

More Information About The Willamette River Report Card Water Quality Indicator

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DEQ is a leader in restoring,
maintaining and enhancing
the quality of Oregon's air,
land and water.



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Introduction

This document provides additional background information for the water quality indicator in the Willamette River Report Card. The report card has a simple water quality score for each three river regions with no additional information as to what specific parameters are in good or bad condition, and if the river is getting better or worse over time. This document provides that information.

The Report Card uses the Oregon Water Quality Index (OWQI) for the water quality indicator. The Oregon Department of Environmental quality has used the OWQI since the 1970's to communicate information about the water quality status and trend of Oregon's rivers and streams in an easy-to-understand, non-technical format to the Oregon Legislature, government officials and the general public. The OWQI is a single number that expresses water quality by integrating measurements of eight water quality variables: temperature, dissolved oxygen, biochemical oxygen demand, pH, ammonia+nitrate nitrogen, total phosphorus, total solids, and fecal bacteria. The purpose of the OWQI is to provide a simple and concise method for expressing the general, overall ambient water quality of rivers for general recreational use, including fishing and swimming (Cude 2001).

Oregon's Ambient River Water Quality Monitoring Network

To assess the water quality status and trend of Oregon's rivers and streams the Oregon Department of Environmental Quality Laboratory monitors a network 160 river sites six times a year. These sites are located throughout the state and include at least one site on all major rivers. The state-wide network includes 44 sites in the Willamette basin and 9 sites in the Willamette River (Figure 1). Monitoring data collected at some of these sites goes back to the late 1940's.

OWQI Strengths and Weaknesses

The OWQI has been used by DEQ to communicate basic water quality information in a simple, non-technical format for many years using 'traditional' water quality parameters such as fecal bacteria, algal nutrients and dissolved oxygen. However, the index does not include many possible stressors to rivers. It is simply one of several tools that helps DEQ get a better understanding of Oregon's water quality. For example, the index does not cover toxic contaminants, habitat conditions or biological community health. A single index cannot identify all potential water quality issues in a watershed.

Also, creating an index like the OWQI involves a simplification of complex systems with the potential for loss and distortion of information. Although the index may have weaknesses, the reader should keep in mind that the strength of the OWQI is that it provides general, qualitative information on overall water quality using routinely measured parameters to a mostly non-technical audience. More quantitative, technical assessments of Oregon's waters are available from Total Maximum Daily Load studies, basin assessments, and other reports available on DEQ's web page <http://www.deq.state.or.us/lab/wqm/watershed.htm>.

Assessment Methods

The OWQI scores used in the report card are three-year averages of seasonal minimum scores for water years 2012 to 2014 (October 1, 2011 to September 30, 2014). Condition are presented in

Table 1 and Figure 1 as five color-coded categories ranging from dark green for very good to red for very poor. Sites were analyzed for significant 10-year trends using the nonparametric Seasonal-Kendall test for trending at the 80 percent or greater confidence level. Statistically significant 10-year trends are indicated in Table 1 by up or down arrows for increasing and decreasing trends, or dashes for non changing trends.

There is more information on the report card and the calculations involved in converting raw data to an OWQI score on DEQ web page and in the references listed at the end of this report. See: <http://www.deq.state.or.us/lab/wqm/wqimain.htm>. The Willamette River Report Card Scores and Scoring Methodology (Constanzo, et al, 2015) has more information on how the OWQI is incorporated into the Report Card.

Water Quality Results

Figure 1 presents the water quality condition and ten-year trends for overall water quality as well as the individual parameters that are combined into the overall index. Conditions and 10-year trends are presented for the assessment reach average and for each individual site. The overall water quality of the Willamette River declines from very good conditions in the upper region to fair conditions in the lower region. Biochemical oxygen demand (BOD) total solids (TS), and nutrients (N and P) showing the greatest declines from upstream to downstream. All three regions and individual sites have an overall improving trend in water quality. Of the individual sites assessed six had improving water quality trends and three had no change trends and none had declining trends. Most individual parameters also had improving trends. Only BOD and total solids were the two parameters with the most declining condition trends.

Figure 2 presents more than 30 years of OWQI scores for each of the three assessment regions. The running three-year reach average as the red line and the overall 1980 to 2014 trend line in black. All reaches and sites have a consistent overall improvement in water quality during this period. Since 1980 the population of the Willamette basin increased by approximately 1,000,000 people (Hulse, et al, 2002).

The following sections have more information on each index parameter.

pH

What is pH?

pH is a indicator of the acid/base balance of water. The pH scale ranges from 1 to 14 with values less than 7 being acidic, values greater than 7 being basic or alkaline, and exactly 7 as being neutral. Chemically, pH is defined as the concentration or activity of hydrogen ions in water in moles per liter.

