Molalla River Watershed

Drinking Water Source Area Assessment

Annotated Bibliography

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Molalla Watershed-Specific Studies and Data

ODEQ 2018: City of Canby – The ODEQ Updated Source Water Assessment and DEQ Drinking Water Online Database

https://www.deq.state.or.us/wq/dwp/docs/uswareports/USWA_00157Canby.pdf
https://yourwater.oregon.gov/inventory.php?pwsno=00157

The Canby Utility serves 4,927 connections and approximately 16,866 individuals (2016). The drinking water 8-hour time of travel source area is 92 sq mi, encompassing 246 stream miles. The full source area is 345 sq mi, with 1,689 stream miles. 84% of the 8-hour time of travel source area has high erosion potential (208 stream miles); 96% of the entire source area has high erosion potential (1,625 stream miles). Land uses in the entire source area are dominated by agriculture (44.94 sq mi, 13.03%); industrial forest (144.38 sq mi, 41.85%); and private rural areas (70.74 sq mi, 20.50%). The updated assessment provides information and resources to assist the City of Canby to implement local drinking water protection efforts. The assessment includes a basemap with the source area delineated, and maps with natural characteristics, land uses, potential sources of pollutants, and historic landslides. The assessment outlines locations and types of potential pollutant sources present in the drinking water source area, including the following: soil erosion potential, CAFOs, mining sites, hazardous waste generations, points-source discharge, transportation network and stream crossings, etc. The Drinking Water Database includes information on the treatment system, well logs, water quality alerts/advisories, and violations. **Finished Water Quality Monitoring: coliform bacteria, nitrate-nitrite, arsenic, radionuclides, cyanotoxins, total organic carbon and alkalinity (raw and treated), and turbidity**.

ODEQ 2018. City of Molalla – The ODEQ Updated Source Water Assessment and DEQ Drinking Water Online Database

https://www.deq.state.or.us/wq/dwp/docs/uswareports/USWA_00534Molalla.pdf
https://yourwater.oregon.gov/inventory.php?pwsno=00534

The Molalla Utility serves 2,518 connections and approximately 9,139 individuals (2018). The drinking water 8-hour time of travel source area is 63 sq mi, encompassing 349 stream miles. The full source area is 203 sq mi, with 1,166 stream miles. 98% of the 8-hour time of travel source area has high erosion potential (343 stream miles); 97% of the entire source area has high erosion potential (1,136 stream miles). Land uses in the entire source area are dominated by industrial forest (113.69 sq mi, 56%); BLM (66.02 sq mi, 33%); and private rural areas (13.54 sq mi, 7%). Less than 1% (0.22 sq mi) of the area is in agricultural land use. The assessment includes the details outlined above.

ODEQ 2018. Colton Water District – The ODEQ Updated Source Water Assessment and DEQ Drinking Water Online Database

https://www.deq.state.or.us/wq/dwp/docs/uswareports/USWA_00202Colton.pdf
https://yourwater.oregon.gov/inventory.php?pwsno=00202

The Colton Water Distrit serves 494 connections and approximately 1,500 individuals (2015). The drinking water source area is 3.33 sq mi, encompassing 9.43 stream miles. 100% of the watershed has high erosion potential (9.43 stream miles). Ownership: industrial forest—2.42 ac. (73%) and BLM—0.91 ac. (27%). The assessment includes the details outlined above.

ODA 2016: Molalla-Pudding-French Prairie-North Santiam Agricultural Water Quality Management Area Plan (2016), Biennial review (2016), Administrative Rules (2002), Executive Summary (2002)

https://www.oregon.gov/ODA/programs/NaturalResources/AgWQ/Pages/AgWQPlans.aspx

The Area Plan guides local landowners and their conservation partners on how to prevent pollution. **Agricultural water quality concerns in the Molalla-Pudding-French Prairie-North Santiam area are primarily: Temperature, pH, Dissolved oxygen, Bacteria, Legacy pesticides, Toxics, Nitrates, Metals, Phosphorous, and Turbidity**. The Program focuses on voluntary and cooperative efforts by landowners and others to protect water quality. The Agricultural Water Quality Management Act also includes enforcement to ensure prevention and control of water pollution from agricultural sources. Area Rules allow landowners flexibility in how they protect water quality. The day-to-day implementation of the Area Plan is accomplished through an intergovernmental agreement between ODA and each SWCD. Each SWCD implements the Area Plan by providing outreach and technical assistance to landowners. SWCDs also work with ODA and the LAC to establish implementation priorities, evaluate progress toward meeting Area Plan goals and objectives, and revise the Area Plan and Area Rules as needed. The

USDA Natural Resource Conservation Service estimated Plan Area average acreage field size to be 17 acres. Molalla Characterization: This watershed is mostly forest and pastures, Christmas tree parcels, and timber parcels managed by commercial timber companies. Most farmed parcels range from 2 to 100 acres, and there are few full-time farmers -- many work as far away as Portland.

ODEQ 2018: Water Quality Status and Trends report for the Molalla-Pudding French Prairie North Santiam AgWQ Management Area

https://deq15.deq.state.or.us/sc/wqwebreporting/strMolPudding.html
Water quality data were retrieved from DEQ (LASAR and ELEMENT), U.S. Environmental Protection Agency (WQX/Storet) U.S. Geological Survey NWIS (USGS 2016), and Water Quality Portal) databases. Many other organizations provided data that were queried and evaluated for use in this report (see Appendix). Data collected between January 01, 2000 to March 01, 2018 and only within the Molalla-Pudding French Prairie North Santiam agricultural water quality management area were included in this report. **Monitoring Site:** DEQ 10637 – Molalla River at Knights Bridge Road (Canby). Watershed area: 892 km^2; 3% urban, 60% forest, 15% agricultural, 22% range. **Water quality monitoring parameters: temperature, pH, dissolved oxygen, total suspended solids, total phosphorus, and bacteria (E. coli, fecal coliform, and Enterococcus)**. **DEQ 10637 – Molalla River at Knights Bridge Road (Canby) Site monitoring results: Dissolved Oxygen** – Exceeds, Improving; **E. Col** – 99% Exceeds, Degrading; **pH** – Meets, No Sig Trend; **Total Phosphorus** – minimum (2000) maximum (2018) observations (105); **Total Suspended Solids** – 90% Significance Level/% exceedance (0%), minimum (2000) maximum (2018) observations (109).

ODEQ 2008: Molalla-Pudding Subbasin TMDL

https://www.oregon.gov/deq/wq/tmdls/Pages/TMDLs-Willamette-Basin.aspx
Oregon establishes Total Maximum Daily Loads (TMDLs) for streams segments which do not meet water quality standards. The TMDL identifies the level of pollutants that a water body can absorb and still meet water quality standards. TMDLs take into account pollution from all sources, including discharges from industry and sewage treatment facilities; runoff from farms, forests and urban areas; and natural sources. TMDLs also include a safety margin to account for uncertainty. Designated beneficial uses for the Molalla River include water for drinking, irrigation, and livestock; anadromous fish passage, spawning, and rearing; habitat for resident fish and aquatic life; fishing; boating; water contact recreation; and hydropower. ODEQ developed a Water Quality Management Plan (WQMP) to describe the overall framework for implementing the Molalla-Pudding Subbasin TMDL for the following 303(d) parameters: **Temperature, Bacteria, Toxics (As, Mn, Fe, dieldrin, chlordane, DDT, nitrate)**. The report includes land use strategies and BMPs for each of the parameters (**Table 7-2**).

