaries within the Rock Creek - Clackamas River and North Fork Deep Creek subbasins.

Key Finding: Pasture and Hay, which dominate agricultural area in the SWP Area, likely contribute to high loads of pesticides in surface waters in the SWP Area, especially Glyphosate and Triclopyr.

Pesticides are a broad category of chemicals, many of which have unique loading patterns within the SWP Area subbasins. In agricultural areas, pesticides are largely dependent on the crop type. **Table 16** shows the recommended pesticide and nutrient application rates in pounds per acre for 17 common pesticides and nitrogen and phosphorus by the crop types found in the SWP Area (Schmidt, 2012). Crop types highlighted in red represent crops with total fertilizer and/or pesticide application rates in the top 25th percentile among the crops listed. These values are based on recommended application rates, and actual application rates of fertilizer and pesticides will vary based on site conditions and individual producers.

The dominant crop type, both proportionally and outright by land area, for agricultural area in the SWP Area, is pasture and hay. While the total pesticide application rate for pasture and hay is relatively low (6.6 lbs./acre) compared to other crop types, it has the highest application rate in pounds per acre of the pesticide triclopyr and one of the highest application rates of glyphosate. Lower Clear Creek, North Fork Deep Creek, Rock Creek, and Tickle Creek subbasins have similar acreage of pasture and hay, and thus produce similar loads of triclopyr and glyphosate (**Figure 39**). North Fork Eagle Creek has significantly less acreage of pasture and hay, and thus produces a much lower load of these pesticides.

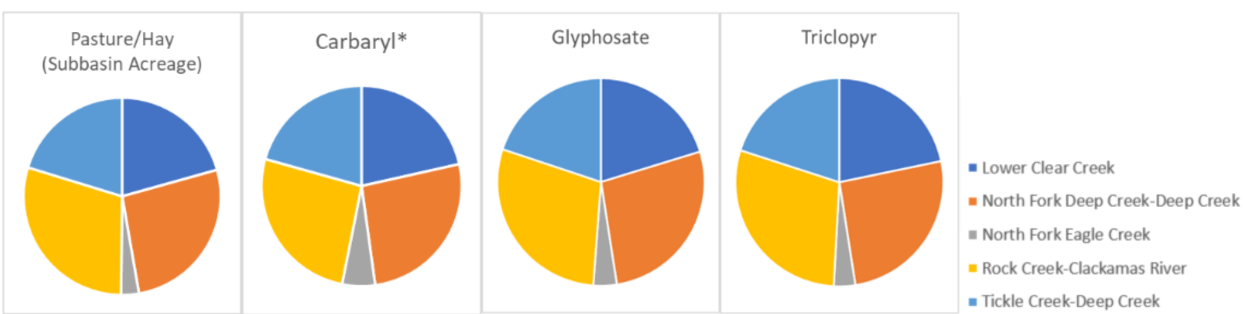

Figure 39. Acreage by SWP Area subbasin of Pasture and Hay and resulting subbasin loads of the pesticides Carbaryl, Glyphosate, and Triclopyr.

As noted, in Section **4.2.1.3.**, Triclopyr and Glyphosate often accounted for most of the total pesticide load in water samples from tributaries throughout the SWP Area (Carpenter et al., 2008). This strongly supports that a large portion of the total pesticide load may be attributable to pasture and hay cultivation by virtue of the prevalence and high acreage of this crop within the SWP Area. **Figure 39** also shows the loads (in pounds) of the pesticide Carbaryl in the SWP Area which generally reflects the relative area of pasture and hay per subbasin. However, as shown in **Figure 40**, the yield of Carbaryl per acre area per subbasin has a different distribution; this is likely due to the relatively high acreage of Christmas trees in the Lower Clear Creek and North Fork Deep Creek subbasins, a crop which is also associated with Carbaryl. Thus, these two subbasins are the focus of the following additional analysis, which breaks down potential pesticide loading within subbasins by crop type.

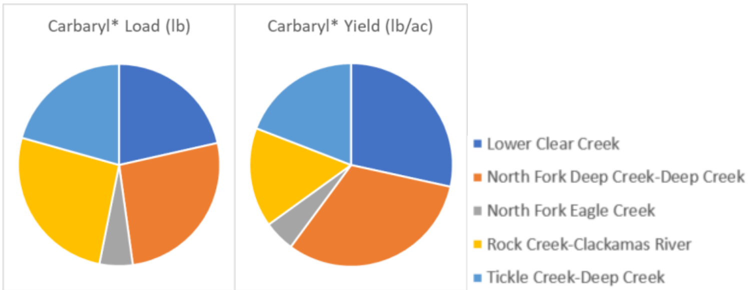

Figure 40. Comparison of Carbaryl load (lb) to Carbaryl yield (lb/ac) in the SWP Area subbasins.

Table 16. Recommended chemical application rates for crops grown within the SWP Area.

Crop Type	Chemical Application Rate (lb/ac) Adapted from Herrera Environmental Consultants 2012 Agriculture Risk Assessment Tables																				
	Nitrogen	Phosphorus (P2O5)	2,4-D*	Atrazine#	Dichlobenil	Dimethenamid-P	Diuron*	Glyphosate	Hexazinone	Napropamide	Simazine	Triclopyr	Trifluralin	Chlorpyrifos*+	Diazinon*	Endosulfan*^	Ethoprop+	Metalaxyl	Carbaryl*	**Total Fertilizer**	**Total Pesticide**
Alfalfa	0	75	1	0	0	0	1.8	1.88	0.98	0	0	0	1.13	0	0	0	0	0	1	75	7.8
Apples	218	1308	0.83	0	5	0	0.5	0.57	0	5	3.2	0	0.75	3	3	0.67	0	0	2.5	1,526	25.0
Barley	105	30	0.63	0	0	0	1.4	0.56	0	0	0	0	0	0.38	0	0	0	0.22	30	135	33.2
Beets	150	110	0	0	0	0	0	0	0	0	0	0	0	0	2.13	0	0	0	1.25	260	3.4
Blueberry	100	15	1.4	0	3.98	0	3	0.57	2	2	2	0	0	0	0.5	0	0	0	1.25	115	16.7
Cabbage	80	140	0	0	0	0	0	0	0	1.5	0	0	0.75	1.38	4	0	0	0	1.25	220	8.9
Canola	175	15	0	0	0	0	0	0	0	0	0	0	0.75	0	0	0	0	0	0	190	0.8
Cauliflower	200	140	1.5	0	0	0.77	0	0	0	0	0	0	0.75	1.38	4	0	0	0	1.25	340	9.7
Cherry Orchard	150	100	0.83	0	5	0	0.75	0.57	0	2.5	3.2	0	0.75	2.15	4.5	4.5	0	0	2.5	250	27.3
Christmas Trees	75	180	2.38	3	2.96	0	0	0.57	1.5	0	3	1.31	0	1	0	0	0	0	3	255	18.7
Clover and Wildflowers	0	40	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0	0	1.25	40	2.9
Corn	85	70	0.85	1.8	0	0.73	0	2.25	0	0	0	0	0	0.75	0.09	0	3	0.09	1.5	155	11.1
Cranberries	50	30	3	0	2.1	0	0	0.57	0	6	0	0	0	1.41	2	0	0	0	1.75	80	16.8
Dry Beans	85	105	0	0	0	0	0	0	0	0	0	0	0.53	0.63	0	0	0	0	1.25	190	2.4
Garlic	200	150	0	0	0	0.77	0	0	0	0	0	0	0	0	3.5	0	0	0	1.5	350	5.8
Grapes	25	30	0	0	5	0	2.4	2.49	0	2	0	0	1.75	1.41	0	0.5	0	0	1.75	55	17.3
Greens	150	125	0	0	0	0	0	0	0	0	3	0	0.75	1.38	3	0	0	0	1.25	275	9.4
Herbs	115	125	0	0	0	0	0	0	0	0	0	0	0.75	1.25	0	0	3	0	1.5	240	6.5
Hops	100	50	0.48	0	0	0	0	0.56	0	0	0	0	0.63	0	0	0	3	0	0	150	4.7
Mint	170	120	0	0	0	0	1.5	0.25	0	2	0	0	0.63	1.25	0	0	3	0	0	290	8.6
Misc. Fruits and Veg.	150	100	0	3.04	0.77	2.2	0.99	2	2.64	2.82	0	0.82	1.07	2.72	1.75	0	0	1.39	1.76	250	24.0
Nurseries and Greenhouses*	110	60	0	3	5.5	0.98	3.2	2.63	0	4.5	2.5	0	4	2	2	3	3	0.25	4	170	40.6
Oats	120	30	0.62	0	0	0	2	0.56	0	0	0	0	0	0.38	0	0	0	0.26	30	150	33.8

Crop Type	Chemical Application Rate (lb/ac) Adapted from Herrera Environmental Consultants 2012 Agriculture Risk Assessment Tables																			
	Nitrogen	Phosphorus (P2O5)	2,4-D*	Atrazine#	Dichlobenil	Dimethenamid-P	Diuron*	Glyphosate	Hexazinone	Napropamide	Simazine	Triclopyr	Trifluralin	Chlorpyrifos*+	Diazinon*	Endosulfan*^	Ethoprop+	Metalaxyl	Carbaryl*	**Total Fertilizer**	**Total Pesticide**
Onions	145	170	0	0	0	0.77	0	0	0	0	0	0	0.5	1	3	0	0	0	0	315	5.3
Other Crops	110	60	0.96	0	2.96	0.77	1.55	1.04	0.95	0	0	1.46	0.77	0.7	0.2	0.75	0	0.23	2	170	14.3
Other Hays	150	50	0	0	0	0	0	0.56	0	0	0	1.03	0	0	0	0	0	0	1	200	2.6
Other Tree Nuts	180	0	0.83	0	5	0	0.5	0.57	0	2.5	3.2	0	0.75	2.34	1	3	0	0	3.5	180	23.2
Pasture and Grass	150	50	1.36	0	0	0	0	1.97	0.66	0	0	1.75	0	0	0	0	0	0	0.88	200	6.6
Pasture and Hay	150	50	1.36	0	0	0	0	1.97	0.66	0	0	1.75	0	0	0	0	0	0	0.88	200	6.6
Peas	0	40	0	0	0	0	0	0	0	0	0	0	0.38	0.17	3	0.75	0	0	1.25	40	5.6
Pecans	180	0	0.83	0	5	0	0.5	0.57	0	2.5	3.2	0	0.75	1.34	1	3	0	0	3.5	180	22.2
Peppers	125	125	0	0	0	0	0	0	0	1.5	0	0	0.75	0	0	0	0	0	1.25	250	3.5
Plums	60	0	0.83	0	5	0	0.75	0.57	0	2.5	3.2	0	0.75	3	4	0	3	0	3	60	26.6
Potatoes	125	140	0	0	0	0.82	0	0.74	0	0	0	0	1.5	0	0	0	0	0	1.25	265	4.3
Prunes	90	360	0.83	0	5	0	0.5	0.57	0	2.5	3.2	0	0.75	3	4	0	0	0	3	450	23.4
Radish	100	140	0	0	0	0.77	0	0	0	0	0	0	0	0	3	0	0	0	1.5	240	5.3
Rye	120	30	0.95	0	0	0	1.2	0.57	0	0	0	0	0.75	0.38	0	0	0	0.26	30	150	34.1
Seed and Sod Grass	150	30	0	0	0	0.82	2	0	0	0	0	0	0	0.75	0	0	0	0	1.25	180	4.8
Spring Wheat	125	25	0.83	0	0	0	0	0.56	0	0	0	0	0	0.38	0	0	0	0.26	30	150	32.0
Squash	105	75	0	0	0	0.7	0	0.59	0	0	0	0	0.75	0.005	0	0	0	0	1	180	3.0
Strawberries	60	60	1.15	0	0	0	0	0.57	0	2	1	0	0	1.47	0.75	1	0	0	1.5	120	9.4
Sweet Corn	70	75	0	2.5	0	0.77	0	2.25	0	0	2.8	0	0	1.75	0.31	0	0	0	1.25	145	11.6
Triticale	120	30	0.95	0	0	0	1.2	0.57	0	0	0	0	0.75	0.38	0	0	0	0.26	30	150	34.1
Turnips	75	105	0	0	0	0	0	0	0	0	0	0	0.75	0	2.5	0	0	0	0.38	180	3.6
Vetch	0	40	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0	0	1.25	40	2.9
Walnuts	872	0	0.83	0	5	0	0.75	0.57	0	2.5	2.8	0	0.75	2.6	0	4	0	0	3.75	872	23.6
Winter Wheat	120	30	0.95	0	0	0	1.2	0.57	0	0	0	0	0.75	0.38	0	0	0	0.26	30	150	34.1

* Absent other data, nurseries and greenhouses were assigned the same nitrogen and phosphorus application rates as "Other Crops"

After pasture and hay, the second-most dominant crop type in Lower Clear Creek is Christmas trees (**Table 14**), which have a higher pesticide application rate than pasture and hay (18.7 lb/ac vs 6.6 lb/ac for pasture and hay). The dominant pesticides associated with Christmas trees are Atrazine, 2, 4-D, Dichlobenil, Simazine, and Carbaryl (**Table 16**). In **Figure 41** below, the application profile (in pounds) of pesticides in Lower Clear Creek is reflective of the recommended pesticide application for both Christmas trees and pasture and hay (lb/ac). Note the strong correlation between the pesticide application profile for Lower Clear Creek and the recommended application for Christmas trees. Although Christmas tree cover in Lower Clear Creek is only about 12% of the pasture and hay cover by acreage, the comparatively high pesticide application rate for Christmas trees allows for a larger impact of these crop lands.