Why is pH important?

pH is an important water quality parameter that has many effects on aquatic life including direct impacts on the health and survival of aquatic organisms as well as indirect effects on the overall water chemistry. Most aquatic species in the Willamette River are comfortable in a pH range around neutral (7) and become increasingly stressed at pH below 6.5 and above 8.5.

What affects pH?

In most natural water pH is determined by the dissolution of carbon dioxide to form carbonic acid. Carbon dioxide comes from the atmosphere as well as from biological activity in the water. The process of photosynthesis during the daytime by algae and aquatic macrophytes absorbs carbon dioxide from the water, making the water more alkaline and causing a rise in pH. Cellular respiration by all living things has the opposite effect by releasing carbon dioxide, making the water more acidic and lowering pH. The pH can vary over the course of a day and year as the photosynthesis and cellular respiration change with day light and temperature. Introducing large amounts of organic material from soil erosion or human and animal waste can increase the oxygen demand as the material is decomposed and increasing carbon dioxide in the water and lowering the pH. Introducing large amounts of nitrogen and phosphorus nutrients from fertilizer runoff can increase algae growth and photosynthesis, raising pH during the day, especially during warm, sunny weather. Decreasing stream side shade by removing riparian vegetation can increase solar energy inputs and warm river temperature resulting in increased photosynthesis.

pH in the Willamette River

The pH levels of the Willamette River are generally in a desired range for protecting aquatic life in all assessment sections with an even no change trend.

DO: Dissolved Oxygen

What is DO?

Dissolved oxygen (DO) is the amount of oxygen gas dissolved in the water. It is measured in milligrams per liter and also expressed as a percent of saturation. Saturation is the total amount oxygen gas that the water can contain.

Why is DO Important?

DO is critically important to living things in the water to breakdown organic material and release energy for growth and activity. This is called cellular respiration. Without enough oxygen fish, insects and other aquatic life quickly dies. The minimum oxygen requirements can vary with different species and different life stages, but sensitive species like salmon and trout need fairly high oxygen levels at or near saturation at all life stages to survive and thrive.

What Affects DO?

The concentration of DO in water depends on oxygen sources and sinks. Sources of oxygen include diffusion from the air into the water, turbulent mixing of air and water in fast moving water, and photosynthesis by algae and aquatic macrophytes (plants). DO sinks are cellular respiration and biochemical oxygen demand as bacteria and fungi break down organic material in the water and consume oxygen. Introducing large amounts of plant nutrients to the water will fertilize algae growth increasing DO inputs during the day. DO can vary widely over the course of a day or year as photosynthesis and cellular respiration change with changing day light and temperature. Other factors that determine the total amount of oxygen the water can hold at saturation are temperature and atmospheric pressure. Warmer water can hold less total oxygen than colder water at saturation. The amount of oxygen at saturation will be lower for higher elevations because the atmospheric pressure is lower.

DO in the Willamette River

The DO levels in all assessment reaches is at or near the levels needed to protect sensitive aquatic life most of the time with improving dissolved oxygen trends in the mid and upper reaches.

BOD: Biochemical Oxygen Demand

What is BOD?

Biochemical oxygen demand (BOD) is the amount of dissolved oxygen needed by aerobic organisms in a water body to break down organic material present in the water in a certain amount of time and at a certain temperature. It is expressed as milligrams of dissolved oxygen per liter. BOD is measured at the DEQ laboratory after five days incubation at 20 °C. Although it isn't a precise test, BOD is widely used in water quality assessments as an indication of the overall amount organic material in the water. Most natural, unpolluted waters contain at least some BOD.

Why is BOD important?

Aerobic aquatic microorganisms use the organic matter in the water measured by the BOD test for food to get energy for growth, reproduction and activity. As BOD increases these microorganisms also increase and consume more oxygen. If the BOD is high enough, the metabolic activity by the microorganisms will deplete the dissolved oxygen faster than oxygen sources can replenish it. Fish and other aquatic life may die if the oxygen is depleted below what they need to survive.

What Affects BOD?

Anything that increases the input of organic material into the water would increase the BOD. This would include soil erosion, dead plant material, sewage treatment plant and industrial discharges, animal waste, or anything else that can be decomposed by microorganisms. Nutrients that increase algae and plant growth will also increase BOD as those organisms die and are decomposed. Warmer water temperatures will stimulate microbiological metabolism and oxygen consumption.