DEQ does not designate the **Molalla River Irrigation District** a DMA for this TMDL because DEQ only learned of the District at the end of the public comment period and the District did not have an opportunity to comment during the public comment period. The Molalla River Irrigation District has existed on record since the early part of this century, and may have existed several decades before that. The District serves approximately 20 landowners on 750 acres. Molalla River water is diverted at a dike and via two culverts upstream of Feyrer Park Bridge, where Feyrer Park Road crosses the Molalla River. Water is conveyed in a ditch. The ditch has a rudimentary water control structure installed that alternately raises the water level and allows the water to flow down the ditch. Users withdraw their water rights from the ditch and the remainder flows back into the Molalla River just upstream of the Highway 213 crossing. The associated water rights permits require that all irrigation take place on lands that drain toward the Molalla River, not across a ridge to the west, which would drain to Bear Creek in the Pudding River portion of the subbasin. Two smaller ditches that divert from the main ditch have been designated off-stream fish habitat.

USGS 2012: Geomorphic Setting, Aquatic Habitat and Water Quality Conditions of the Molalla River 2009-10

https://pubs.usgs.gov/sir/2012/5017/pdf/sir20125017.pdf
The report describes the geomorphic setting and processes governing the physical layout of the river channel and evaluates changes in river geometry over the past several decades using analyses of aerial imagery and other quantitative techniques. The report also describes water-quality, benthic algae, and benthic invertebrate conditions that were examined during summer low-flow periods to determine the overall health of the river and to provide possible insights into the physical or chemical influences on diatom assemblages.

The peak-flow hydrology in the Molalla River has been characterized by a series of large floods during the 1960s and 1970s, a period of relatively small peak flows from 1975 to 1995, and a relative increase in severity of events in the past 15 years. The study area along the Molalla River was divided into six unique geomorphic reaches. The upper-most reach, designated GR6, is a narrow, bedrock-controlled reach with ample shade and large riffles. The next downstream reach, GR5, is also largely bedrock controlled but has a wider flood plain and active channel-migration zone. The longest geomorphic reach, GR4, has a wide channel-migration zone with many strategically placed revetments that work in concert with bounding bedrock to the northeast to suppress overall channel movement. In contrast, GR3 is a wide, active reach that responds more dramatically to flood and non-flood periods than the other geomorphic reaches. The anthropogenically confined GR2, adjacent the City of Canby, has relatively little historical channel movement and relatively few gravel bars. Finally, the farthest downstream reach, GR1, is an actively meandering reach that most closely resembles its predevelopment state.

Longitudinal changes in water quality, including downstream increases in **water temperature** and **specific conductance**, were observed in the Molalla River during August and September. Such patterns are typical of many rivers receiving inputs from anthropogenic sources in the flood plain, including agricultural and rural residential lands (Milk and Gribble Creek basins) as well as some urban runoff in the lower river. **Nutrient** concentrations in the Molalla River were generally low at most sampling sites but did increase at the Goods Bridge and Knights Bridge sites, presumably from a greater influence from anthropogenic sources that enter the river from tributaries, agricultural irrigation returns, or groundwater in the lower basin. **Nitrate** concentrations at Glen Avon and Knights Bridges exceeded their respective reference values for streams in the Cascade Range and Willamette Valley. Although the nitrate-nitrogen concentrations were somewhat elevated, phosphorus, in contrast, is relatively much less abundant in the Molalla River. N:P ratios for soluble, biologically available nitrogen and phosphorus were lower in the upper middle reaches (less than 5), but the absolute concentrations of **orthophosphorus** (0.010 milligrams per liter or less in July) suggest that attached periphytic algae in the river may be limited by phosphorus concentrations or some other factor, but probably not by nitrogen. The Molalla River has lower phosphorus concentrations than other rivers draining the Cascade Range because the phosphate-rich rocks of the Oregon High Cascades, prevalent in other drainages, are not present in the Molalla River basin, which is wholly contained within the Western Cascade Range geologic province. Generally, **riffle habitats appeared healthy**, **with little sediment and low substrate embeddedness** (that is, the degree of infilling of fine sediments around gravels and cobbles) was less than 5 percent at all sites except the Knights Bridge site, where embeddedness was about 10 to 25 percent higher. Algal biomass levels in July were moderate, ranging from 30 to 55 mg of chlorophyll-a per square meter. **Long filaments of *Cladophora glomerata* were observed in the area near the Canby drinking-water treatment plant**, **where in previous years, algae have clogged water intakes during periods of senescence** when algae detach from the river bed and enter the intake. In 2010, algal biomass conditions were not as severe and the intakes were not affected. Although some relatively high pH values were measured (as much as 8.4 units), none of the pH measurements exceeded State of Oregon water-quality standards, even in the afternoon hours on warm sunny days. Dissolved oxygen concentrations at Goods Bridge and Knights Bridge did not meet the 8 milligrams per liter criteria in the early morning hours, but compliance with the standards is only evaluated with 30-day average minimum values, which were not available. Relative to the salmon spawning criteria, for which the data collected during this study applies only to the **Glen Avon Bridge site in September, water temperature, pH, and concentrations of dissolved oxygen all met the state standard in effect**. **Together, most of these algae (and overall algal biomass) are typical of generally high quality waters with little organic pollution, high concentrations of dissolved oxygen, and alkaline pH.** The relatively high percentage of eutrophic taxa does, however, suggest some degree of nutrient enrichment in the river, despite the relatively low concentrations observed at most sites. Although only qualitatively addressed for this study, **benthic macroinvertebrates, including mayflies, caddisflies, and stoneflies, were abundant in the Molalla River** and indicate a high degree of secondary production in the riffles throughout the study reach.

ODEQ 2012: Drinking Water Source Monitoring Project Phase I and Phase II (2008-2010)

https://www.oregon.gov/deq/FilterDocs/dwpSourceMonPhase1-2Rpt.pdf

In phase I, DEQ collected surface water from 6 source areas above intakes and groundwater samples from 7 wells that have multiple land uses in the source areas and are considered high-risk sources, as identified through a state analysis of susceptible systems. **In phase II DEQ collected surface water and groundwater samples from 11 intakes, 9 wells, and 1 spring where there have been high levels of nitrate contamination, from systems that requested testing, and from those systems considered vulnerable** to nearby sources of contaminants. (**No sites in the Molalla were sampled.**) After developing lists within each pollutant group, the final priorities were selected by toxicologists based on determinations of potential risks to public health. Most of the chemical compounds that were analyzed for are not monitored under the Safe Drinking Water Act requirements. **Over 50 compounds (Table 1) were identified as "contaminants of interest"** for drinking water in Oregon, including:

- herbicides (total of 12 from agriculture/forestry/urban land uses or sources)
- insecticides (12 from agriculture/urban sources)
- fungicides (3 from agriculture/forestry sources)
- metals (copper, arsenic, mercury)

- bacteria/pathogens (coliform from human and animal wastes)
- drugs (5 from human waste discharge---onsite or wastewater treatment plants)
- cleaners/VOCs (7 from wastewater/industry sources)
- fire retardants (3 from wastewater/urban sources)
- PAHs (5 from combustion-air deposition/runoff from industrial or urban
- sources)
- plasticizers (1 from industry/urban sources)

The report identifies potential land uses or activities where contaminants can originate in drinking water source areas.