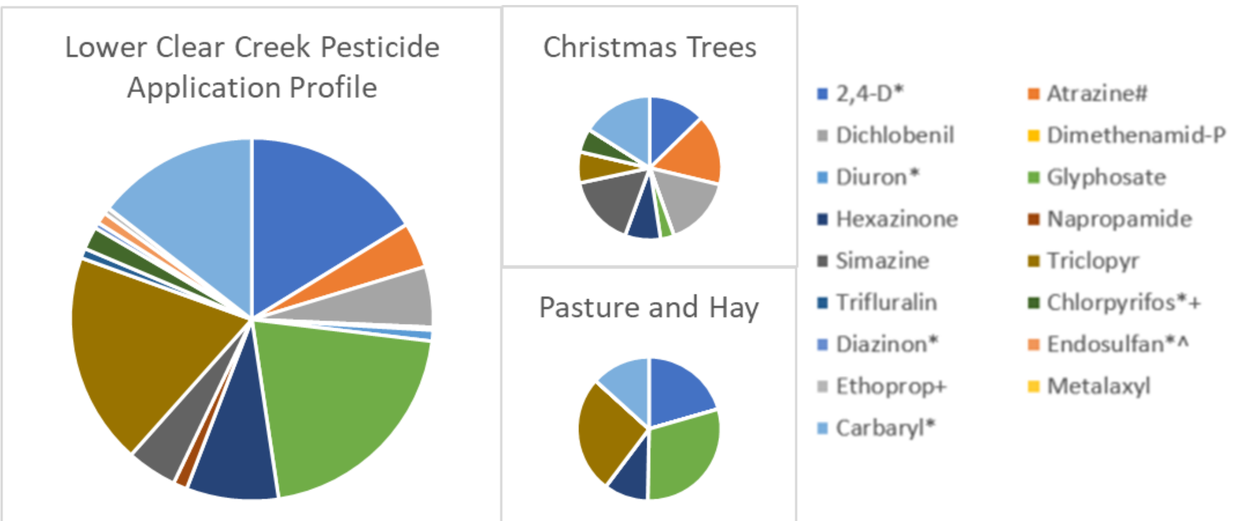

Figure 41. Pesticide application rates (lb) for the Lower Clear Creek subbasin are reflective of the application rates (lb/ac) of the two most prominent agricultural crop types in the subbasin: Christmas trees and pasture and hay.

Lower Clear Creek has the highest acreage of Christmas trees in the SWP Area. Therefore, the highest estimated yields of atrazine and simazine to the Clackamas River are also attributable to Lower Clear Creek (**Figure 42**). A greater proportion of atrazine and simazine from the North Fork Deep Creek subbasin is likely due to the high presence of nurseries and greenhouses, which is also linked to high atrazine application. High atrazine estimated loads from these two subbasins are supported by ambient water quality data, discussed in **Section 4.2.1.3**, which notes that a disproportionate atrazine load in the SWP Area was contributed by Clear Creek.

Key Finding: High atrazine loads in Clear Creek are likely attributable to the cultivation of Christmas trees in the Lower Clear Creek subbasin and numerous greenhouses and nurseries present in the North Fork Deep Creek subbasin.

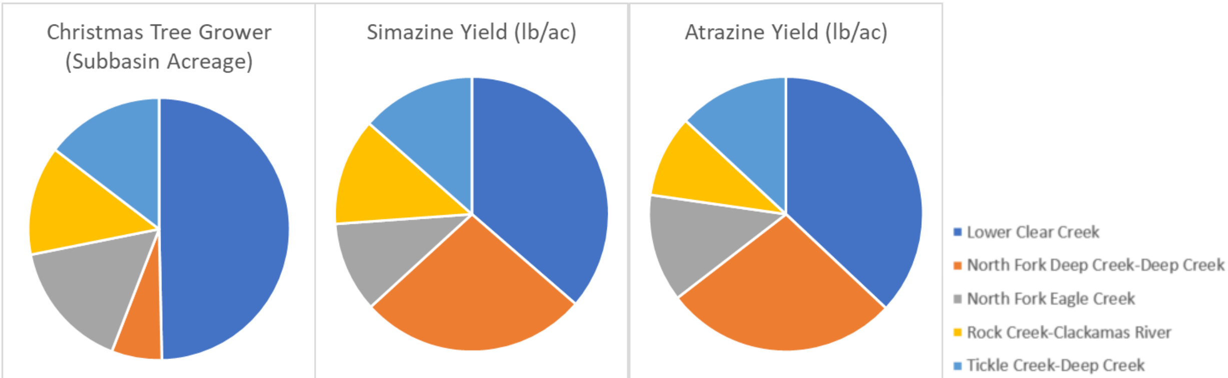

Figure 42. SWP Area acreage by subbasin of Christmas Trees and resulting subbasin yields (lb/ac) of the associated pesticides Simazine and Atrazine.

Nurseries and greenhouses have the highest recommended pesticide application rate per acre out of all the crops found in the SWP Area (**Table 16**). They also have the most diverse recommended pesticide application profiles (i.e., most types of recommended pesticides) of the crops grown in the SWP Area. The dominant pesticides associated with nurseries and greenhouses are shown in the middle panel of **Figure 43** and include Napropamide, Trifluralin, Ethoprop, Atrazine, and Diuron. The application profile (lb) of pesticides in the North Fork Deep Creek subbasin is reflective of the recommended pesticide application for both nurseries and greenhouses and pasture and hay. Also note the strong correlation between the pesticide application profile for North Fork Deep Creek and the recommended application for nurseries and greenhouses. Although nursery and greenhouse cover in North Fork Deep Creek is only about 7% of the pasture and hay cover, the high pesticide application rate for nurseries and greenhouses (40.6 lb/ac) allows for a larger impact of these crop lands.

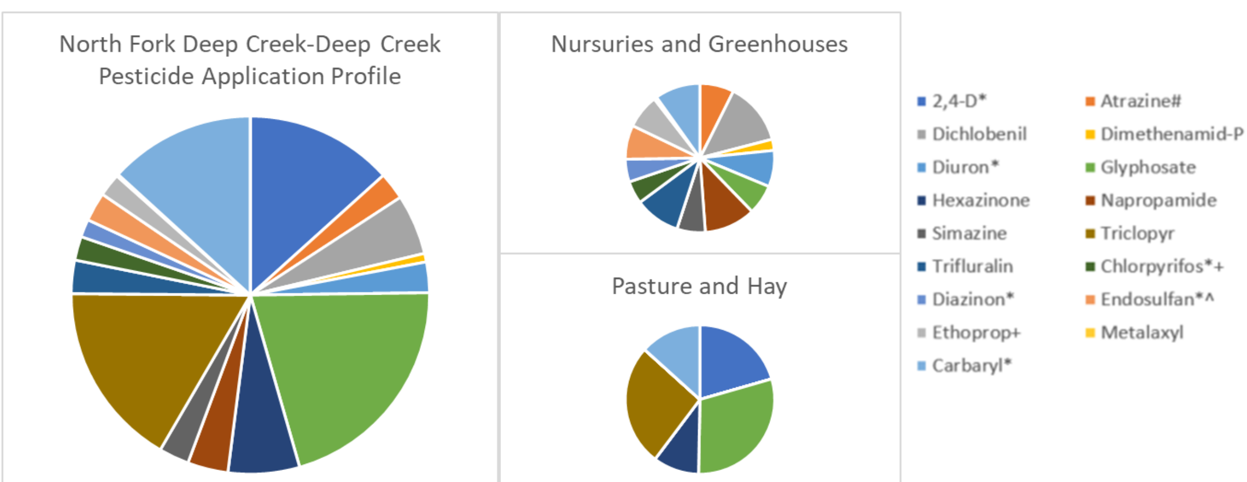

Figure 43. Pesticide application rates (lb) for the North Fork Deep Creek subbasin are reflective of the application rates (lb/ac) of the two most prominent agricultural crop types in the subbasin: nurseries and greenhouses and pasture and hay.

North Fork Deep Creek has the highest acreage of nurseries and greenhouses in the SWP Area (**Figure 44**); therefore, the highest yields of Trifluralin, Diuron, Napropamide, Endosulfan, Metalaxyl, Diazinon, Ethoprop, and Dimethenamid-P to the Clackamas River are also attributable to North Fork Deep Creek. This is supported by the 2008 study on ALBs (Carpenter et al, 2008), which found that the Deep Creek tributaries contained the largest number of individual pesticides per sample. This is likely attributable to the large variety of pesticides used in nurseries and greenhouses.

Key Finding: Nurseries and greenhouses contribute a wide variety of pesticides to surface waters. The highest acreage of nurseries and greenhouses in the SWP Area is in the North Fork Deep Creek subbasin.

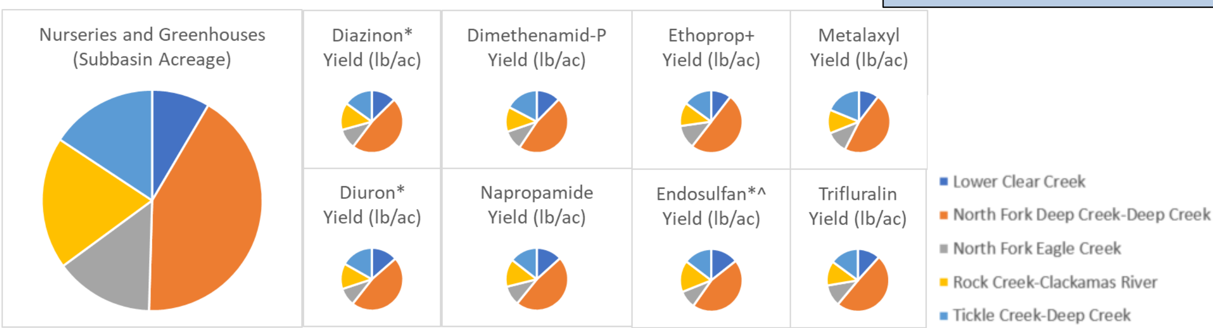

Figure 44. SWP Area acreage by subbasin of nurseries and greenhouses and resulting subbasin yields (lb/ac) of the associated pesticides: Trifluralin, Diuron, Napropamide, Endosulfan, Metalaxyl, Diazinon, Ethoprop, and Dimethenamid-P.

Note that for most pesticides, that the North Fork Eagle Creek subbasin contributes relatively little load to the Clackamas River. This is due to the subbasin having a relatively small area of agricultural land compared to forested land and open space (**Figure 36**). This is supported by ambient water quality data, which found relatively few types of pesticides in North Fork Eagle Creek compared to other creeks in the SWP Area. However, of the relatively small acreage of agricultural land in North Fork Eagle Creek, a relatively high percentage is Christmas trees and nurseries (**Table 14**). This indicates that treatment strategies developed for Lower Clear Creek and North Fork Deep Creek may also be applicable in North Fork Eagle Creek. Notably, it is possible that some forested area in the North Fork Eagle Creek subbasin could be actively managed; this analysis did not account for any pesticides that may be used in forest management activities.

Key Finding: Though North Fork Eagle Creek contributes relatively little pesticide load to surface waters, agriculture in this subbasin consists predominantly of Christmas trees and nurseries and greenhouses, which both contribute relatively high yields of pesticides.

Other pesticide risks were identified by the Clackamas Pesticide Stewardship Partnership (PSP) (Kilder and Cloutier, 2021) but not included in the analyses above due to limited data. These pesticides, and where they were found within the SWP Area in 2020, included those listed in **Table 17**.

Table 17. Summary of 2020 Pesticide Stewardship Partnership pesticide detections within the SWP Area.

Pesticide	Use	North Fork Deep Creek	Noyer Creek	Rock Creek	Sieben Creek	Clackamas River near Gladstone
Acephate	Various fruit and vegetable crops, greenhouses, and Christmas trees. Also has residential uses	X	X			
Acetamiprid	Various fruit and vegetable crops	X				X
Azoxystrobin	Fruit crops	X	X			
Bifenthrin	Landscaping purposes only		X			
Bromacil	Nonagricultural areas including transportation right-of-ways					
Deisopropylatrazine		X	X		X	
Dichlorobenzamide	Various fruit crops, rights-of-way, and recreational areas	X	X	X	X	
Imidacloprid	Various crops		X			
Metolachlor	Various crops	X	X	X	X	X
Metribuzin	Various crops	X	X	X	X	
Metsulfuron-methyl	Various crops	X	X	X		
Oxyfluorfen	Various crops and residential landscaping		X			
Prometon	Primarily non-crop areas				X	
Propiconazole	Various crops and turfgrass	X				
Pyraclostrobin	Various crops	X	X			
Sulfometuron methyl	Primarily non-crop areas				X	
Tebuthiuron	Pasture and transportation rights-of-way		X			
Triadimefon	Various crops, Christmas trees, sod and turf, and landscaping	X				

5.2.1.1. Spatial Risk

Proximity of potential contamination sources to surface water bodies may increase risks of contamination to drinking water supplies. A spatial assessment of agricultural area by crop type was conducted to identify and evaluate areas of elevated concern for pesticide and nutrient pollution near water bodies. This effort also highlights areas of interest and focus contaminants where resources might be targeted to increase impact.

Crop types grown within 100 ft of the Clackamas River and its tributaries within the SWP Area were inventoried to understand the types of crops, and therefore the types and amounts of pesticides and fertilizers, that might be applied close to surface waters, and thus might be the more likely to appear downstream at drinking water intakes. 100 ft was assumed as a reasonably conservative riparian buffer to streams that are used for domestic water sources, the activities within which have increased potential to affect stream water quality. This width is consistent with Oregon's riparian streamside protection rules (Oregon Department of Forestry, 2012) and other watershed assessments (NRCS, 2019) and has been shown to provide good control of sediment and nutrients (Wenger, 1999).

In each subbasin, except North Fork Eagle Creek, pasture and hay accounts for some 70% - 85% of the agricultural area, both within the subbasin as a whole and within 100 ft of water bodies. Importantly, though about 67% of the agricultural area in the North Fork Eagle Creek subbasin consists of pasture and hay, only about 12% of the agricultural area within 100 ft of water bodies is pasture and hay.

Aside from pasture and hay, the proportion of agricultural land area devoted to different crop types changes when focusing on land areas within 100 ft of a water body versus the subbasin as a whole. **Figure 45** shows the proportion of agricultural area in each subbasin by crop type, excluding pasture and hay, which is the dominant crop type in each subbasin. The composition of agricultural areas within 100 ft of water bodies is slightly different in each subbasin than for the subbasin as a whole. For example, though Christmas trees make up approximately 25% of the agricultural area that is not pasture and hay in the Tickle Creek subbasin as a whole, they comprise less than 10% of the land area within 100 ft of water bodies in that subbasin.

Notably, no mapped areas of apples, plums, rye, and triticale (which all have relatively high pesticide and/or fertilizer application rates), were found within the 100-ft buffered area. Importantly, pesticides associated with these crops, including Carbaryl, Simazine, and Napropamide, are present in ambient water quality data (**Section 4.2.1.3**), but are likely associated with more prevalent crop types such as pasture and hay and nurseries and greenhouses. Therefore, these crops and their associated nutrient and pesticide loads might be considered a lower priority when targeting resources and efforts to abate pesticides and nutrients in agricultural surface water runoff, though they would still benefit considerably from management strategies.