BOD in the Willamette River

Overall, BOD is the worst performing OWQI parameter in the Willamette River. BOD is in fair condition in the mid and upper reaches, and mostly poor condition in the lower reach, representing an overall decline in BOD condition from upstream to downstream. BOD trends are unchanging in the upper reach and mostly in declining condition in the mid and lower reaches.

TS: Total solids

What are TS?

The total solids (TS) are the weight of material that is left when a known volume of water is evaporated to dryness. It is measured in milligrams per liter and includes all dissolved and suspended material. It is an indication of the amount of sediment suspended the water column.

Why are TS important?

All natural water contains at least some solids. Increased total solids input to rivers can have adverse effects on aquatic organisms. High total solids can impair the ability of fish to find prey and avoid predators, can smother fish eggs and benthic organisms, decrease inter-gravel dissolved oxygen and eliminate or impair benthic fish and macroinvertebrate habitat. Nutrient, contaminants and BOD are often contained in fine particulate matter in the water. Increased sediment loading to streams can change the physical stream channel by filling in pool habitat, filling in spaces between coarse substrate in riffles and affecting the overall channel shape and sinuosity.

What Affects TS?

Anything that increases the input of particulate or dissolved matter into the river increases total solids. Erosion from the disturbed land surfaces and poor riparian condition are often major inputs of total solids.

TS in the Willamette River

In general, the total solids condition declines from upstream to downstream with an overall unchanging 10-year trend in the mid and lower reaches, and declining condition trend in the upper reach. Total solids indicator in the upper reach (specifically at the Springfield site) is one of the few indicators that has a declining 10-year condition trend.

N and P: Nitrogen and Phosphorus Nutrients

What are Nitrogen and Phosphorus?

The nitrogen and phosphorus nutrient parameters in the OWQI is dissolved inorganic nitrogen in the form of ammonia, nitrate and nitrite combined; and total phosphorus, mostly in the form of phosphate. These nutrients are important for algae and macrophyte growth. Natural waters contain at least some of these nutrients.

Why are Nitrogen and Phosphorus Nutrients Important?

These nutrients are necessary for algae and aquatic macrophyte growth. Typically, one of these nutrient limits the growth of algae in most waters. Phosphorus is usually the algae limiting nutrient. Adding more phosphorus to waters usually stimulates more algae growth. Nitrogen is usually not the nutrient that limits algae growth in water but can stimulate growth with high phosphorus levels. Although nitrogen is usually not the limiting nutrient for algal growth, waters with high phosphorus and other nutrients relative to nitrogen can become nitrogen limited. This promotes dense blooms of blue-green algae which use atmospheric nitrogen (N₂) for growth unlike other algae and plants. Blue-green algae blooms can release toxins into the water that can sicken or kill people or animals that come in close contact with the water or drink it.

What Influences N and P Nutrients?

As nitrogen and phosphorus are necessary nutrient for algae and aquatic plants to grow, they are also necessary for terrestrial plants. Fertilizer containing nitrogen and phosphorus is applied to crops, forest lands, gardens, and lawns to stimulate growth. Fertilizer nutrients applied in excess of what the plants take up for growth can wind up in the groundwater and rivers and increase algae growth. Soil erosion and sewage plant discharges are also sources of nutrients in rivers. Decomposition of organic material releases nutrients into the water.

N and P Nutrients in the Willamette River

The overall pattern is that nutrient conditions decline from upstream to downstream. Nitrogen conditions range from very good to good in the upper reach to poor to very poor in the lower reach. Phosphorus conditions similarly range from good to fair in the upper reach, fair in the middle reach, and mostly poor in the lower reach. The 10-year trends for both nutrients are improving at all sites and assessment reaches.

Bact: *Escherichia coli* bacteria

What is *Escherichia coli*?

Escherichia coli (*E. coli*) is a bacterium that lives in the intestines of warm blooded animal (mammals and birds).

Why is *E. coli* important?

There are many bacteria, viruses, and protozoa cause disease in people that can be present in water. People can swallow these organisms and get sick when swimming or drinking. Most of these disease causing organisms are transmitted to humans through water contaminated with fecal material from an infected animal or human. It is impractical to regularly test water for all the different disease-causing microorganisms. DEQ regularly tests rivers for *E. coli* as an indicator organism for fecal pollution. Most types of *E. coli* are harmless, but its presence is a clear indication of fecal contamination and that the organisms are still living in the water. Oregon's bacteria standard for safe swimming is 406 *E. coli* organisms per 100 milliliters of water for a single sample (Oregon Administrative Rules 340-041-0009).

What Influences *E. coli*?