ODEQ 2019: Spill Response Database – Molalla Watershed

https://www.oregon.gov/deq/Hazards-and-Cleanup/env-cleanup/Pages/ecsi.aspx
(downloaded 2/12/2019)
The DEQ Environmental Cleanup Site Information database for the Molalla Watershed. 39 records were found related to past and current spill responses in the Molalla Watershed with the following status: No further state action required (22); expanded assessment recommended (1); site screening or investigation recommended (9); remedial action recommended (2); close out activities on completed project (2); partial no further action (1); remedial design(1); long term care/control recommended (1). Documented spills included industrial facilities (e.g., sulfuric acid, chlorinated solvents, solid paint-related wastes, heavy metals); nurseries (e.g., pesticides); a gun club (e.g., Lead, polyaromatic hydrocarbons (PAHs)); abandoned landfills (e.g., heavy metals); closed sawmills (e.g., PCPs, oil & grease, dioxins, heavy metals); petroleum storage facilities (e.g., petroleum and petroleum constituents).

DEQ maintains the database to track sites in Oregon with known or potential contamination from hazardous substances, and to document sites where DEQ has determined that no further action is required. Data in ECSI is "working information" used by DEQ's Environmental Cleanup Section. Note that: Some information in ECSI may be unconfirmed, outdated, or incomplete; data in ECSI is summary in nature, rather than comprehensive; there may be contaminated sites in Oregon that are unknown to DEQ and do not appear in ECSI; conversely, the appearance of a site in ECSI does not necessarily mean that the site is contaminated; and Information in ECSI is subject to change at any time.

Wherry 2012: Climate Change Effects and Water Vulnerability in the Molalla Pudding River Basin, Oregon, USA

https://pdxscholar.library.pdx.edu/open_access_etds/556/
Three out of the five datasets in this study predicted increased precipitation (+97-115 mm/year) over the Molalla Pudding basin and the two datasets using the CCSM iiGCM data predicted either no change or slightly decreased precipitation (-60 mm/year) over the Molalla Pudding basin in 2041-2068. All datasets predicted increased minimum and maximum average temperature of +1.5°C and +1.4°C respectively, and all datasets displayed increasing trends in temperature. **The drought indices predicted fewer drought events** (-2.4 events) over 2041-2068 but with increased event durations (+1.9 months). Results from the hydrologic modeling predicted increased streamflow (+4-249 cfs) in four out of the five future datasets. **The seasonality of runoff is also predicted to change with decreased flows in the Winter/Spring months, little to no change of flow in the summer months and increased flow in the fall months**. Using the predicted changes in hydrologic variables and social/economic census data from

2000, two types of water vulnerability indices were calculated for the twelve cities of interest. **The results suggested that cities in the western portion of the basin would be more susceptible to current and future water vulnerability due to high irrigation demands for water**. The study used an existing calibrated Precipitation-Runoff Modeling System (PRMS) model of the Molalla Pudding basin to perform hydrologic modeling over historical and future periods. Social Vulnerability Index based on: age, income/poverty, minority status, disabled, employment, mobile homes/renters, gender, education and density.

American Rivers & Native Fish Society 2009: White Paper – The Ecological and Recreational Benefits of the Molalla River

http://www.molallariveralliance.org/pdf/Molalla_Final_Report.pdf

A summary of the ecological and recreational values of the Molalla River, a designated State Scenic Waterway, with a specific focus on the upper part of the watershed above the city of Molalla. The paper outlines challenges that the upper part of the river and surrounding riparian areas face in terms of water quality limitation and land use practices.

Willamette Basin Water Quality Studies

USGS 1997: Distribution of Dissolved Pesticides and Other Water Quality Constituents in Small Streams, and their Relation to Land Use, in the Willamette River Basin, Oregon

https://pubs.usgs.gov/wri/1997/4268/report.pdf

Water quality samples were collected at sites in 16 randomly selected agricultural and 4 urban subbasins as part of Phase III of the Willamette River Basin Water Quality Study in Oregon during 1996. The sampling sites were on 16 small, randomly selected agricultural streams and on 4 urban streams. Major tributary watersheds represented by the sampling sites included the Pudding, Tualatin, Yamhill, Long Tom, and Calapooia. Two sites, Senecal Creek (60% agriculture, 23 crop types – highly diverse) and Deer Creeks (70% agriculture, 20 crop types – highly diverse) were located in the Pudding Watershed. **These sites are among a group of sites are associated with the largest variety of both herbicides (9) and insecticides (4), in addition to the frequently detected pesticides.** Ninety-five samples were collected and analyzed for suspended sediment, conventional constituents (temperature, dissolved oxygen, pH, specific conductance, nutrients, biochemical oxygen demand, and bacteria) and a suite of 86 dissolved pesticides. The data were collected to characterize the distribution of dissolved pesticide concentrations in small streams (drainage areas 2.6– 13 square miles) throughout the basin, to document exceedances of water quality standards and guidelines, and to identify the relative importance of several upstream land use categories (urban, agricultural, percent agricultural land, percent of land in grass seed crops, crop diversity) and seasonality in affecting these distributions. A total of 36 pesticides (29 herbicides and 7 insecticides) were detected basinwide. **The five most frequently detected compounds were the herbicides atrazine (99% of samples), desethylatrazine (93%), simazine (85%), metolachlor (85%), and diuron (73%).** Fifteen compounds were detected in 12–35% of samples, and 16 compounds were detected in 1–9% of samples. A large number of unusually high concentrations (1–90 parts per billion) were detected, indicating that pesticides in the runoff sampled in these small streams were more highly concentrated than in the larger streams sampled in previous studies. These pulses could have had short term toxicological implications for the affected streams; however, additional toxicological assessment of the detected pesticides was limited because of a lack of available information on the response of aquatic life to the observed pesticide concentrations. Six pesticides, including atrazine, diuron, and metolachlor, had significantly higher ($p<0.08$ for metolachlor, $p<0.05$ for the other five) median concentrations at agricultural sites than at urban sites. Five other com-pounds—carbaryl, diazinon, dichlobenil, prometon, and tebuthiuron—had significantly higher ($p<0.05$) concentrations at the urban sites than at the agricultural sites. A cluster analysis of the data grouped sites according to their pesticide detections in a manner that was almost identical to a grouping made solely on the basis of their upstream land use patterns (urban, agri-cultural, crop diversity, percentage of basin in agricultural production). In this way inferences about pesticide associations with different land uses could be drawn, illustrating the strength of these broad land use categories in determining the types of pesticides that can be expected to occur. Among the associations observed were pesticides that occurred at a group of agricultural sites, but which have primarily noncropland uses such as vegetation control along rights-of-way. Also, the amount of forested land in a basin was negatively associated with pesticide occurrence, suggesting that riparian growth or runoff from forested lands helped reduce pesticide concentrations.