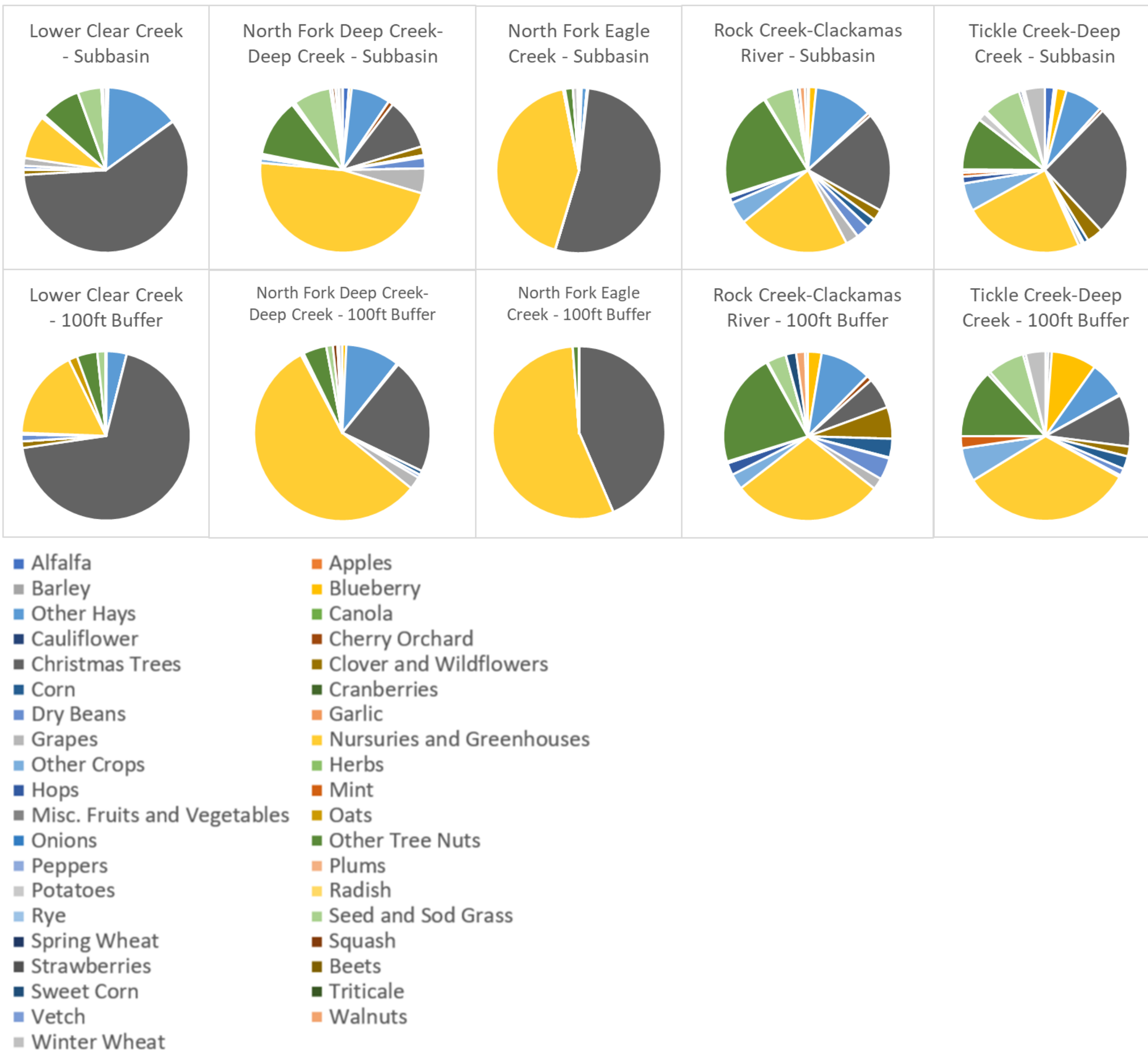

Figure 45. Proportion of agricultural land in the SWP Area by subbasin (top row) and within 100 ft of water bodies in each subbasin (bottom row), excluding pasture and hay which comprise most of the agricultural area in each subbasin.

The crop type spatial analysis was used along with fertilizer and pesticide application rates (**Table 16**) to understand the relative proportions of pesticide and fertilizer loads that might originate from specific crop types in each subbasin, adjacent to streams. **Figure 46** and **Figure 47** show the crop types within 100 ft of water bodies in each subbasin that contribute proportionally to fertilizer (top row) or pesticide (bottom row) loads to the Clackamas River. **Figure 46** includes pasture and hay, while **Figure 47** excludes pasture and hay.

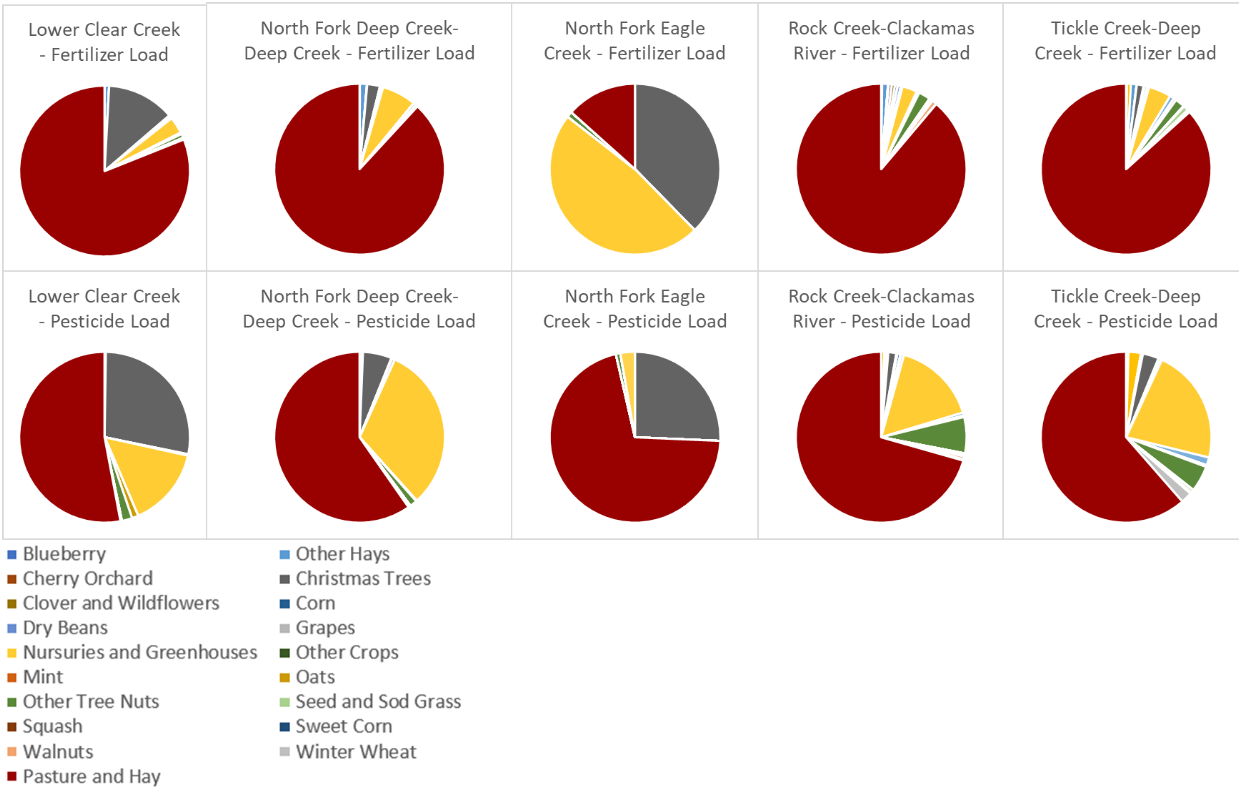

Figure 46. Relative contributions of fertilizer and pesticide loads from agricultural crop types (<u>including pasture and hay</u>) within 100 ft of water bodies in each SWP Area subbasin.

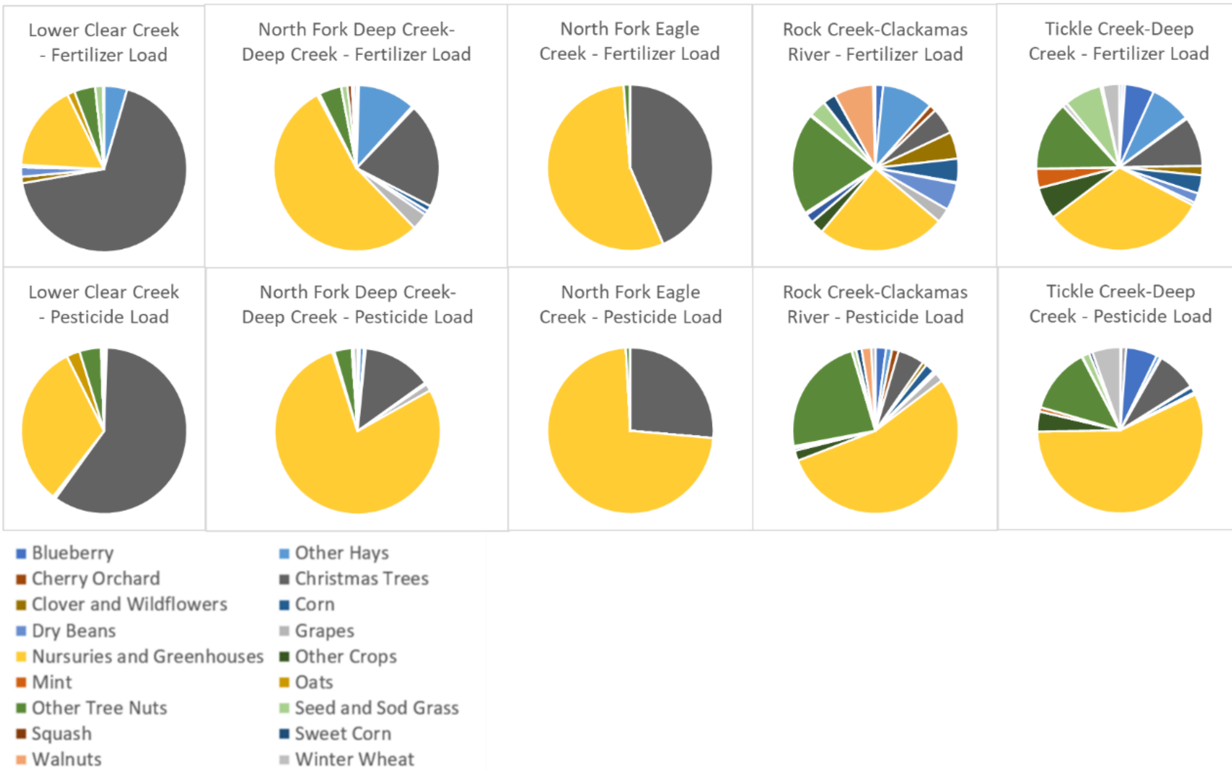

Figure 47. Relative contributions of fertilizer and pesticide loads from agricultural crop types (excluding pasture and hay) within 100 ft of water bodies in each SWP Area subbasin.

As shown in the figures above, pasture and hay, nurseries and greenhouses, Christmas trees, and tree nuts (e.g., hazelnuts) contribute most significantly to nutrient and pesticide loads which originate within 100 ft of the Clackamas River or its tributaries. Additionally, crops like walnuts, other hays, seed and sod grass, and blueberries also contribute somewhat to nutrient and pesticide loads. Due to the prevalence of these crops in proximity to surface water bodies and their large contributions to nutrient and pesticide loads in the Clackamas River, it is recommended that nurseries and greenhouses, Christmas trees, tree nuts, walnuts, and blueberries are targeted for management efforts. **Section 5.3.2** further describes possible targeted BMPs and potential locations.

5.2.2. Risks to Groundwater

As discussed in **Section 4.1.2.1**, most groundwater recharge to the SWP Area is due to local precipitation, making this the source of most groundwater resources in the SWP Area. Therefore, land use is anticipated to influence groundwater recharge water quality in developed areas where surface runoff infiltrates during and after storm events. Other factors, such as surface water – groundwater interactions, contaminant fate and transport characteristics, and groundwater residence times are expected to influence the risks that potentially contaminated groundwater may pose to surface water quality and water supply intakes in the SWP Area.

Carpenter (2003) documented reports of high nutrient contributions to the lower Clackamas River from shallow wells and seeps. This interaction might still occur in the Rock Creek subbasin, which contains significant agricultural land to this day (**Figure 36**) that could result in nitrogen and phosphorus loading to groundwater (**Figure 37**). Although seeps may also occur in the upper basin, as shown in **Figure 26**, the Rock Creek subbasin contains reaches of the Clackamas River that studies have shown gain streamflow from groundwater sources. Additionally, groundwater recharge in the Rock Creek subbasin may have relatively short residence times compared to recharge from the upper basins in the SWP Area, allowing less time for natural processes to reduce nutrients in recharged groundwaters. Presumably, pesticide compounds could also be present in the groundwater seepage occurring Rock Creek subbasin, however no studies have documented this in the region. Also, in theory, certain pesticides in groundwater may break down before reaching the Clackamas River depending on the specific chemical properties of the compound. These factors lead to some concern for pollutant loading to the Clackamas River from groundwater sources in the lower SWP Area, although further studies would be needed to confirm and quantify this hypothesis.

Regarding the other subbasins, the highest infiltration rates from precipitation are most likely to be found in the upper reaches of the SWP Area, including the North Fork Eagle Creek and Tickle Creek – Deep Creek subbasins **Section 4.1.2.1**). As shown in **Figure 36**, these subbasins are largely undeveloped and have the least (North Fork Eagle Creek) and next-to-least (Tickle Creek – Deep Creek) agricultural area of the subbasins in the SWP Area. As most land area in both subbasins is forested, groundwater recharge in these subbasins is expected to carry relatively lower pollutant loads than might be expected from areas in the lower SWP Area. Additionally, as depicted in **Figure 26**, tributaries in these subbasins, as well as a large section of the Clackamas River downstream of these subbasins, are considered to be losing reaches, meaning that groundwater is unlikely to make its way into stream baseflow. Finally, as these reaches are in the uppermost part of the SWP Area, and the drinking water intakes are in the lowest reaches of the Clackamas River in the SWP Area (**Figure 6**), groundwater recharge from this area will have a long residence time, which should allow for some treatment through filtration and other processes.

Overall, risks from groundwater are likely minor compared to the risks associated with surface water unless future studies suggest otherwise. Additionally, risks to groundwater can be mitigated by many of the same mitigation efforts that are used to mitigate surface water contamination, as discussed in **Section 5.3**.