USGS 2012: Reconnaissance of Land-Use Sources of Pesticides in Drinking Water, McKenzie River, Oregon
https://pubs.usgs.gov/sir/2012/5091/pdf/sir20125091.pdf
The distribution of detected pesticide compounds across the range of land-use settings shows that the largest number of compounds was associated with urban land use. A total of 37 compounds were detected at urban sites at least once during this study, and 18 of these were uniquely detected at urban sites. In contrast, 14 compounds were detected at forestry sites and 8 compounds at agricultural sites, all of which were widely observed in a range of land-use settings, frequently associated with mixed land-use sites. Caffeine was the most frequently detected compound, and with **hexazinone, 2,4-D, atrazine, glyphosate and its metabolite AMPA, and carbaryl, accounted for approximately 46 percent of all detections. Nine compounds were detected at the treatment-plant intake, most of which were frequently detected at other sites: Atrazine, Hexazinone, Sulfometuron-methyl, Carbaryl, Cypermethrin, Diazinon**. Human-health benchmarks were available for six of these compounds and were several orders of magnitude higher than measured concentrations, indicating that pesticide concentrations at the drinking-water intake present a negligible threat to human health. The data indicate that urban/rural residential and agricultural pesticides are important components of pesticide transport in tributary drainage basins with a mix of land use, despite the relatively small proportion of drainage basin area associated with these uses. (However, agricultural pesticide runoff is not well characterized by the limited data available.) Although forest land use is predominant in the basin, and forestry pesticide use can be detected in small tributaries draining forested lands following application, these compounds rarely were detectable in the McKenzie River. Forestry pesticide use, therefore, probably is not a potential threat to drinking-water quality at the present time.
Potential threats to drinking water quality are identified by the occurrence of pesticide compounds that are regulated for drinking water or suspected of endocrine disruption. **Observed concentrations of pesticides at the drinking water intake, while uniformly low (< 0.1 µg/L), include one regulated**

compound and four suspected endocrine disruptors, making the reduction of sources for these compounds a high priority for EWEB. These compounds were estimated to be either associated with exclusive urban (cypermethrin) or predominantly agricultural (atrazine and diazinon) land use, or both urban and agricultural applications (carbaryl).

USGS 1998: Seasonal and Spatial Variability of Nutrients and Pesticides in Streams of the Willamette Basin, Oregon, 1993-95

https://pubs.usgs.gov/wri/1997/4082c/report.pdf

From April 1993 to September 1995, the USGS conducted a study of the occurrence and distribution of nutrients and pesticides in surface water of the Willamette Basin. About 260 samples were collected at 51 sites during the study; of these, more than 60 percent of the pesticide samples and more than 70 percent of the nutrient samples were collected at 7 sites in a fixed-station network (primary sites) to characterize seasonal water-quality variability related to a variety of land-use activities. This report describes concentrations of 4 nutrient species (total nitrogen, filtered nitrite plus nitrate, total phosphorus, and soluble reactive phosphorus) and 86 pesticides and pesticide degradation products in streams, during high- and low flow conditions, receiving runoff from urban, agricultural, forested, and mixed-use lands.

Two types of sampling programs the fixed-station network and the synoptic network were designed to accomplish this goal. The fixed-station monitoring network consisted of seven stations distributed throughout the northern Willamette Basin -- these stations were sampled for 2-1/2 years to monitor seasonal changes in water quality resulting from a variety of land-use activities. Additional water samples were collected during spring runoff (late March through early June) following application of pesticides and fertilizers, and fall/winter runoff (October through January) following the heaviest seasonal rains. Three sites were located in the Tualatin River Subbasin and three sites were located within the Pudding River Subbasin in a nested design. (**None of the fixed-station sites were located in the Molalla Watershed**). Both subbasins included a forested site selected to reflect background water quality conditions, an "indicator" site, selected to represent one predominant land use (urban or agricultural), and an "integrator" site (located near the terminus of the subbasin) selected to represent an integration of water-quality conditions from a mixture of land uses (agricultural, forested, and urban). The synoptic monitoring network included 44 additional sites that were located in selected agricultural settings and sampled during periods of 1 week or less. **Four synoptic sites were located in the Molalla Watershed (samples collected in April during a high flow event and one sample in August to capture low flows**: **Molalla R above Pine Creek near Wilhoit** (sampled 4/1993; 0% urban, 0% agriculture, 100% forestry land uses); **Molalla R near Canby** (4/1993; 3% urban, 15% agriculture, 81% forestry); **Gribble Creek near Canby** (8/1994; 9% urban, 89% agriculture, 2% forestry); **Molalla River at Knights Bridge near Canby** (4/1993 and 5/1994; 3% urban, 15% agriculture, 81% forestry). **All of the Molalla sites had low levels of nitrite, soluble reactive phosphorus, atrazine, and simazine.**

The highest nutrient concentrations were observed at agricultural sites. Most of the upper 10 percent of the concentrations for both nitrogen species occurred at sites receiving predominantly agricultural runoff (a few sites were downstream from point-source discharges). **With the exception of soluble reactive phosphorus, peak nutrient concentrations were recorded at agricultural sites during winter rains, whereas peak pesticide concentrations occurred at agricultural sites during spring rains**.

Nutrient concentrations at forested sites were among the smallest observed at any of the sites sampled. In addition, **only one pesticide and one pesticide degradation product were detected at forested sites, at concentrations near the method detection limits**. Most of the upper 10 percent of the concentrations for both TP and SRP also occurred at sites receiving predominantly agricultural runoff (a few sites were downstream from point-source discharges). A**bout 47 percent of the TP concentrations equaled or exceeded the 0.10 mg/L desired limit for TP considered necessary for the prevention of nuisance plant growth in streams**. Zollner Creek near Mount Angel, located in the Pudding River Subbasin and indicator site for agricultural activities (99% agricultural land uses), generally had the largest nutrient concentrations. **Forty-nine of the 50 pesticides were detected at agricultural sites**, 2 at forested sites, 25 at urban sites, and 29 at mixed-use sites. From 72 to 94 percent of water samples had detections of atrazine, simazine, metolachlor, and desethylatrazine. These pesticides were among the top four most frequently detected compounds in samples collected from 20 of the Nation's major watersheds during the first set of the NAWQA water-quality assessments during 1991-95. Samples collected at the Zollner Creek site had the greatest number of different pesticides detected (43) of any site sampled in the Willamette Basin. The largest concentrations for 27 of the 50 different pesticides detected in the Willamette Basin occurred at the Zollner Creek site.

Clackamas Drinking Water Studies

Clackamas River Water Providers 2010: The Drinking Water Protection Plan for the Clackamas River

http://www.clackamasproviders.org/resource/

CRWPs have two primary goals for establishing a source water protection program for the Clackamas River: 1) 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; 2)Promote public awareness and stewardship of healthy watershed ecology in collaboration with other stakeholders. Over 1,200 potential contaminant sources were identified in the Clackamas River Source Water Assessments. These potential contaminants identified were ranked by risk:

- Above Ground/Underground Storage Tanks
- Agriculture
- Nurseries
- CAFOs and Animal Management
- Dams/Powerhouses/Upstream Reservoirs, Fish Hatcheries Forest Practices – clearcuts, landslides, pesticides Industrial and Commercial Facilities
- Landfill/Dumps/Illegal Dumping/Junk yards Permitted Point-Source Discharges Recreation – campgrounds, boats, river recreation, golf courses, parks
- Resource Extraction - mines/gravel pits (Low Risk)
- Road Vegetation Management
- Storm Sewer Outfalls Transportation
- Urbanization

- Septic System Failures
- Wastewater Treatment Plants

The highest risks to river water quality were identified as follows (not in rank order):

- Urban storm sewer discharges,
- Stormwater runoff impacts from increased development (conversion of farm and forest land to urbanized development),
- Commercial and industrial facilities potential spills and stormwater runoff,
- Runoff from agricultural practices,
- Roadside vegetation management,
- Potential domestic wastewater discharges from wastewater treatment plants and septic systems, and
- Hazardous material spills from commercial and industrial areas, transportation activities along HWY 212/224, the railroad line, and the numerous road bridges that cross the Clackamas River and its tributaries.

Geosyntech for Clackamas River Water Providers 2014: Clackamas River Basin Pollutant Load Modeling Tool

http://www.clackamasproviders.org/wp-content/uploads/2014/10/CRWP-PLMT-Report.pdf

Herrera Environmental Consultants, Inc. for Clackamas River Water Providers (CRWP) 2012: Clackamas River Drinking Water Risk Analysis Final Memos:

1. **Septic Systems Analysis;**
2. **Agricultural Analysis;**
3. **Forestry Analysis;**
4. **Urban Development Analysis;**
5. **Vulnerable Soils Analysis;**
6. **Point Source Pollution Analysis;**
7. **Watershed Emergency Response System;**
8. **Updated GIS Hazardous Materials Spill Risk Analyses Results and Recommendations**

http://www.clackamasproviders.org/resource/

The goal of the GIS analyses was to map risk factors known to have a strong negative correlation with drinking water quality in the Clackamas River watershed. Mapped high-risk "hot spots" for each category provides a spatial context for both the geography and intensity of risk by activity that can be used by the CRWP help prioritize mitigation efforts.

1. Septic System Analysis

The primary threat identified by CRWPs to surface water from septic system malfunction is direct runoff of partially treated waste or exfiltration of contaminated groundwater. The major contaminants that can be discharge from malfunctioning septic systems include pathogens, nitrates, organic matter, ammonia, nitrogen, phosphates, synthetic organics, metals, PCPs, and pharmaceuticals. Approximately 10 to 25 percent of septic systems fail at some point during their operational life. This often results in the release of untreated wastewater into the underlying groundwater and/or nearby surface water. The risk of septic system malfunction increases based on the following conditions: (1) Septic system age; (2)

Statistically-significant septic system clusters; (3) Proximity to surface water and upstream distance from municipal surface water intakes; (4) Vulnerable soils; and (5) Parcel size. The GIS analysis ranked, weighted, and overlaid each septic system risk factor to produce a map of cumulative predicted risk to source water quality from septic system failure at the parcel level. **More than half of the approximately 20 million septic systems used in the United States were installed over 30 years ago when on-site rules were nonexistent or poorly enforced. Approximately 76 percent of potential septic system parcels in the Clackamas River watershed are greater than 30 years old**. Approximately 6,250 of the total 9,000 potential septic systems identified in the Clackamas River watershed are in clusters (Potential Hot Spots). **Of the approximately 9,000 potential septic system parcels identified in the Clackamas River watershed, about 4500 were ranked as very low or low risk for septic system failure, 3500 were ranked as moderate risk, and 1000 were ranked as high risk**.

2. Agricultural Analysis

The CRWP has identified stormwater runoff from agricultural practices as being one of the most significant sources of risk to drinking water quality. The primary threats to source water from agricultural activities include: (1) Non-point source pollution from sediments, nutrients, pathogens, oxygen-depleting organics, pesticides, metals and salts from irrigation and non-irrigated crop areas, plant nurseries, animal grazing areas, boarding stables, farm machinery repair shops, and chemical mixing/storing/handling areas. (2) Increased runoff of nitrates, bacteria, pharmaceuticals, and soil from Confined Animal Feed Operations (CAFOs) where large numbers of animals are confined in one location. Datasets: **Herrera mapped crop distribution and nurseries and greenhouses locations; estimated cropspecific fertilizer and pesticide application rates to apply to each field or nursery; mapped CAFOs, and other animal activities; calculated proximity of agriculture activities to Clackamas River tributaries; and mapped vulnerable soils and irrigated land.** The next step was to rank and overlay the datasets together to determine aggregate risk from agricultural activities to source water quality in the Clackamas River watershed. Herrera reviewed 119 water quality sample results collected in the Clackamas River watershed between 2000 and 2005 to identify pesticides that 1) were detected in at least 20% of samples or 2) were detected at levels that exceeded aquatic-life benchmarks. 17 pesticide compounds met one or both of these criteria, with the most frequent detection rates being: 3,4-Dichlorophenyl isocyanate, a degradate of diuron (100%); glyphosate (71%); simazine (52%); atrazine (47%); napropamide (44%); and diuron (44%). Based on the results of this analysis, the **top crops grown by acreage in the Clackamas River watershed between 2009 and 2011 were: 1) pastures and hay; 2) nurseries and greenhouses; 3) cranberries; 4) seed and sod grass; 5) blueberries; 6) Christmas trees; and 7) Hazelnuts (2009 and 2010 only)**. **The highest average rates of herbicides recommended for use are for nurseries and greenhouses, Christmas trees, blueberries, and cranberries**. The **highest average rate rates for insecticide application are nurseries and greenhouses, cranberries, and Christmas trees**. The **highest average rates for nitrogen application are hazelnuts, pastures and hay, and seed and sod grass**. The **highest average rates for phosphorous application are Christmas trees and pastures and hay**. The analysis identified several regions with high potential aggregate risk to source water quality from fertilizer use in the Clackamas River watershed based on the GIS predictive modeling. The largest high potential aggregate risk “hot spot” from pesticide uses is the area northwest of the City of Sandy, primarily due to the concentration of nurseries and greenhouses located in this area.

3. Forestry Analysis

The GIS analysis mapped the extent and intensity of forestry activities in the Clackamas River watershed to help predict the potential risk of stormwater runoff: 1) fertilizer and herbicide use; 2) clearcutting; 3) pre-commercial and commercial thinning; 3) burning; 4) road construction; 5) site preparation; and 6) other harvest activities. These activities were evaluated by identifying and mapping the proximity to vulnerable soils, floodplains, and landslide areas that could contribute to water quality impacts from forestry activities. **The overall risk analysis categories that appear to have the most significant numbers of "hot spots" on National Forest lands are thinning activities, fertilizer applications, and burning activities; for state and private forest land, they are road construction activities and clear-cutting**.