Groundwater withdraws from wells in the SWP Area are largely for irrigation and domestic consumption, and to a lesser extent for industry and livestock (Oregon Water Resources Department, 2020). As such, risks to groundwater should be mitigated where reasonably possible and appropriate, especially when mitigation strategies may overlap with potential strategies addressing surface water concerns, as discussed in **Section 5.3**.

5.3. Analysis of Treatment and Opportunities

This section describes management strategies that address the risks described in **Sections 5.1** and **5.2** above. **Section 0** highlights strategies and programs that already exist within the Basin, while **Section 5.3.2** discusses opportunities for additional management projects, programs, and strategies as well as where projects might be most impactful. **Section 6** describes the practicalities and logistics for implementing opportunities discussed in this section.

5.3.1. Existing Programs and Strategies

Since pesticides have been observed in source water draining agricultural and urban areas in the basin for at least the last two decades, some management strategies have already been developed and implemented in response. These currently include, but are not limited to:

- Pesticide Collection Events: the CRWP has been sponsoring Pesticide Collection Events with partners in the Clackamas River watershed since 2007. Through these efforts, which offer free disposal and container recycling, over 151,900 lbs. of pesticides had been collected in 2019 (ODA, 2019);

- Pesticide Reduction Program (Spencer, 2020): CRWP works with the Clackamas River Basin Council (CRBC) to support an outreach program for voluntary pesticide reduction through:

    - distribution of educational fact sheets on a suite of topics including “Reading Pesticide Labels,” “Alternatives to Pesticides,” “Integrated Pest Management,” and “Pesticide Application,” as well as tips specific to Christmas tree growers and nursery growers;

    - implementation of the “Parting with Pesticides Pledge,” in which homeowners or residents in the Clackamas River watershed make a declaration to reduce or eliminate the use of pesticides on their yard or property; and

    - consultations with landowners;

- Pesticide reduction efforts with the Clackamas Soil and Water Conservation District (CSWCD): CRWP works with CSWCD to fund pesticide reduction workshops and several pesticide reduction programs (CRWP, 2021). These programs are:

    - the Windsock Program, which provides a free calibrated windsock to agricultural producers, which help producers apply pesticides while reducing chemical drift from wind;

- the Sprayer Efficiency Cost-Share Program, which provides cost share on the replacement of a limited number of parts for commercial pesticide spray equipment. The purpose is to increase sprayer efficiency and reduce the amount of pesticide used;
- the Field to Faucet campaign, which is conducted in partnership with CRWP and engages producers with technical assistance on matters including pesticide management, invasive plants, and integrated pest management (ODA, 2019); and

- Pesticide Stewardship Partners: CRWP is an active participant in the Clackamas Basin Pesticide Stewardship Partnership (PSP) (CRWP, 2021) – The PSP is a voluntary, collaborative effort to offer water quality monitoring data, resources, and training to help landowners and managers enable more efficient and effective pesticide use while protecting the river and its tributaries.

Efforts have also been made in the basin to improve source water quality by reducing risk posed by sediment and nutrients. These include:

- Drinking Water Protection Plan (DWPP): CRWP developed a DWPP in 2010 to provide a roadmap of potential strategies and programs to implement to preserve the Clackamas River as a high-quality drinking water source. This was followed by development and deployment of an Implementation Plan as well as a 2015-2020 CRWP Workplan. The workplan included programs ranging from water quality monitoring and evaluating stream health metrics; pollutant source evaluations and mitigations; disaster and emergency preparedness and response; and public outreach and information sharing infrastructure;

- ODA Strategic Implementation Areas (SIAs): ODA and various partners have identified Clear Creek as a SIA area by which to improve water quality by improving agricultural management (Kilders and Cloutier, 2021 and Sanchez, 2021). This effort includes desktop and field assessments of agricultural parcels to identify potential violations of Agricultural Water Quality Management Area Rules and opportunities for improvement, such as removing livestock or manure piles from the streamside and planting native riparian vegetation. This effort also identified potential vulnerable soils on early-establishment Christmas tree farms due to recent heat waves. ODA plans to follow with outreach to landowners and monitoring;

- Clackamas Soil and Water Conservation Outreach: the CSWCD curates a library of videos detailing BMPs for landowners. Content includes erosion control on Christmas tree farms, wet season erosion and sediment control practices for growers, and horse pasture and manure management (CSWCD, 2021). The CSWCD also offers technical assistance with respect to soil heath, septic care, and manure management through their Field to Faucet campaign, and engages producers in testing and improving soil health through the Clackamas Cotton Brief "Soil Your Undies" Challenge (ODA, 2019);

- CRBC Shade Our Streams, which is a community tree-planting initiative aimed at improving water quality in the Clackamas basin by restoring streamside native tree species. Free to participants, over 21 stream miles had been revegetated as of 2017 (ODA, 2019);

- Clackamas Stewardship Partners, which is a collaborative group of stakeholders that work with public and governmental entities, as well as private landowners, on opportunities related to forestry and the ecological health of the Clackamas Basin. The group also works collaboratively with the US Forest Service at Mt. Hood National Forest to implement projects on the ground including restoration, habitat improvement, and a variety of preventative measures for insect and wildfire damage;

- USGS and USFS wildfire impact studies, which are ongoing post-fire monitoring and research into potential wildfire impacts on water quality in the basin (Oregon Wildfire Risk Explorer, 2020); and

- Oregon DEQ Mercury TMDL: the updated Mercury TMDL will promote implementation of erosion and sediment control practices (DEQ, 2019).

As seen in the list above, many of the programs currently in place in the basin are based on information and outreach with some provisions for programmatic technical assistance. Opportunities to support agricultural producers interested in infrastructure BMPs to manage pesticides, nutrients, and other pollutants from their practices are more limited.

5.3.2. Potential Management Strategies for Agricultural Landowners

Potential management strategies that may be implemented by agricultural landowners and producers to address the potential risks identified in **Section 5.2** are described in this section, including an assessment of impact and feasibility. The most promising management strategies are highlighted in the summary and recommendations (**Section 6**).

5.3.2.1. BMP Evaluation via Pollutant Load Model (PLM)

The PLM evaluated the potential pollutant reduction from several different types of BMPs. Details about each of these BMPs is provided in **Table 18**. The BMPs included in the PLM with potential to reduce pesticides and nutrients in source water, often in addition to other pollutants, include Integrated Pest Management, Conservation Buffers, Streamside Management Areas, Water Quality Basins, Bioretention/Biofilters, Media Filters, Organic Farming, Drinking Water Protection Zones, and Nutrient Management Plans. It should be noted that of these, Bioretention/Biofilters are suited to manage urban runoff rather than agricultural sources. The eight BMPs that are suited to reducing pesticides and nutrients that run off from agricultural sources are highlighted in purple in **Table 18** below.

Table 18: BMPs supported in the Pollutant Load Model.

BMP	Description	Pollutant(s) Captured	Source(s) Addressed
Nutrient Management Plans	Management of the amount, source, placement, form, and timing of application of soil amendments and irrigation	Nutrients	Agriculture and Urban Runoff
Integrated Pest Management	Combines biological, cultural, physical, and chemical tools to minimize risks associated with pest management	Pesticides	Agriculture and Urban Runoff
Incentive Program	Incentives for connecting septic system to sewer and/or performing annual inspection/maintenance	BOD, Nutrients, Bacteria	Septic Systems
Conservation Buffers	Strips of permanently vegetated land placed to trap and degrade pollutants	TSS, BOD, Nutrients, Metals, Pesticides	Agriculture Runoff
Streamside Management Areas	Restriction of activities and/or livestock near watercourses	TSS, BOD, Nutrients, Bacteria, Pesticides	Agriculture Runoff; Forestry Activities
Water Quality Basins	Storage of stormwater runoff in an excavated basin. Types include detention, retention, and wetland.	TSS, BOD, Nutrients, Metals, Bacteria, Pesticides	Agriculture and Urban Runoff; Fish Hatchery Effluent
Bioretention / Biofilters	Engineered vegetated areas that filter and/or infiltrate water. Types include swales, media strips, and rain gardens.	TSS, BOD, Nutrients, Metals, Bacteria, Pesticides, Oil/Grease	Urban Runoff
Media Filter	Bed of aggregate with materials that filter influent. Unlike a biofilter, does not contain vegetated soils.	TSS, Nutrients, Metals, Bacteria, Pesticides, Oil/Grease	Agriculture, Urban, and Highway Runoff; Fish Hatchery Effluent
Impervious Area Reduction (IAR)	Minimizes the amount of impervious area from buildings, roads, parking, and sidewalks. Examples include porous pavement, green roofs, and dry wells.	TSS, Nutrients, Metals	Urban Runoff
Organic Farming	Form of agriculture in which no synthetic fertilizers or pesticides are used.	BOD, Nutrients, Pesticides	Agriculture Runoff
Drinking Water Protection Zones	Restriction of activities or facilities that could jeopardize purity of drinking water source, particularly around a source water intake.	TSS, BOD, Nutrients, Metals, Bacteria, Pesticides, Oil/Grease	Agriculture Runoff, Fish Hatchery Effluent, Forestry Activities
Emergency Response Plan	Documented plan that describes actions taken in response to a major event.	Oil/Grease	Urban and Highway Runoff

A set of management strategy scenarios were developed using the PLM to evaluate the most technically effective BMPs for reduction of pesticide loading from agricultural runoff. The scenarios demonstrate the relative effectiveness or impact of each BMP type, should only one type be applied to the maximum possible extent across the SWP Area subbasins. The individual scenarios represent hypothetical tests, not recommended management strategies. Note that Nutrient Management Plans were not included as a management strategy scenario due to the relatively broad suite of activities that might be encompassed by this category; **Section 5.3.2.2** discusses more specific BMPs that might fall into this or other PLM BMP categories.

The pesticide reduction results for each scenario are detailed in **Table 19**, along with the key assumptions. Greyed out results for a specific pollutant under a specific scenario indicate the BMP implemented in the scenario is not expected to reduce load of that pollutant. The PLM only allows for BMP implementation extents to be set on a watershed scale and not by subbasin or individual creek spatial scale. Note this assessment does not evaluate the practicability of each BMP for the specific crop types of concern identified in **Section 5.2** (see **Appendix A**). The practicability of each BMP will be discussed below in **Sections 6** and **7**.

Table 19: Modeled pollutant load reductions in the SWP Area under theoretical management scenarios.

Total % Reduction	Theoretical Management Scenarios						
Pollutant	**Integrated Pest Mgmt.***	**Conservation Buffer***	**Stream-side Mgmt. Area***	**Water Quality Basin***	**Media Filter***	**Organic Farming***	**Drinking Water Protection Zone***
TSS	0.0%	30.2%	8.0%	32.1%	34.9%	0.0%	11.2%
TP	0.0%	0.0%	0.0%	4.0%	0.0%	0.0%	0.0%
NO3	0.0%	61.5%	15.0%	67.2%	56.9%	12.5%	20.8%
NH3	0.0%	1.5%	4.3%	8.3%	7.4%	3.6%	6.0%
PB	0.0%	33.0%	7.7%	32.9%	33.8%	0.0%	10.8%
CU	0.0%	7.2%	7.6%	19.6%	11.2%	0.0%	10.6%
ZN	0.0%	19.7%	7.4%	21.4%	23.9%	0.0%	10.3%
BOD	0.0%	12.3%	8.6%	5.7%	10.7%	7.1%	11.9%
ECOLI	0.0%	9.6%	7.7%	25.1%	23.1%	0.0%	10.7%
Glyphosate	19.0%	17.1%	17.1%	48.0%	21.4%	47.5%	23.8%
2, 4-D	19.2%	17.3%	17.3%	48.5%	21.6%	48.0%	24.0%
Carbaryl	17.5%	15.8%	15.8%	44.3%	19.7%	43.8%	21.9%
Oil & Grease	0.0%	0.0%	7.8%	11.5%	0.0%	0.0%	8.7%

*Assumed implementation across 100% of agricultural area in the SWP Area subbasins

These PLM results suggest the most effective BMPs for reducing pesticide load, from a purely technical standpoint, are likely water quality basins (including detention, retention, and wet ponds) and organic farming. However, it should be reiterated that these results are strictly theoretical and do not necessarily reflect the best BMPs for the SWP Area based on other factors such as crop type, cost, topography, or producer involvement. Other BMPs, such as conservation buffers and streamside management areas appear to be less effective for pesticides in the model, but may be more effective on the ground due to feasibility of implementation. Although, model results do suggest that conservation buffers appear to be highly effective for reduction of nitrate. Overall, the PLM results suggest that the agricultural BMPs are slightly less effective at reducing loads of Carbaryl than Glyphosate and 2,4-D from a technical standpoint. This may be due to the application of Carbaryl in urban areas that are not treated by these BMPs. However, there are many limitations to the implications of the PLM model results in the context of this SWPP.

The PLM only models Glyphosate, Carbaryl, and 2,4-D, which are prominent in the watershed but are also likely sourced primarily from grassland and pasture. These results may not apply to other pesticides and may therefore not be entirely applicable to areas with high density of crops with relatively heavy applications of other pesticides, such as Christmas tree farms and nurseries. Similarly, not all agricultural BMPs can be applied equally to different types of crops. For example, organic farming may be the most practical solution for wide swaths of grassland and pasture, while it may be more feasible to implement a water quality basins that drains a controlled area like a nursery. Another example is the specificity required for successful implementation of integrated pest management; different practices may be recommended for protecting hazelnut trees than for blueberries, as the behavior of different pests and associated mitigative methods may vary.

An additional element for consideration is that, while the primary goal is to implement BMPs that reduce pesticide and nutrient loads from agricultural sources, some of the methods explored in **Table 19** are expected to reduce loads of other pollutants as well. For example, water quality basins and organic farming are both similarly effective methods of reducing pesticide loads. However, water quality basins also capture a wide range of other pollutants including TSS, metals, bacteria, and oil & grease, which organic farming does not. Furthermore, the results suggest that water quality basins are far more effective at reducing nutrient load in runoff than organic farming. While the ability of BMPs to mitigate other pollutants may not be the primary factor in decision-making around treatment opportunities, they may be considered as an additional benefit of specific treatment plans.

The PLM is not an exhaustive tool and only operates on the subbasin-wide basis. Rather, it seeks to demonstrate trends and relationships between general types of BMPs and pollutants/pollutant sources. Other, more specific BMPs may prove more effective in mitigating pesticides and nutrients from the specific crop types identified in **Section 5.2**. These are discussed below.

5.3.2.2. Other BMP Strategies

Other, more specific BMPs that may be effective in mitigating pesticides and nutrients from agricultural sources in the SWP Area are described qualitatively below (NRCS, 2019). Practices that fall within one of the PLM categories described in **Table 18** above are noted. The BMP strategies include, but are not limited to:

- No-Till (or Reduced Till) Practices: Benefits of these sustainable techniques, when implemented correctly, can include soil erosion protection, weed suppression, and prevention of runoff. These practices are gateways to integrated pest management.

- Cover Crops: Benefits of these sustainable techniques, when implemented correctly, can include soil erosion protection, weed suppression, and prevention of runoff. These practices are gateways to integrated pest management.

- Conservation Cover: Similar to cover crops, conservation cover reduces soil erosion and improves water quality in runoff by introducing permanent vegetation in orchards, vineyards, berry farms, and nurseries. Depending on their implementation, conservation cover may have similar benefits as Conservation Buffers described in **Table 18**.

- Grassy Borders: Also known as field borders, grassy borders can control sheet, rill, gully, and wind erosion while also providing some water quality improvement. Depending on planting, grassy borders may also be harvested. Grassy borders fall into the PLM category of Conservation Buffers (**Table 18**).

- Buffer/Filter Strips: Similar to grassy borders, buffer strips prevent loss of soil and runoff of nutrients and pesticides while also providing potential habitat for pollinators and other beneficial insects. Buffer strips may be planted along contours within fields to reduce water erosion on steeper slopes in addition to field borders. Buffer Strips fall into the PLM category of Conservation Buffers (**Table 18**).

- Nutrient Management: Similar to the Nutrient Management Plans discussed in **Section 5.3.2.1** (**Table 18**), nutrient management tailors the timing, rate, and method of fertilizer application to specific crop types and field characteristics to reduce the amount of nutrients applied and the likelihood for runoff.

- Riparian Buffers: Restoring riparian vegetation and riparian buffers can act as a last line of defense between agricultural runoff and receiving streams by trapping sediments and uptaking water and nutrients. Riparian buffers fall into the PLM category of Conservation Buffers (**Table 18**)

- Improved Irrigation: Improved irrigation systems, which improve the timing, precision, and quantity of water applied to crops, can reduce agricultural runoff and associated pollutant loads. Improved irrigation may fall under the PLM category of Nutrient Management Plans (**Table 18**).

- Terracing: Terracing land can reduce erosion, runoff, and associated pollutant loads by decreasing land slopes and allowing for more infiltration. Terracing is not readily categorized under any of the PLM BMP categories.

- Critical Area Planting: This practice seeds bare areas without another purpose, which can reduce or slow runoff, reduce soil erosion, and increase infiltration. Critical Area Planning is most closely associated with the PLM category of Conservation Buffers (**Table 18**).

While technical potential to reduce pollutant loads is key, agricultural producer acceptance of BMPs is a vital component of successful water quality improvement through load reductions. BMPs with stakeholder support within the SWP Area are recommended. These will be discussed further in **Sections 6** and **7**.

5.3.2.3. Programmatic Synergies

- NRCS cost list: This cost list can be provided annually to highlight the Environmental Quality Incentives Program (EQIP) payment rate and cost-share amounts for common practices.

- Conservation Reserve Enhancement Program (CREP): CREP is a land conservation program administered by the Farm Service Agency (FSA). In exchange for a yearly rental payment, farmers enrolled in the program agree to remove environmentally sensitive land from agricultural production and plant species that will improve environmental health and quality, especially woody vegetation along riparian buffers. This practice may sometimes be known as riparian buffer installation.

- NRCS Conservation Implementation Strategy: Proposals submitted to NRCS may be implemented to target high priority natural resource concerns, resulting in a measurable improvement of natural resources. Specific proposals may be dedicated to addressing degraded riparian habitat and drinking water quality degradation.

- Healthy Farms Clean Water Program: Similar to the programs supported by CRWP, this neighboring program offered by the Eugene Water & Electric Board is an example of one that protects water quality and increases economic viability of farmers by offering free soil and leaf sampling, chemical disposal for pesticides or fertilizers, reimbursement for organic certification costs, technical assistance for developing a nutrient management program, and cost share programing for off stream watering projects.

5.3.2.4. Potential Management Locations

The potential management strategies described above would likely provide some benefit to water quality in the Lower Clackamas River if implemented by any producer within the subbasin. However, the loading and spatial analyses described in **Section 5.2.1** identified crop types and locations (within 100 ft of streams and tributaries) which are likely to have a higher contribution to pollutant loads at downstream drinking water intakes. Targeting these parcels for potential management strategies would likely result in greater improvement in water quality at downstream drinking water intake locations than crops with lower pollutant yields and/or on parcels that are not located near streams.

Figure 48 – **Figure 53** show these high priority parcels, as described in **Section 5.2.1**. These represent potential "high impact" opportunities for implementation of BMPs described above.

As shown in **Figure 49**, in the North Fork Eagle Creek subbasin, there are five licensed nursery or greenhouse growers, one licensed Christmas tree grower, and one parcel of tree nuts within 100 ft of streams. In the Tickle Creek – Deep Creek subbasin, there are two licensed nursery or greenhouse growers within 100 ft of streams. Additionally, there are several parcels of tree nuts and seed and sod grass in the upper reaches of Lower Fork Tickle Creek, and the upper reaches of Tickle Creek and its unnamed tributaries contain significant parcels of pasture and hay, as well as tree nuts (**Figure 50**). In the North Fork – Deep Creek subbasin, there are three licensed Christmas tree growers and 13 licensed nursery or greenhouse growers within 100 ft of streams among dozens total in the subbasin. Additionally, the upper tributaries of North Fork Deep Creek, including Dolan Creek and Doane Creek, contain a high concentration of agricultural area including pasture and hay, tree nuts, and other hays (**Figure 51**). In Lower Clear Creek, there are two licensed nursery or greenhouse growers and 10 licensed Christmas tree growers with 100 ft of streams among approximately twenty total in the subbasin. Additionally, there are areas with a high concentration of pasture and hay, other hays, and tree nuts in the upper reaches of unnamed tributaries to Clear Creek (**Figure 52**). Finally, in the Rock Creek subbasin, there are seven licensed nursery or greenhouse growers and one licensed Christmas tree grower within 100 ft of streams. Additionally, there are several areas with a high density of agriculture, including high concentrations of pasture and hay, tree nuts, and seed and sod grass as shown in **Figure 53**. A few isolated parcels of blueberries and walnuts, which both have high pesticide application rates, are also present within 100 ft of streams in the Rock Creek subbasin.

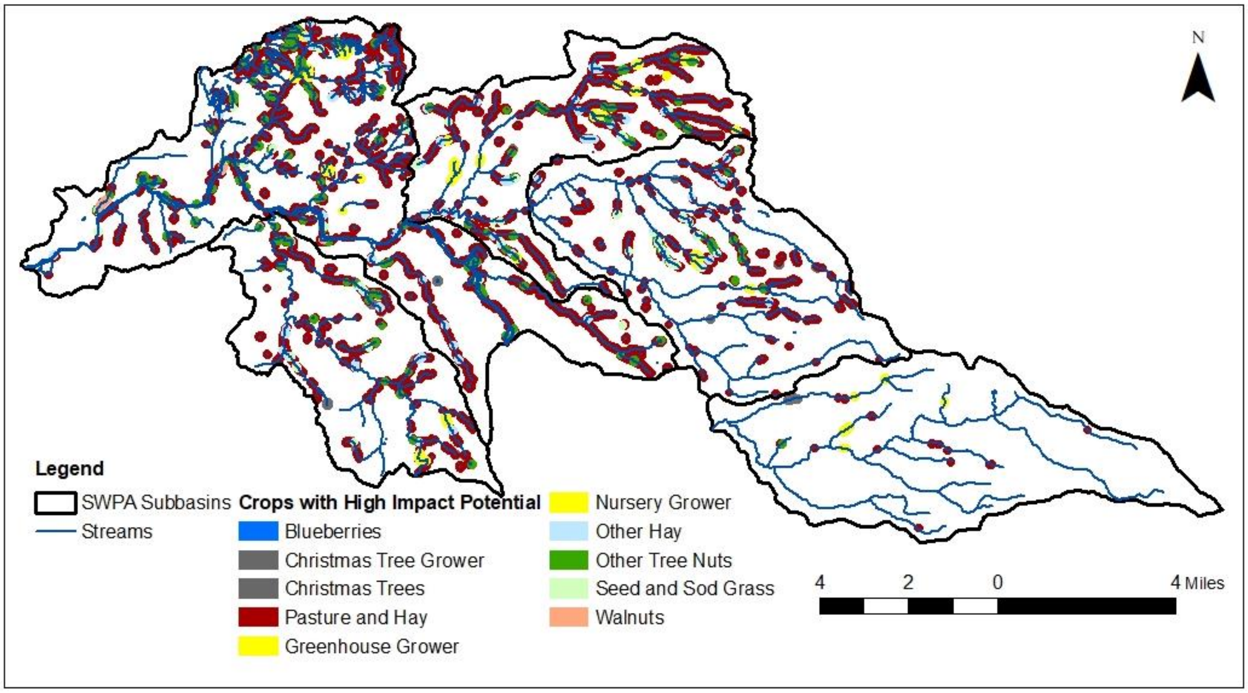

Figure 48. Agricultural parcels in the SWP Area within 100 ft of streams containing crops with a high potential for impact to water quality in the Clackamas River.

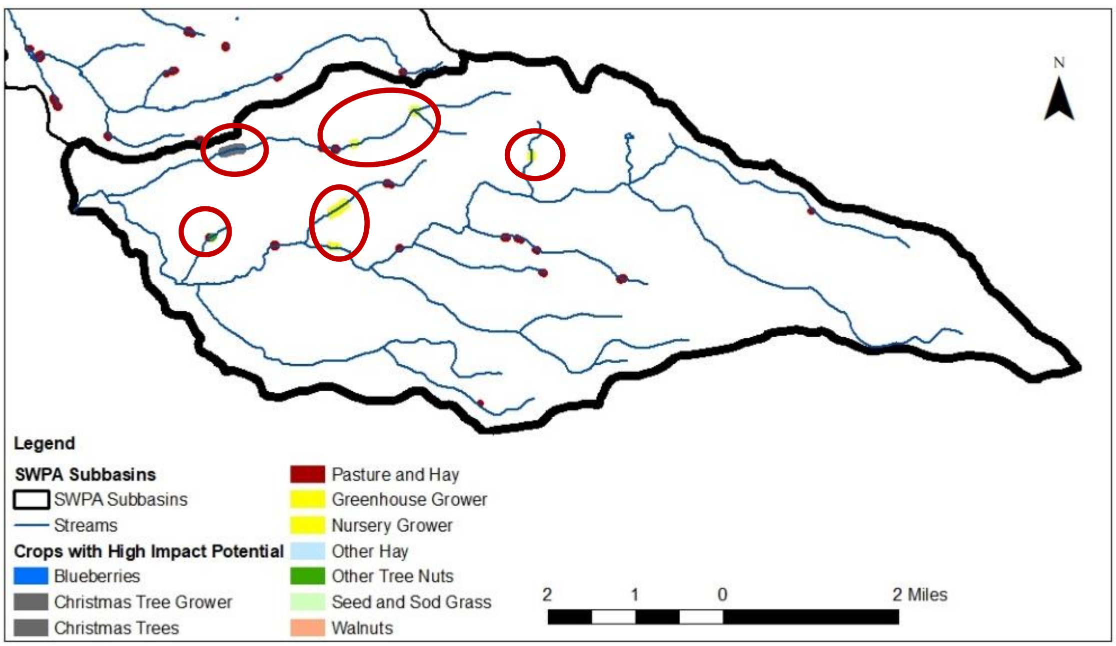

Figure 49. Agricultural parcels in the North Fork Eagle Creek subbasin within 100 ft of streams containing crops with a high potential for impact to water quality in the Clackamas River. Circled areas indicate identified potential treatment opportunity locations.

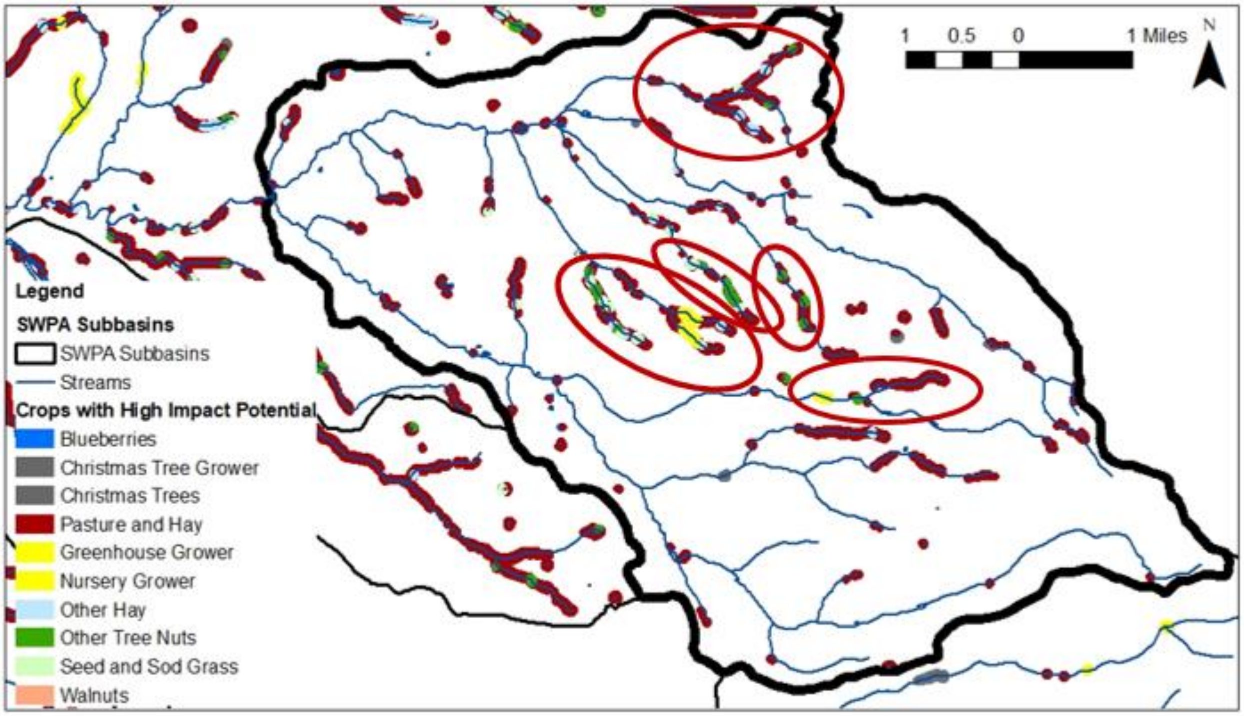

Figure 50. Agricultural parcels in the Tickle Creek – Deep Creek subbasin within 100 ft of streams containing crops with a high potential for impact to water quality in the Clackamas River. Circled areas indicate identified potential treatment opportunity locations.