4. Urban Development Analysis

The CRWP identified unpermitted urban stormwater runoff to the Clackamas River from impervious surfaces such as building roof tops, driveways, sidewalks, parking lots, and highways as being one of the most significant threats to source water quality in the Clackamas River watershed. The primary threats to source water quality from **urbanization are: 1) Increased stormwater runoff quantities, due to impervious surfaces. Increased runoff quantity causes decreased water quality via elevated export of solids and nutrients from bank erosion. 2) Decreased water quality from pollutant washoff from impervious surfaces to receiving waters**. This runoff contains numerous pollutants that can impact human and aquatic health, including sediment, nutrients, metals, hydrocarbons, bacteria and pathogens, organic carbons, and pesticides. 3) Increased stream temperatures resulting both from lost streambank vegetation during urban development and warmer stormwater runoff temperatures during summer months from hot asphalt and concrete.

A GIS urban build-out analysis predicted the extent and intensity of development on vacant and partially developed land in urbanizing areas at maximum build-out capacity through the year 2030. The purpose of a build-out analysis is to show what land is available for development, how much development can occur and at what densities, and what consequences may result when complete build-out of available land occurs according to Clackamas County zoning ordinances. The results of the GIS build-out analysis focuses monitoring and mitigation efforts on the areas predicted to have the highest-intensity future urban development. **The evaluation overlaid five spatial datasets: 1) Vacant and partially-developed land. 2) Significant future development constraints that would make developing a parcel very difficult or impossible. 3) Zoning designations; 4) Number of potential new lots per vacant or partially-developed parcel at maximum build-out capacity. 5) Percent change in future impervious cover at maximum build-out capacity.** After identifying vacant land with no significant development constraints, estimating the number of new lots that could be built on the land based on zoning designations, calculating the linear distance from vacant land to the nearest Clackamas River tributary, and estimating percent change in future impervious cover at full build-out capacity, the final step was to rank and overlay the datasets together to determine aggregate risk from urban development to source water quality in the Clackamas River watershed. Each individual dataset was assigned a ranking scheme on a scale of 1 to 5, with a value of 1 indicating urban development posing a low risk to source water quality and a value of 5 indicating a high risk. **The areas with the highest risk from urban development at full buildout capacity are north of Highway 212 just outside of the City of Happy Valley, within the City of Happy Valley, and in the Cities of Sandy and Estacada. The majority of these high-risk areas are zoned**

as single-family residential. To reduce this risk, stringent stream buffer requirements should be required in these areas in connection with future watershed planning efforts. Additional stormwater management efforts should also be implemented in these areas as they begin to build-out. In particular, low impact development practices should be required where feasible to reduce stormwater runoff quantities and pollutant loads.

5. Vulnerable Soils Analysis

The CRWP identified risks from vulnerable soils: 1) Increased septic system failure risk from effluent exceeding the absorbent capacity of soils, resulting in the release of partially treated effluent onto the ground surface. 2) Soil erosion and increased rates of sediment, pesticide, and fertilizer runoff from agricultural land after crops have been harvested. 3) Potential leaking of contaminants into groundwater from sewer lines that are located in highly permeable soils adjacent to streams. 4) Runoff and erosion from dirt and gravel roads. The GIS analysis focused on summarizing the following soil characteristics: Permeability; Erodibility; Slope; Restrictive horizons; and Landslides.

6. Point Source Pollution Analy*s*is

The CRWP identified the need to implement a point source pollution subprogram to "inventory, track, evaluate, and monitor point sources (water quality and other permits) of potential pollution to understand these potential threats to drinking water. The evaluation focused on identifying the locations of point source facilities and identifying the areas in the watershed with the highest concentration of permitted point source facilities with surface water proximity to produce a map of cumulative predicted risk to source water quality from point source pollutants. Pollutants were classified into four categories: Oil (petroleum or vegetable), light or medium fractioned petroleum, solvents (alcohols, ketones, Chlorinated), acids and bases.

7. Watershed Emergency Response System

CRWP identified hazardous material spills from commercial and industrial areas, railroad lines, transportation activities along HWY 212/224, and road bridges crossing the Clackamas River were identified as being one of the most significant threats to source water quality in the Clackamas River watershed. The memo outlines a watershed emergency response plan that is intended to help emergency first responders avoid the initial confusion that may accompany the first few hours after a hazardous spill by providing necessary response logistics quickly and efficiently. The Plan: 1) provides the location and intensity of potential contaminant sources; 2) identifies critical resources to be prioritized for protection in the event of a spill such as surface water intakes and sensitive habitat; 3) outlines site-specific spill response strategies, equipment availability, command post locations, first responder bases, and other logistical information; and 4) identifies potential spill response constraints, including seasonal weather patterns and access issues, reach-specific flow velocities, and infrastructure such as narrow roads and bridge loading rates. **Based on the results of the GIS "hot spot" risk analysis, CRWPs identified and coordinated with partner agencies and other key stakeholders to conduct a workshop where stakeholders contributed to the development of site-specific spill response strategies, and the gathering of information on equipment availability, communication details, and other logistics. The results of the GIS risk analysis and the information gathered in the workshop were incorporated into a web-based and/or mobile GIS watershed emergency response tool that can be distributed to first responders for use in the event of an emergency**.

8. Updated GIS Hazardous Materials Spill Risk Analyses Results and Recommendations

CRWP identified hazardous materials spills as being a high risk factor that could affect drinking water quality. The GIS analyses (1) mapped the locations and density of facilities storing or transporting large quantities of reportable hazardous substances in the Clackamas River watershed in four categories: Oil (petroleum or vegetable), light or medium fractioned petroleum, solvents (alcohols, ketones, Chlorinated), acids and bases; and (2) identified potential pathways from facilities in the commercial and industrial focus area at the bottom of the watershed to the Clackamas River. The results of the GIS analysis showed a high-risk hotspot near the commercial and industrial area at the bottom of the watershed from historic and repeat spills, hazardous substance storage facilities, and roadway safety and historic vehicle crashes.

USGS 2011: Seepage Investigations of the Clackamas River, Oregon
https://pubs.usgs.gov/sir/2011/5191/pdf/sir20115191.pdf

The Clackamas River provides downstream communities with a reliable source of municipal and drinking water while meeting in-stream requirements for fish. However, demand for water for municipal, irrigation, recreational, and in-stream uses in the basin is increasing. Characteristics of the connections between the groundwater and surface-water systems in the Clackamas River basin have not been well defined, and to evaluate the quantity and quality of water available to water providers, an improved understanding of those connections is necessary. The purpose is to present an assessment of the interaction of the stream and groundwater system of the Clackamas River basin by analysis of gains and losses in streamflow. Analysis of streamflow measurements of the Clackamas River from Estacada to Oregon City during low-flow conditions in September 2006 enabled an estimation of gains and losses on a reach-by-reach scale; these gains and losses were attributable to the geomorphic setting. During late summer, most groundwater discharge occurs upstream of Estacada, and groundwater contributions to streamflow downstream of Estacada are minor. High nutrient concentrations observed in near-stream wells and springs (Carpenter, 2003) suggest that the Clackamas River might be receiving nutrients from groundwater discharge by way of springs and/or seepage.