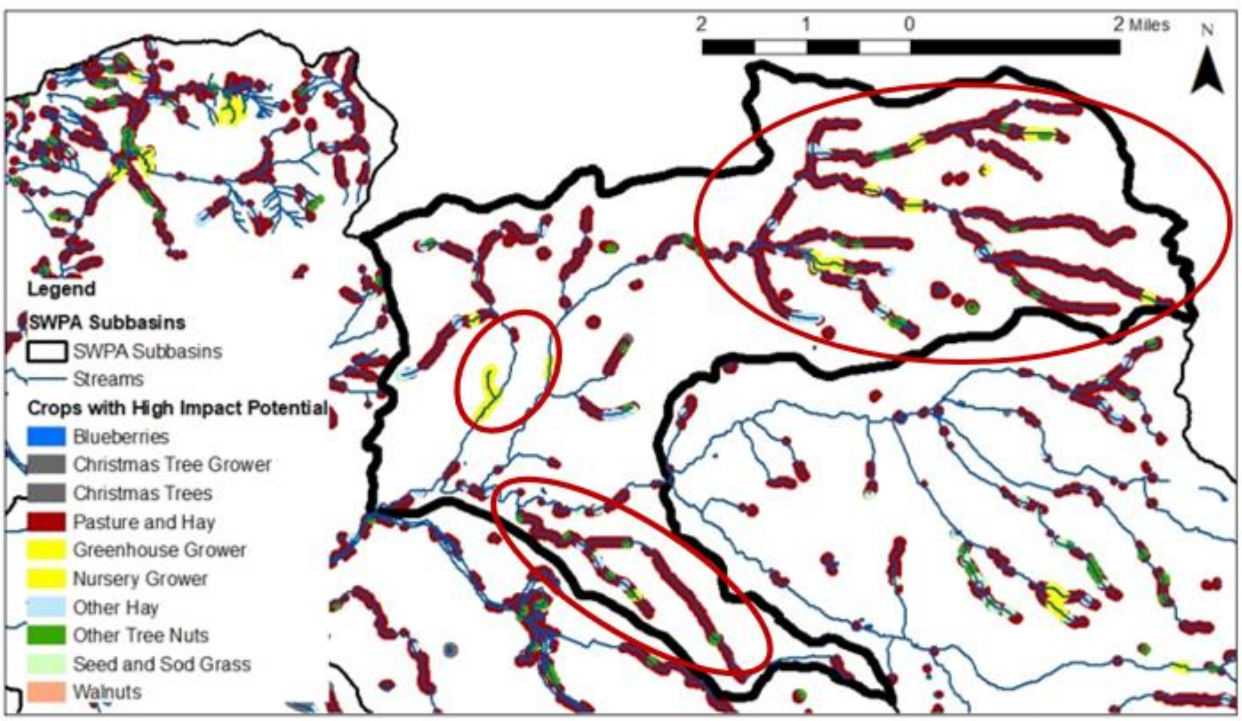

Figure 51. Agricultural parcels in the North Fork – Deep Creek subbasin within 100 ft of streams containing crops with a high potential for impact to water quality in the Clackamas River. Circled areas indicate identified potential treatment opportunity locations.

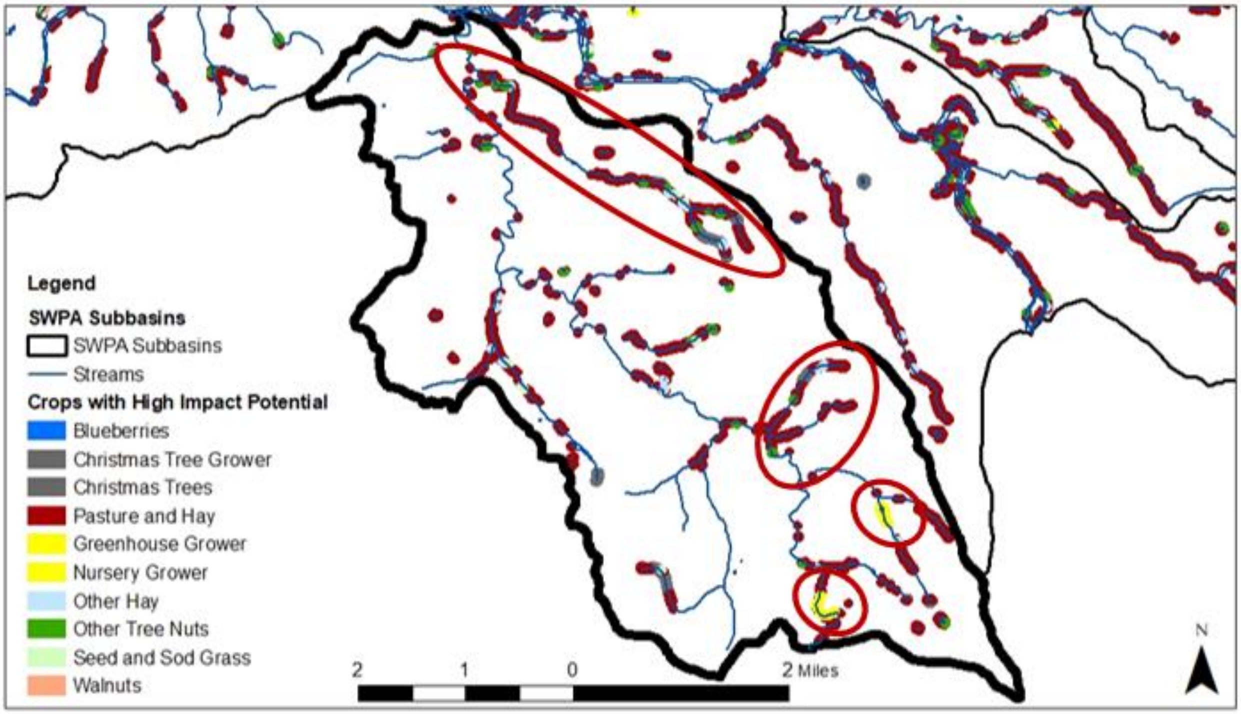

Figure 52. Agricultural parcels in the Lower Clear Creek subbasin within 100 ft of streams containing crops with a high potential for impact to water quality in the Clackamas River. Circled areas indicate identified potential treatment opportunity locations.

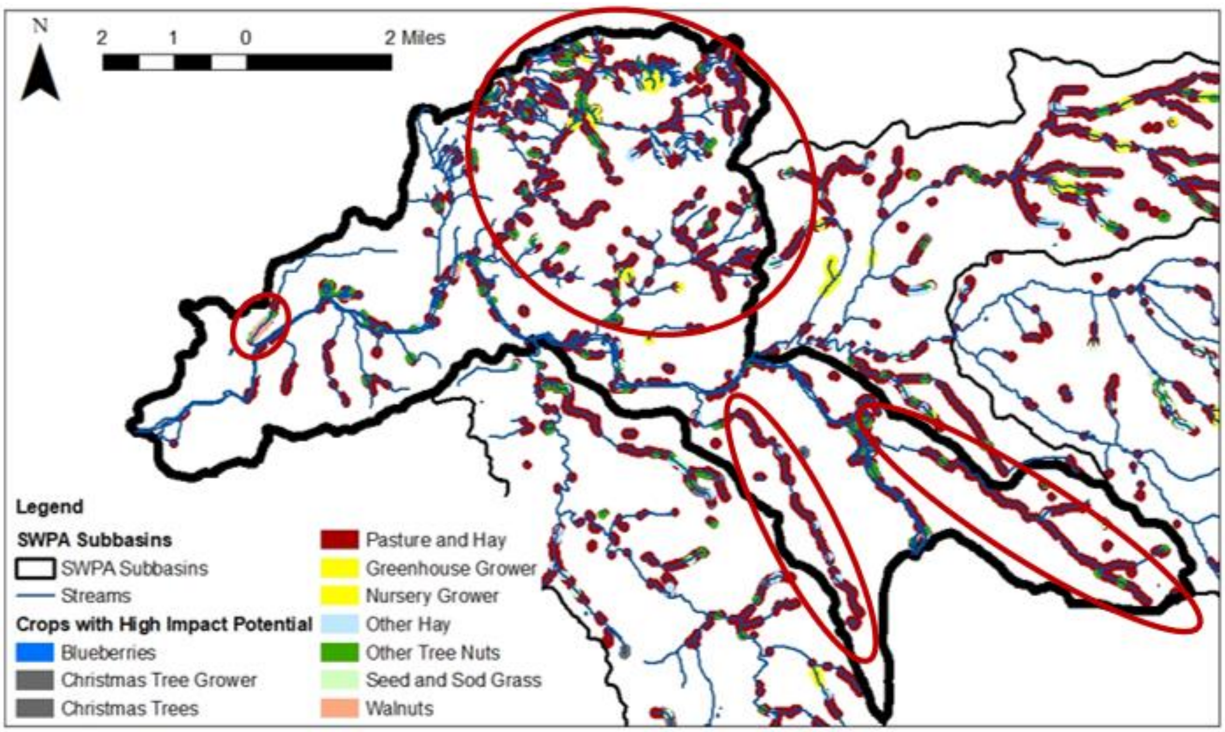

Figure 53. Agricultural parcels in the Rock Creek subbasin within 100 ft of streams containing crops with a high potential for impact to water quality in the Clackamas River. Circled areas indicate identified potential treatment opportunity locations.

Exceptions to this targeted BMP implementation strategy may be considered in the Rock Creek subbasin, where contaminated groundwater due to infiltration could contribute high nutrient to the lower Clackamas River from shallow wells and seeps (as discussed in **Section 5.2.2**). In the Rock Creek subbasin, management strategies that directly prevent the application of nutrients and pesticides—such as nutrient management plans, integrated pest management, and organic farming—as opposed to preventing their runoff into creeks and streams (e.g., filters or buffers) would improve groundwater recharge quality, which may also improve water quality in the lower Clackamas River. Therefore, these BMPs should be targeted in the Rock Creek subbasin to agricultural areas producing crops with high rates of nutrient or pesticide application (those highlighted red in **Table 16**), regardless of proximity to streams. Additional recommendations will be discussed in the following sections.

6. SUMMARY AND RECOMMENDATIONS

6.1. Summary of Resource Concerns

This section summarizes resource concerns in the Clackamas River as they relate to the drinking water services provided by the partners of the CRWP. The primary concerns in the Clackamas River in the SWP Area are related to water quality and include high concentrations of pesticides and nutrients, high summer water temperatures, and bacteria and other pathogens. Also of concern are hydrocarbons (petroleum), low DO levels, heavy metals, and organic compounds. These concerns are reflected in Oregon 303(d) listings (DEQ, 2020) for sections of the Clackamas River or its tributaries, including for temperature, bacteria, DO, harmful algal blooms, and methylmercury. They are also echoed in the CRWP's DWPP (2010) list of potential contaminants.

These water quality concerns are closely related to specific land uses within the watershed, which in the SWP Area include large percentages of forested and agricultural area, with some developed urban area. Ambient water quality within the SWP Area, including levels of nutrients and pesticides, is correlated to the acreage and types of crops grown upstream of the sampling points.

To improve water quality concerns described above, impacts from the associated agricultural land uses must be addressed. Treatment opportunities should be targeted at crop types and land uses which are most impactful in degrading water quality, whether from high acreage, high pollutant application rate, or proximity to water bodies.

6.2. Description of Goals and Objectives

The intent of participation in the NWQI program is to partner with local producers to implement projects and practices within the Clackamas Basin watershed which will improve water quality over time in the Clackamas River and its tributaries. The establishment of goals and objectives will guide the implementation of this SWAP.

It is important to distinguish between goals and objectives for the purposes of measuring progress of this SWAP, as discussed in **Section 6.3**. Goals reflect intended outcomes, while objectives are the specific actions and steps taken to realize these goals. Each is discussed below.

6.2.1. SWAP Goals

The overall goal of implementing this SWAP through the NWQI program is to improve receiving water quality, especially with respect to levels of nutrients, pesticides, and suspended solids. This is achieved through reductions in pollutant loads from agricultural land (among other sources) within the lower Clackamas Basin to receiving waters. It is important to acknowledge the natural variability in environmental conditions that exists within the lower Clackamas Basin which may substantially impact nutrient and sediment loads from year to year. Nutrient and sediment loads may vary based on influences from wildfire, precipitation patterns, and accumulated pollutants which likely exist in stream sediments. Progress towards improving receiving water quality will therefore likely be difficult to assess, especially in the short term (Mulla et al., 2005). Nevertheless, improvements in water quality are important to evaluate over time as this SWAP is implemented. Specific goals of the SWAP include:

- Reduced concentrations of pesticides in receiving waters;
- Reduced concentrations of nitrogen in receiving waters;
- Reduced concentrations of phosphorus in receiving waters; and
- Reduced concentrations of sediments in receiving waters.

6.2.2. SWAP Objectives

Because of the natural variability that may be seen in receiving water quality concentration trends, the evaluation of the implementation of this SWAP will focus on the objectives of partnering with producers to implement projects and practices which will reduce nutrient, pesticide, and sediment loads to the lower Clackamas River and its tributaries. These objectives will include:

- Increased quantity and quality of partnerships with producers and agricultural communities;
- Increased producer program participation;
- Increased funding acquisition for project implementation; and
- Increased acres treated.

6.3. Interim Metrics

An important aspect in implementing this SWAP will be tracking progress towards the goals and objectives outlined in **Section 6.2**. Progress can be tracked through interim metrics, which may be categorized into short term Outputs, or a measurement of progress towards objectives, and longer-term Outcomes, or a measurement of the impacts of the projects implemented. Interim metrics are described in **Table 20**, and progress towards these metrics will be assessed every five (5) years.

It should be noted that for the purposes of assessment metrics, this SWAP considers receiving waters to include the mainstem of the Clackamas River as well as its tributaries, understanding that the mainstem is a function of many upstream factors and tributaries may provide better opportunities to observe changes stemming from BMP implementation. Additionally, there are several existing water quality sampling sites in tributaries to the Clackamas River which could be leveraged for interim assessment.