USGS 2008: Pesticide Occurrence and Distribution in the Lower Clackamas River Basin, Oregon, 2000-2005

http://pubs.usgs.gov/sir/2008/5027/

Pesticide occurrence and distribution in the lower Clackamas River basin was evaluated in 2000–2005, when 119 water samples were analyzed for a suite of 86–198 dissolved pesticides. Sampling included the lower-basin tributaries and the Clackamas River mainstem, along with paired samples of pre- and post-treatment drinking water (source and finished water) from water-treatment plants that draw water from the lower river. Most of the sampling in the tributaries occurred during storms, whereas most of the source and finished water samples from the study drinking-water treatment plant were obtained at regular intervals, and targeted one storm event in 2005. **63 pesticide compounds were detected, including 33 herbicides, 15 insecticides, 6 fungicides, and 9 pesticide degradation products. Atrazine and simazine were detected in about half of samples, and atrazine and one of its degradants (deethylatrazine) were detected together in 30 percent of samples**. Other high-use herbicides such as glyphosate, triclopyr, 2,4-D, and metolachlor also were frequently detected, particularly in the lower-basin tributaries. **Although pesticides were detected in all of the lower basin tributaries, the highest pesticide loads (amounts) were found in Deep and Rock Creeks**. **These medium-sized streams drain a mix of agricultural land (row crops and nurseries), pastureland, and rural residential areas**. The highest pesticide concentration in finished drinking water was 0.18 µg/L of diuron, which was 11 times lower than its low HBSL benchmark. **Samples varied based on rainfall timing and the greatest number of pesticides and the highest total pesticide concentrations were detected during storms**. A Rock Creek site was sampled in the morning, prior to the onset of the heavy rains and this sample contained fewer compounds and had lower pesticide concentrations compared with the next upstream site. This site was sampled later in the day after heavy rainfall, when turbidity was considerably higher and his sample contained some of the highest pesticide concentrations detected during the study. Although 0–2 pesticides were detected in most finished water samples, 9 and 6 pesticides were detected in 2 storm-associated finished drinking water samples from May and September 2005, respectively. Three of the unregulated compounds detected in finished drinking water (diazinon-oxon, deethylatrazine [CIAT], and N, N-diethyl-mtoluamide [DEET]) do not have human-health benchmarks available for comparison.

USGS 2009: Organic Compounds in Clackamas River Water Used for Public Supply near Portland, Oregon, 2003–05

https://pubs.usgs.gov/fs/2009/3030/pdf/fs20093030.pdf

This study characterized the amount and quality of organic matter (dissolved organic carbon (DOC)) in the Clackamas River to gain an understanding of sources that contribute to the formation of chlorinated and brominated disinfection by-products (DBPs), focusing on regulated DBPs in treated drinking water. **The two classes of DBPs analyzed in this study—trihalomethanes (THMs) and haloacetic acids (HAAs)—form from precursors within the dissolved and particulate pools of organic matter present in source water**. Concentrations of DBPs in finished (treated) water averaged 0.024 milligrams per liter (mg/L) for THMs and 0.022 mg/L for HAAs; maximum values were about 0.040 mg/L for both classes of DBPs. Although DBP concentrations were somewhat higher within the distribution system, none of the samples collected for this study or for the quarterly compliance monitoring by the water utilities exceeded levels permissible under existing U.S. Environmental Protection Agency (USEPA) regulations: 0.080 mg/L for THMs and 0.060 mg/L for HAAs. DOC concentrations were generally low in the Clackamas River, typically about 1.0–1.5 mg/L. The continuous in-situ fluorescent dissolved organic matter (FDOM) measurements indicated sharp rises in DOC concentrations in the mainstem following rainfall events; concentrations were relatively stable during summer base flow. Even though the first autumn storm mobilized appreciable quantities of carbon, higher concentrations of DBPs in finished water were observed 3-weeks later, after the ground was saturated from additional rainfall. **The majority of the DOC in the lower Clackamas River appears to originate from the upper basin, suggesting terrestrial carbon was commonly the dominant source**. **Lower-basin tributaries typically contained the highest concentrations of DOC and DBP precursors and contributed substantially to the overall loads in the mainstem during storms**. During low-flow periods, tributaries were not major sources of DOC or DBP precursors to the Clackamas River.

USGS 2003. Water-Quality and Algal Conditions in the Clackamas River basin, Oregon, and their Relations to Land and Water Management

https://pubs.usgs.gov/wri/WRI02-4189/

This report presents findings from a water quality assessment conducted in the Clackamas River Basin, from 1996 to 1999, focusing on nutrient and algal conditions. Concerns about the quality of the Clackamas River emerged in 1994, when a bloom of bluegreen algae (Anabaena spp.) occurred in North Fork Reservoir, concurrent with taste and odor problems in drinking water supplied by the river. **The purpose of the study was to determine the extent of eutrophication in the Clackamas River Basin, including the Clackamas River, its major tributaries, and reservoirs, with an emphasis on basic water quality (nutrients, dissolved oxygen, pH, temperature, and conductance), water quantity (water sources within the basin), and algal conditions (biomass and species composition)**. **Nuisance algal growths, with accompanying negative effects on water quality, were observed at several locations in the basin during this study, including certain tributaries, reservoirs, and the main-stem Clackamas River**. The spatial distribution of nutrient concentrations in streams appeared related to land use and basin location (elevation), with **the highest concentrations of N and P occurring at tributary sites in the lower basin, where most of the agriculture and urban development is located**. **High algal biomass in the Clackamas River appears to be a recent phenomenon, as biomass was low during a previous study** that found 21 mg/m2 chlorophyll a in the lower Clackamas River at river mile 0.4 in late August 1993. **The higher algal biomass is an unambiguous signs of nutrient enrichment**. Any restoration efforts will require management strategies aimed at reducing the transport of nutrients to the Clackamas River and its tributaries. Nutrient sources can be difficult to identify and quantify, especially in watersheds such as the Clackamas Basin that contain diverse land uses. C**oncentrations of disinfection by-products, toxic compounds that form during chlorination, also increased in drinking water during this time, presumably the result of the increased organic matter in the river from the drifting algae**. Nitrogen concentrations in streams in the upper basin were mostly below laboratory reporting levels (<5 µg/L). In contrast, streams draining the middle Clackamas Basin, including Clear Creek, Eagle Creek, and the North Fork of the Clackamas River, showed the opposite pattern, with relatively high concentrations of nitrogen and relatively low concentrations of phosphorus. The nitrate concentrations in these basins significantly exceeding the 5 µg/L reference condition suggested by the U.S. Environmental Protection Agency for streams in the Cascade Range Ecoregion. Nitrate concentrations in upper Eagle Creek in the Salmon-Huckleberry Wilderness Area and Roaring River (two reference streams) were close to the suggested reference condition. **Inputs of nitrogen and phosphorus also occur from the lower basin tributaries, including Deep, Richardson, Rock, and Sieben Creeks**, which had much higher nutrient concentrations compared with other sites, likely reflecting anthropogenic activities. **Inputs from these tributaries likely contributed to the observed proliferations of algae in the Clackamas River during this study**. **Nonpoint sources, including soil erosion, fertilizers, nitrogen-fixing plant species, atmospheric deposition, field burning, and livestock, also may contribute to enriching streams with nutrients**. Another potentially important source of nutrients is ground water, which was shown to contain high levels of nitrogen and phosphorus. Although the quantity of ground water entering the Clackamas River was not determined, the streamflow data suggest that it may be significant, especially in the reach between River Mill Dam and Barton. Timber production, agriculture, and urban development, the major land uses in the basin, may each be contributing to declines in water quality. **A positive correlation was found between the amount of non-forest upland (including clear cuts and other areas without vegetation) and concentrations of total phosphorus among streams in the middle and upper Clackamas Basin, where forest management is the dominant land use**. An increase in nitrate was observed only at sites in the middle basin, where most the timberland is privately owned. Nitrogen from these sites may originate from several sources, including tree harvesting (which reduces uptake of N by vegetation), post-harvest burning of slash debris, wildfires, fertilizer applications, atmospheric deposition, and proliferations of N-fixing plants such as red alder and scotch broom that often colonize disturbed soils. **Sites in basins containing the highest amounts of agricultural and urban land had the highest concentrations of nutrients, and algal assemblages included several taxa that are indicative of nutrient enrichment.**

Algal biomass at 3 of the 4 sites most affected by agricultural and urban influences (Deep, Rock, and Sieben) was within or well above the nuisance level of 100–150 mg/m2 chl a in July. **The highest concentrations of both nitrogen and phosphorus, 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. Multiple lines of evidence presented in this report suggest that algal growth in many of the streams in the Clackamas Basin, including the main-stem Clackamas River, is regulated by nitrogen**. If this is the case, reductions in nitrogen through management strategies could ultimately reduce algal growth in the river. **Strategies to reduce the effects of nutrient enrichment: restoring riparian vegetation; restoring wetlands; increasing stream complexity and floodplain access; reducing erosion through storm-water management; fertilizer-use education**; removal of invasive nitrogen-fixing plants. **Management strategies aimed at reducing concentrations of disinfection by-products in drinking water could include watershed restoration efforts that reduce algal growth in the basin (nutrient reduction strategies and stream vegetation enhancements), thereby reducing the amount of organic matter in raw water**. Nonpoint sources that would bear investigation include (1) fertilizer use in agricultural, urban, and forested settings, (2) soil erosion, which is discussed separately below (3) field burning in agricultural and forested areas, which converts organic matter into NO3 that can subsequently leach into ground water and streams, (4) livestock, which contribute nutrients and bacteria to streams, (5) atmospheric deposition of N from being located in Portland's airshed, and (6) ground water, which has already been shown to contain nutrients, often at high levels.

USGS 2013: Sources and Characteristics of Organic Matter in the Clackamas River, Oregon, Related to the Formation of Disinfection By-Products in Treated Drinking Water

https://pubs.usgs.gov/sir/2013/5001/pdf/sir20135001.pdf

This study characterized the amount and quality of organic matter in the Clackamas River to gain an understanding of sources that contribute to the formation of chlorinated and brominated disinfection by-products (DBPs). Although the river, for the most part, is exceptionally clear, it sometimes becomes turbid with sediment and organic matter from storm runoff that degrades the quality of source water at the drinking-water intakes in the lower river. The use of chlorine as a disinfectant, although essential for pathogen control, leads to the halogenation of organic matter present in source water. Halogenated (chlorine- and bromine-containing) compounds form from dissolved and particulate organic carbon during water treatment and are collectively referred to as disinfection by-products (DBPs). Understanding the timing, sources, and composition of organic matter entering drinking-water intakes will help drinking-water utilities develop source-water-protection programs, facilitate successful and cost-effective treatment strategies, and help plan for future upgrades to treatment plants. The central hypothesis guiding this study was that natural organic matter leaching out of the forested watershed, in-stream growth of benthic algae, and phytoplankton blooms in the reservoirs contribute different and varying proportions of organic carbon to the river. When periphyton detaches from the riverbed and becomes entrained in the flow during algal “sloughing” events, the cells and stalks of diatoms, filaments of green algae, and colonies of blue-green algae (Cyanobacteria) in varying states of decomposition enrich the river with organic carbon. This algae has the capacity to clog water intakes and negatively affect drinking-water quality through the production of tastes and odors and algal toxins (Graham and others, 2010). Algae also contribute carbon that contains DBP precursors The two classes of DBPs analyzed in this study—trihalomethanes (THMs) and haloacetic acids (HAAs)—form from precursors within the dissolved and particulate pools of organic matter present in source water. Data collection consisted of (1) monthly sampling of source and finished water at two drinking-water treatment plants; (2) event-based sampling in the mainstem, tributaries, and North Fork Reservoir; and (3) in-situ continuous monitoring of fluorescent dissolved organic matter (FDOM), turbidity, chlorophyll-a, and other constituents to continuously track source-water conditions in near real-time. Dissolved organic carbon (DOC) concentrations were generally low in the Clackamas River, typically about 1.0–1.5 mg/L. Concentrations in the mainstem occasionally increased to nearly 2.5 mg/L during storms; DOC concentrations in tributaries were sometimes much higher (up to 7.8 mg/L). The continuous in-situ FDOM measurements indicated sharp rises in DOC concentrations in the mainstem following rainfall events; concentrations were relatively stable during summer base flow. Even though the first autumn storm mobilized appreciable quantities of carbon, higher concentrations of DBPs in finished water were observed 3-weeks later, after the ground was saturated from additional rainfall. The majority of the DOC in the lower Clackamas River appears to originate from the upper basin, suggesting terrestrial carbon was commonly the dominant source. Lowerbasin tributaries typically contained the highest concentrations of DOC and DBP precursors and contributed substantially to the overall loads in the mainstem during storms. During lowflow periods, tributaries were not major sources of DOC or DBP precursors to the Clackamas River. Overall, concentrations of THM and HAA precursors were closely linked to DOC concentrations. Given the low concentrations of algae in the water column during this study, additional surveys during more typical river conditions could provide a more complete understanding of how algae contribute DBP precursors.

Drinking Water Source Protection Planning References (No Summaries)

ODEQ Source Water Protection Plan Resources
https://www.deq.state.or.us/wq/dwp/swrpts.asp

Oregon Public Water Systems Surface Water Resource Guide For Drinking Water Source Protection, 2018
https://www.oregon.gov/deq/FilterDocs/SurfaceWaterResourceGuide.pdf

The general planning process for development of an area-wide plan is documented in the National Planning Procedures Handbook (NPPH), Subpart F – Area-wide Conservation Planning
https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=36483.wba

American Water Works Association/ANSI G300 standard for source water protection
https://store.awwa.org/store/productdetail.aspx?productid=39814230

National Management Measures to Control Nonpoint Source Pollution from Agriculture, 2003
https://www.epa.gov/nps/national-management-measures-control-nonpoint-source-pollution-agriculture

Oregon's Integrated Water Resources Strategy Guidelines: A Tool for Conducting Place-Based Integrated Water Resources Planning in Oregon, 2015
https://www.oregon.gov/OWRD/WRDPublications1/2015_February_Draft_Place_Based_Guidelines.pdf