Table 20. Short term and long-term goal assessment metrics

Assessment Metrics	
Metric	**Goal**
Short-Term Outputs	
Partnerships with Basin Agriculture Communities	Increase in number or quality
Producer Program Participation	Increase in number or quality
Funding Pursued or Secured	Increase in amount
Number of Practices Implemented	Increase in number
Agricultural Acreage Treated	Increase in acreage
Track projects being implemented through other programs like the Soil and Water Conservation District.	Increase in number of projects and partnerships
Long-Term Outcomes	
Average Pesticide Concentration in Receiving Waters	Trending down from baseline
Average Nitrogen Concentration in Receiving Waters	Trending down from baseline
Average Phosphorus Concentration in Receiving Waters	Trending down from baseline
Average TSS Concentration in Receiving Waters	Trending down from baseline
Estimated or Modeled Nitrogen Loss	Reduced from baseline
Estimated or Modeled Phosphorus Loss	Reduced from baseline
Estimated or Modeled Sediment Loss	Reduced from baseline

These metrics will be assessed through existing or planned working groups, infrastructures, and communications channels; no specialized data collection is expected to be necessary to inform evaluation of progress towards the metrics listed above. It is expected that the metrics will be assessed through:

- Attendance at producer group meetings;
- Grant applications;
- Project implementation reports, including modeded estimates of pollutant loss;
- Analyses of receiving water quality data from:
    - Clackamas Basin Technical Workgroup water quality monitoring efforts;
    - Pesticide Reduction Program monitoring efforts and special studies;
    - Strategic Implementation Area (SIA) monitoring in Clear Creek (monitoring program in development);
    - Potentially raw water quality monitoring from the partner drinking water treatment facilities with intakes along the Clackamas River, depending on the water quality constituent monitored;

- CRWP Annual Reports; and
- Other special studies conducted by other parties within the Clackamas Basin.

6.4. Description of Planned Practices

As described in **Section 5.2.1**, the primary agricultural risks to surface water quality come from the cultivation of pasture and hay, Christmas trees, and tree nuts, as well as nursery and greenhouse operations. Other hays, blueberries, seed and sod grasses, and grapes also contribute appreciable pesticide or nutrient loads in subbasins where they are grown (**Figure 47**). Apples, cherries, and plums also have high pesticide or fertilizer application rates (**Table 16**) that could benefit from targeted BMP practices as well.

The primary pollutants of concern for each crop type listed above were identified as having a high, medium, or low soil sorption potential (based on organic carbon-water partition coefficient [K_{oc}] values). Fertilizers were assumed to be highly mobile in water. This information can help identify the most applicable BMP opportunities for each crop type. That is, crop types using pesticides that are highly sorbent to sediment may benefit from BMPs which control erosion or trap sediment in runoff, while crop types using pesticides or fertilizers that are highly water soluble may benefit from BMPs which limit runoff or minimize the application of the pollutant.

Table 21 highlights the crop types of concern, the associated primary pollutants of concern, their expected affinity for sediment sorption, and the recommended class of BMP practices. The sediment affinity rankings are based on the National Pesticide Information Center's Pesticide Properties Database (Vogue et al., 1994).

Table 21. Recommended BMPs for pollutants of concern related to high-risk crops

Crop	Primary Pollutants of Concern	Affinity for Sediment Sorption	Recommended BMP Type
Pasture / Hay	Glyphosate	High	Trap
	Triclopyr	Low	Avoid or Control
	Nutrients	Low	
Nurseries / Greenhouses	Trifluralin	High	Trap
	Diuron	Moderate	Trap, Avoid, or Control
	Napropamide	Moderate	
	Atrazine	Low	Avoid or Control
	Ethoprop	Low	
Christmas Trees	Carbaryl	High	Trap
	Dichlobenil	Moderate	Trap, Avoid, or Control
	Nutrients	Low	Avoid or Control
	Triclopyr	Low	

Crop	Primary Pollutants of Concern	Affinity for Sediment Sorption	Recommended BMP Type
	Atrazine	Low	
	2, 4-D	Low	
	Simazine	Low	
Tree Nuts	Nutrients	Low	Avoid or Control
	Simazine	Low	
Other Hays	Triclopyr	Low	Avoid or Control
	Nutrients	Low	
Blueberries	Dichlobenil	Moderate	Trap
Seed and Sod Grasses	Dimethenamid-P	Moderate	Trap, Avoid, or Control
	Diuron	Moderate	
Grapes	Glyphosate	High	Trap
	Trifluralin	High	
	Diuron	Moderate	
Apple Trees	Nutrients	Low	Avoid
Cherries	Diazinon	High	Trap
	Endosulfan	High	
	Napropamide	Moderate	
Plums	Dichlobenil	Moderate	Avoid or Control
	Nutrients	Low	
	Simazine	Low	

The BMP practices outlined in **Table 21**, as well as other potentially applicable BMPs discussed in **Section 5.3.2** are categorized by the NWQI process as Avoiding, Controlling, or Trapping. Avoidance practices reduce the amount of nutrients or other pollutants available for runoff. Controlling practices prevents the loss of pollutants through increased infiltration, reduced runoff, or reduced erosion. Trapping practices are generally applied at the edge-of-field to prevent eroded sediments or runoff from leaving the field and encourage nutrient uptake. **Table 22** provides a list of these practices, their Environmental Quality Incentives Program (EQIP) Code, and their BMP category.

Table 22. EQIP Core Practices to Address Natural Resource Concerns in the Clackamas River Watershed

Practice	EQIP Code	Avoid	Control	Trap
Soil Health Management Plan	116	X	X	X
Nutrient Management Design and Implementation Activity	157	X	X	X
Pest Management Conservation System Design and Implementation Activity	161	X	X	X
Soil Health Management Design and Implementation Activity	162	X	X	X
Soil Health Testing	216	X	X	
Conservation Cover (Orchard Alleyways)	327		X	
Cover Crop	340	X	X	
Critical Area Planting	342		X	X
Sediment Basin	350			X
Pond	378			X
Grassy Border (Field Border)	386			X
Riparian Herbaceous Cover	390			X
Riparian Forest Buffer	391			X
Filter Strip	393		X	X
Grassed Waterway	412			X
Irrigation System	441		X	
Sprinkler System	442		X	
Strip Cropping	585		X	X
Nutrient Management	590	X	X	
Pest Management Conservation System	595	X		
Terrace	600		X	
Water and Sediment Control Basin (WASCOB)	636			X

It is important to note that not every BMP indicated for the appropriate Avoid, Control, or Trap category will be applicable to the corresponding crop types indicated above, or to specific parcels of land.

Appendix A provides a matrix which ties together information in **Sections 5** and **6** which may be used to inform specific BMP selection for the crops which pose the highest risk to surface water quality in the lower Clackamas Basin, as well as where these crops might be located.

Additionally, it is reasonable to expect that producers may be hesitant to adopt certain practices or implement certain BMPs. Additional considerations of BMP implementation from the perspective of engaging producers are discussed in **Section 7**.

The total estimated cost of implementing the planned practices was calculated using the Oregon EQIP Payment Schedule for fiscal year 2022 (USDA NRCS, 2022). The calculation was broken down into the costs of implementing each practice type across each of the high priority crop types, as applicable. This was done by applying the average unit costs for each practice type to the total acreage and/or number of parcels of each applicable crop type within the SWP Area.

Average unit costs per acre and/or other unit were determined by averaging the relevant component costs for each practice type from the EQIP Payment Schedule. A table of the resulting average unit costs is provided in **Table *23***. Where no unit was provided for the cost, it was assumed that a single unit would be sufficient to treat a single parcel and thus the unit cost was per parcel. For practices with units other than cost per acre or per parcel treated, a note is provided with the assumptions used to convert to units of cost per acre or treated.

Table 23: Average unit costs derived from EQIP Payment Schedule

Practice	Average Cost (Per Unit Treated)	
Nutrient Management	$23.61 (Acre)	$3,118.79 (Parcel)
Soil Health Management	$3,038.45 (Acre)	
Soil Health Testing	$104.47 (Acre)	
Pest Management Conservation System	$95.96 (Acre)	$3,090.37 (Parcel)
Cover Crop and/or Conservation Cover (Orchard Alleyways)	$306.08 (Acre)	$2,361.05 (Parcel)
Critical Area Planting	$629.79 (Acre)	
Sediment Control Basin and/or Water Quality Pond	$3,486.38 (Acre)	$2.98 (CuFt)*
Grassy Border (Field Border)	$176.09 (Acre)	
Riparian Herbaceous Cover/Forest Buffer or Grassed Waterway	$1,823.27 (Acre)	$3,805.34 (Acre)**
Buffer/Filter Strip	$136.04 (Acre)	
Irrigation/Sprinkler System	$1,537.35 (Acre)	$18,441.74 (Parcel)
Strip Cropping	$1.24 (Acre)	
Terrace	$259.64 (Acre)	$1.24 (Ft)***
*Converted from volume to acres by assuming runoff coefficient of 0.2, 24-hour design storm depth of 1.61 inches		
**Converted from acres planted to acres treated by assuming 100ft wide strips along one side of treated acre treated (~208 ft)		
***Converted from ft to acres by assuming treated acre contains ~208 ft terrace		

Next, the total number of acres and parcels for each crop type across the SWP Area was determined and is provided in **Appendix B**. The average unit costs were then multiplied by the total units treated, resulting in costs for implementation of each practice across the total acreage or number of parcels of each crop type within the SWP Area. These costs are detailed in **Appendix B**. If a practice had average unit costs both per acre and per parcel, the total cost was estimated by averaging the costs computed by both the total number of acres and the total number of parcels. Whether each practice was applicable to a specific crop type was determined in accordance with **Appendix A**.

The costs for implementation of each practice were then summed for a total estimated cost of approximately $278,222,000. Note that this cost assumes that every applicable treatment is applied to all acres of each priority crop type, which is not likely. It is far more likely that only one or a few treatments will be implemented per parcel or acre, and thus this cost is overestimated. Costs will be best estimated on a project specific basis.

6.5. Documentation of NEPA Concerns

The National Environmental Policy Act (NEPA) requires federal agencies to assess the environmental effects of proposed alternative actions. The NRCS is required to conduct an Environmental Evaluation (EE) for conservation planning activities to consider the impacts of project alternatives on soil, water, air, energy, animal resources, and social and economic concerns. Direct, indirect, and cumulative effects of the proposed alternatives should be considered. The EE is documented on Form NRCS-CPA-52. The following legislation and factors will be considered during the planning phases of proposed practice alternatives:

- Clean Air Act
- Clean Water Act / Waters of the United States
- Coastal Zone Management Areas
- Coral Reef Protection Executive Order
- National Historic Preservation Act
- Endangered and Threatened Species
- Environmental Justice Executive Order
- Essential Fish Habitat (Magnuson-Stevens Act)
- Floodplain Management Executive Order
- Invasive Species Executive Order
- Migratory Birds and Bald/Golden Eagle Protection Act
- Prime and Unique Farmlands (Farmland Protection Act)
- Riparian Areas
- Wetlands
- Wild and Scenic Rivers Act

6.6. Funding Opportunities

The strategies identified through this SWAP will require financial and technical support to be implemented. Funding opportunities offered through the NRCS and the Oregon Watershed Enhancement Board (OWEB) may be leveraged to translate the strategies and programs identified in this SWAP to impactful projects on the ground. Specific funding opportunities are introduced and discussed below.

6.6.1. Funding Opportunities through NRCS

- Environmental Quality Incentives Program: EQIP provides financial and technical assistance directly to agricultural producers to address a wide range of natural resource concerns, including improved water quality. The funds may be used to plan or implement projects including several best management practices identified in this SWAP. However, EQIP funds have traditionally benefitted larger agricultural producers with large acreages of crops and whose primary occupations are related to agriculture. This opportunity, therefore, is not well-suited to the smaller producers common in the lower Clackamas Basin. If this program is to be pursued, it may require the collaboration of groups of producers within the Basin, which may be prohibitive to successful grant acquisitions and practical application of funds. Further investigation into this funding opportunity should be coordinated through local NRCS resources.

- Regional Conservation Partnership Program: The Regional Conservation Partnership Program provides funding opportunities for partnering organizations and agricultural producers to carry out projects within identified critical conservation areas. These funds support collaboration at a regional level to address natural resource goals while also focusing on agricultural productivity. Grants are awarded for between $250,000 and $10,000,000 and are judged based on the criteria of impact, partner contributions, innovation, and partnership and management. The CRWP may be well positioned to pursue this grant opportunity based on the ability to demonstrate impact through analyses presented in this SWAP and the partnership potential with other organizations (including the CSWCD and the Pesticide Working Group) within the Clackamas Basin. Importantly, at least a one-to-one contribution match by the partnering organizations is expected, which may be provided through in-kind contributions.

- Conservation Innovation Grants: Conservation Innovation Grants support the development of innovative tools, approaches, practices, and technologies to further conservation on private lands. Producers may be eligible to participate in On-Farm Trials, which supports the widespread adoption of new agricultural practices and evaluates impacts.

- Conservation Stewardship Program: The Conservation Stewardship Program helps producers expand upon existing conservation practices, including management strategies identified in this SWAP. Producers enrolled in this program are supported via annual or supplemental payments.

- Conservation Reserve Enhancement Program (CREP): Mentioned in Section 5.3.2.3, CREP provides annual rental payments to producers, up to $50,000 annualy, to convert agricultural area to riparian buffers. While funded through the FSA, NRCS is involved in the implementation of the program.

6.6.2. Funding Opportunities through OWEB

OWEB provides a variety of grants to help protect and restore healthy watersheds and natural habitats. Applicable grant programs for producers interested in source water protection include:

- Small Grants Program: Small grants offered through OWEB provide up to $15,000 for restoration projects on private lands in Oregon which support the Oregon Conservation Strategy by benefitting water quality, water quantity, and fish and wildlife. Applicable projects include streamside revegetation and reducing upland erosion due to agricultural practices through measures such as those identified in this SWAP.

- Restoration Grants: Restoration grants are applicable where a potential project may address altered watershed functions, such as impaired water quality.

- Stakeholder Engagement Grants: Stakeholder engagement activities may be a useful first step in the implementation of this SWAP in order to engage with landowners and producers about the need for, feasibility of, and benefits of applicable projects and programs. These grants may support CRWP in these first steps.

- Operating Capacity: Operating Capacity grants are awarded to support the operating costs of watershed organizations, like the Clackamas River Basin Council, as they engage in and collaborate within their communities to support conservation and restoration goals. This could be useful for CRWP to collaborate with the Basin Council to help target outreach to producers.

- Monitoring Grants: Monitoring grants offered through OWEB offer funding for monitoring programs that concretely measure the current or changing conditions within a watershed, or the effectiveness of a specific project. Therefore, this grant opportunity should not be considered for the implementation of this SWAP, but rather to evaluate the effectiveness of specific measures undertaken as part of the Plan. Other entities, organizations, and programs, such as the SIA monitoring planned for Clear Creek, may also be able to access these funds, which would benefit the monitoring of activities implemented as part of this SWAP.

- Focused Investment Partnerships (FIPs): This OWEB grant program invests in ecological restoration activities that address OWEB-identified priorities, are implemented following a long-term strategic action plan, have clear and measurable outcomes, and are implemented using strategic partnerships of organizations. Applicable ecological priorities may include aquatic habitat for native fish species.

7. OUTREACH PLAN

An essential element to successfully implementing projects on the ground is having an effective outreach plan which connects CRWP with producers to build trust and partnerships over time. CRWP's strategies to engage producers and landowners in critical areas and target outreach efforts toward these stakeholders is outlined below. CRWP solicited input from the Clackamas Technical Working Group, a team consisting of representatives from ODA, DEQ, CSWCD, CRBC and USGS, as well as residents of the Clackamas Basin on the best ways to engage producers in the lower Basin. The consensus was that any outreach strategy should primarily consider where farmers already go for community, information, and support. These include the following:

- Oregon Association of Nurseries: The OAN is a non-profit trade association that represents more than 700 individual nursery stock producers, retailers, landscapers, and related companies serving the nursery and greenhouse industry. Due to the prevalence of nurseries and greenhouses in the SWP Area, fostering a relationship with the OAN is a critical component of the outreach plan.

- Christmas Tree Growers Associations: There are several associations for Christmas tree growers in the region. The Pacific Northwest Christmas Tree Association provides resources for including educational and public relations efforts, environmental stewardship, research and industry programs to a broad member base. Meanwhile, the Oregon Christmas Tree Growers Association is an independent grower network specific to Clackamas County. This small group of growers meets February through October at the Oregon State University (OSU) Extension Service in Oregon City to share advice on best practices for growing and selling trees.

- Grange Halls: Granges are community centers in rural and agricultural communities where residents gather for educational events, town meetings, potlucks, and more. Clackamas County has 16 Grange locations. Each has a different monthly schedule for grower meetings. Due to the number of locations, outreach could be coordinated specifically to target locations in high priority areas.

- Facebook Groups and Neighborhood Watch: Some residents with pastures, orchards, Christmas Tree farms, small nurseries, or other small scale agricultural operations may not identify as producers, or farming may not be their primary occupation. Therefore, engagement through the aforementioned groups may not target all of the landowners in high priority areas. Many communities have Facebook pages and/or Neighborhood Watch organizations that provide a forum for hyper-local communication and crowd-sourcing. These groups could provide a medium for information sharing about events or opportunities with a broader group of residents.

- Libraries: Many farmers and residents in the rural areas of the basin are not connected to the internet. Thus, libraries are a common destination for checking email and conducting other routine business requiring Wi-Fi. The handful of libraries in the Clackamas Basin, especially those at Estacada and Oregon City, could be targeted for outreach efforts to reach these residents.

- Forestry Groups: Although this watershed assessment determined that forestry posed a low risk to water quality in the SWP Area, there are several organizations dedicated to local forestry that may already have relationships with community stakeholders. These include the Clackamas County Forest Advisory Board and the Tree School through the OSU Extension Service. These groups may be able to provide assistance with outreach directly to landowners.

The Pesticide Stewardship Strategic Plan for the Clackamas Basin (Kilders and Cloutier, 2021) outlined an outreach approach involving these groups, agencies, and others. CRWP will work with the PSP to achieve the following steps of their plan:

1. Create partnership and dialogue with pesticide users.

2. Create partnership and dialogue with agricultural equipment manufacturers and sellers, crop consultants, wholesale chemical suppliers, and agricultural associations.

3. Create outreach and educational opportunities for the individual pesticide user groups.

4. Organize working group with the OSU Extension agent and local soil and water conservation districts to work on hazelnut orchard cover crops for erosion control.

5. Tap into existing partnerships for outreach and support when working with individual groups.

The Clackamas Technical Working Group also identified potential obstacles that may arise in engaging with specific farmers and suggested how outreach approaches can be tailored to overcome these. For example, seasonality plays a big role in the schedule and routines for different producers. Timing of outreach matters when specific growers are active with different activities in different seasons. Therefore, the PSP has developed a Christmas Tree Crop Calendar that has been reviewed by two independent growers as well as OSU Extension’s Chal Langren and Louisa Santa Maria. This calendar details the insecticide and fungicide application for different pests on different tree species so that creation of guidance materials and distribution can be planned accordingly. Similar considerations will be made when scheduling outreach for nursery and greenhouse producers.

With respect to outreach materials, several mediums will be explored. Brochures will be produced to inform landowners of opportunities for BMPs on their properties. One of the potential risks with brochures is that each landowner's property is different from their neighbors', so the content will target a mix of general information and site-specific compatibility criteria. Additionally, the CRWP is planning to work with CSWCD to develop a series of videos to educate landowners about the benefits of specific BMPs that manage pesticide loading to surface water. These videos would include advice, references to various CSWCD resources, and case studies by local landowners. In this way, the existing relationships with prominent members in the agricultural community are leveraged to create content that's accessible and relevant to others.

One more example of content that will be created to promote education and outreach is pesticide-specific water quality fact sheets. These sheets would be created in collaboration with PSP and Kurt Carpenter at USGS. The content would combine the existing Pesticide User Fact Sheets (CRBC, 2021) and the Organic Compounds in Clackamas River Water Fact Sheet (Carpenter and McGhee, 2009) to tie pesticide use and water quality into big themes of concern to producers at present, including recent heat domes and drought. Messaging might highlight how maintaining healthier soil allows for healthier crops, which in turn improves resiliency to pests and diseases, reducing the need for pesticides. Healthier soils also reduce erosion, benefiting water quality. Healthier soils also increase moisture capacity, making the soil cooler and protecting plants from heat waves. Different versions of these sheets will be geared toward different producers, as the messaging from crop to crop may vary.

Finally, individual landowners within critical areas will be targeted for direct outreach. CRWP has a mailing list for landowners associated with geospatial crop data. Developed by Herrera Environmental Conslultants in 2021 (Schmidt), this database provides contact information for land owners in specific areas growing specific crops. This is an invaluable tool for pinpointing communication efforts to stakeholders in the high priority areas identified in this Plan.

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9. APPENDIX A

Crop Extents:
Total Acreage within Subbasin | Acreage within 100 ft Buffer | No. Licenses/Parcels within 100 ft Buffer

Crop	Lower Clear Creek			North Fork Deep Creek-Deep Creek			North Fork Eagle Creek			Rock Creek-Clackamas River			Tickle Creek-Deep Creek		
	Total Acreage within Subbasin	Acreage within 100 ft Buffer	No. Licenses/Parcels within 100 ft Buffer	Total Acreage within Subbasin	Acreage within 100 ft Buffer	No. Licenses/Parcels within 100 ft Buffer	Total Acreage within Subbasin	Acreage within 100 ft Buffer	No. Licenses/Parcels within 100 ft Buffer	Total Acreage within Subbasin	Acreage within 100 ft Buffer	No. Licenses/Parcels within 100 ft Buffer	Total Acreage within Subbasin	Acreage within 100 ft Buffer	No. Licenses/Parcels within 100 ft Buffer
Pasture and Hay	5,231	181	TNTC	6,739	419	TNTC	740	1.8	TNTC	7,516	509	TNTC	5,129	167	TNTC
Nursuries and Greenhouses	91	8.4	2	483	36.1	13	157	7.4	5	211	18.8	7	171	9.7	2
Christmas Trees	631	33.8	10	103	13.6	3	197	5.8	1	188	3.9	1	186	2.9	4
Tree Nuts (including Walnuts)	84	1.9	~20	118	2.7	~22	5.7	0.2	1	213	15.2	~60	75	3.8	~12
Other Hays	154	1.9	~8	79	6.3	~17	3.9	0.0	0	109	6.4	~8	54	2.1	~7
Blueberry	3.9	0.0	0	5.3	0.5	1	0.2	0.0	0	13.5	1.7	1	14.4	2.5	2
Seed and Sod Grass	49.4	0.7	~5	75	0.8	~3	0.4	0.0	0	56	2.4	~2	53.4	2.1	~12
Grapes	16.2	0.2	~2	50	1.5	~5	0.2	0.0	0	24.3	1.4	~6	4.7	0.1	1
Apples	0.2	0.0	0	0.2	0.0	0	1.1	0.0	0	0.9	0.0	0	2.1	0.0	0
Plums	0.0	0.0	0	2.6	0.0	0	0.0	0.0	0	0.2	0.0	0	0.3	0.0	0
Cherries	1.3	0.0	0	9.8	0.2	1	0.9	0.0	0	5.8	0.7	3	4.5	0.1	2

TNTC = Too Numerous to Count

Crop	Nutrient Management	Soil Health Management	Soil Health Testing	Pest Management Conservation System	Cover Crop and/or Conservation Cover (Orchard Alleyways)	Critical Area Planting	Sediment Control Basin and/or Water Quality Pond	Grassy Border (Field Border)	Riparian Herbaceous Cover/Forest Buffer or Grassed Waterway	Buffer/Filter Strip	Irrigation/Sprinkler System	Strip Cropping	Terrace
	102, 157, 590	116, 162	216	161, 595	327, 340	342	350, 378, 636	386	390, 391, 412	393	441, 442	585	600
Pasture and Hay	X	X	X	X		X		X	X	X	X	X	
Nursuries and Greenhouses	X	X	X	X	X	X	X	X	X	X	X	X	X
Christmas Trees	X	X	X	X	X	X		X	X	X	X	X	X
Tree Nuts (including Walnuts)	X	X	X	X	X	X				X	X	X	X
Other Hays	X	X	X	X		X				X	X	X	
Blueberry	X	X		X		X	X	X	X	X		X	
Seed and Sod Grass	X	X	X	X		X	X	X	X	X	X	X	X
Grapes	X	X		X		X	X	X	X	X		X	
Apples	X	X		X	X								
Plums	X	X	X	X	X	X				X	X	X	X
Cherries	X	X		X		X	X	X	X	X		X	

X = BMP applicable to crop type and corresponding pollutants of concern

10. APPENDIX B

Crop	Lower Clear Creek		North Fork Deep Creek-Deep Creek		North Fork Eagle Creek		Rock Creek-Clackamas River		Tickle Creek-Deep Creek		Total		Nutrient Management	Soil Health Management	Soil Health Testing	Pest Management Conservation System	Cover Crop and/or Conservation Cover (Orchard Alleyways)	Critical Area Planting	Sediment Control Basin and/or Water Quality Pond	Grassy Border (Field Border)	Riparian Herbaceous Cover/Forest Buffer or Grassed Waterway	Buffer/Filter Strip	Irrigation/Sprinkler System	Strip Cropping	Terrace	
	Crop Extents: Total Acreage within Subbasin | Approx. # Licenses/Parcels within Subbasin												157, 590	116, 162	216	161, 595	327, 340	342	350, 378, 636	386	390, 391, 412	393	441, 442	585	600	Total Cost:
Pasture and Hay	5,231	894	6,739	1,317	740	587	7,516	2,403	5,129	1,491	25,355	6,692	$10,734,779	$20,333,289	$699,136	$11,556,951		$15,968,110		$4,464,644	$46,228,542	$3,449,268	$ 81,195,629	$31,440		$ 194,661,787
Nurseries and Greenhouses	91	4	483	157	157	13	211	28	171	22	1,113	224	$ 362,446	$ 680,612	$ 23,402	$ 399,535	$ 434,803	$ 701,083	$ 3,881,067	$ 196,021	$ 2,029,674	$ 151,441	$ 2,921,169	$ 1,380	$289,029	$ 12,071,663
Christmas Trees	631	34	103	12	197	13	188	20	186	13	1,305	92	$ 158,864	$ 279,537	$ 9,612	$ 204,750	$ 308,251	$ 821,565		$ 229,707	$ 2,378,474	$ 177,466	$ 1,851,065	$ 1,618	$338,698	$ 6,759,607
Tree Nuts (including	84	295	118	414	5.7	23	213	681	75	244	495	1,657	$ 2,589,760	$ 5,034,707	$ 173,112	$ 2,584,114	$2,031,860	$ 311,643				$ 67,318	$ 15,659,349	$ 614	$128,478	$ 28,580,956
Other Hays	154	343	79	274	3.9	13	109	353	54	199	401	1,182	$ 1,847,935	$ 3,591,445	$ 123,487	$ 1,845,630		$ 252,292				$ 54,497	$ 11,206,996	$ 497		$ 18,922,778
Blueberry	3.9	15	5.3	16	0.2	1	13.5	46	14.4	47	37	125	$ 195,365	$ 379,806		$ 194,940		$ 23,518	$ 130,189	$ 6,575	$ 68,085	$ 5,080		$ 46		$ 1,003,605
Seed and Sod Grass	49.4	145	75	188	0.4	3	56	172	53.4	172	235	680	$ 1,063,158	$ 2,066,144	$ 71,042	$ 1,061,981		$ 147,727	$ 817,789	$ 41,304	$ 427,678	$ 31,910	$ 6,450,496	$ 291	$ 60,902	$ 12,240,422
Grapes	16.2	73	50	191	0.2	1	24.3	111	4.7	19	96	395	$ 617,091	$ 1,200,187		$ 614,938		$ 60,249	$ 333,529	$ 16,846	$ 174,425	$ 13,014		$ 119		$ 3,030,397
Apples	0.2	1	0.2	1	1.1	4	0.9	2	2.1	7	5	15	$ 23,445	$ 45,577		$ 23,396	$ 18,404									$ 110,821
Plums	0.0	0	2.6	8	0.0	0	0.2	1	0.3	2	3	11	$ 17,190	$ 33,423	$ 1,149	$ 17,146	$ 13,462	$ 1,961				$ 424	$ 103,823	$ 4	$ 808	$ 189,390
Cherries	1.3	6	9.8	32	0.9	4	5.8	23	4.5	18	22	83	$ 129,694	$ 252,191		$ 129,322		$ 14,072	$ 77,901	$ 3,935	$ 40,740	$ 3,040		$ 28		$ 650,922
											Total Cost:		$ 17,739,725	$ 33,896,917	$ 1,100,940	$ 18,632,703	$ 2,806,780	$ 18,302,220	$ 5,240,475	$ 4,959,032	$ 51,347,619	$ 3,953,459	$ 119,388,527	$ 36,036	$ 817,915	$ 278,222,348