E. coli can come from a variety of sources including failing septic systems, discharges of untreated or poorly treated sewage resulting from sewer malfunctions or overflows, storm water runoff carrying feces into surface water from pets, domesticated animals or wildlife from urban, residential, and agricultural lands. Urban areas often have combined sewers where the sanitary sewer and storm water are mixed. Combined sewer can overflow during rain storms resulting in untreated sewage entering surface waters.

***E. coli* in the Willamette River**

Overall, *E. coli* concentrations are below the 406 *E. coli* per 100 mLs level safe for swimming and other contact water recreation most of the time in all three reaches of the river (Figure 3). Since the 1980's high *E. coli* levels usually associated with rainy weather have largely disappeared in recent years .

Figure 1. DEQ Water quality monitoring sites in the Willamette River. Base map Constanzo, et al, 2015

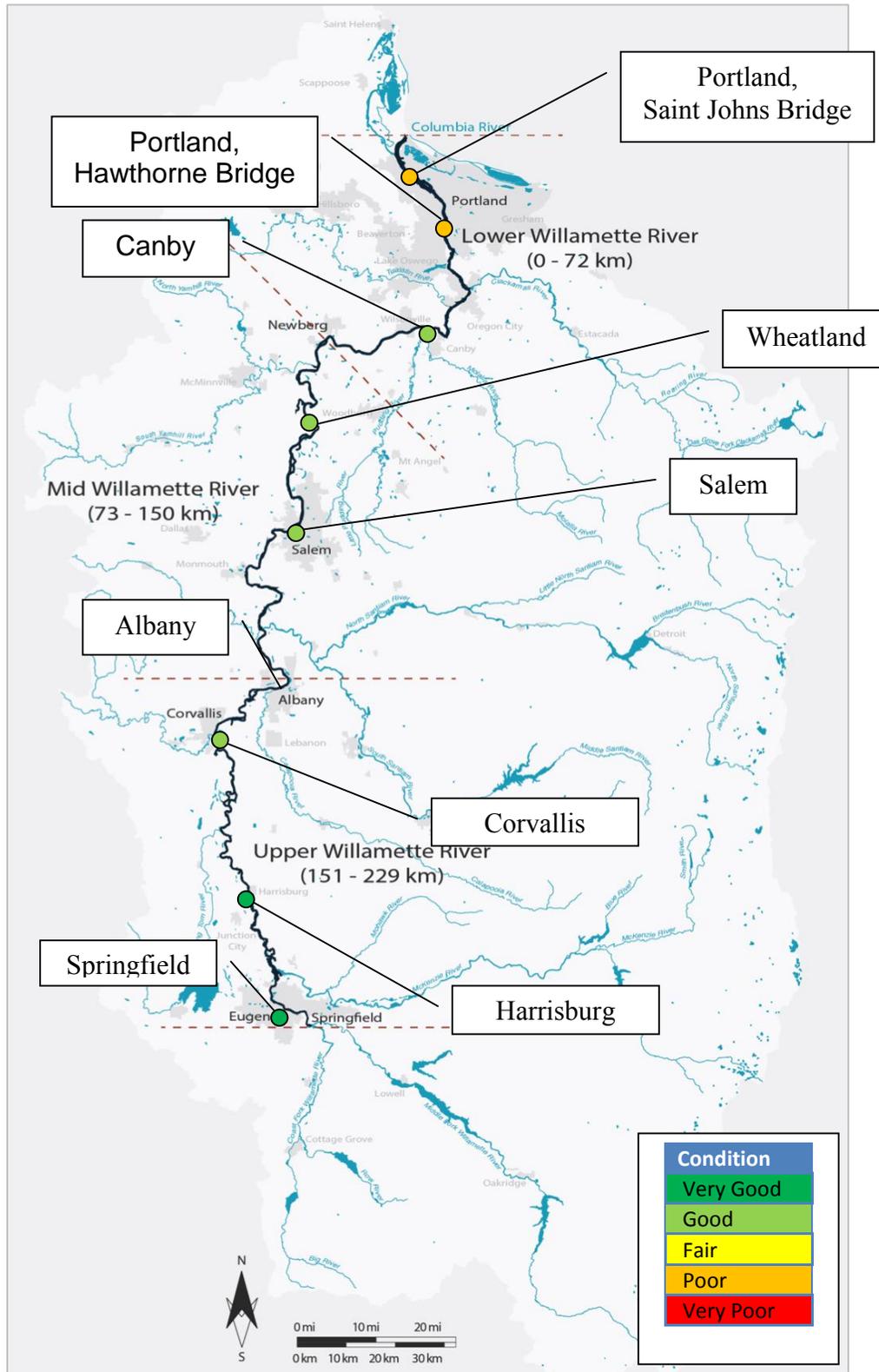


Table 1. 2012-2014 WQI, average seasonal minimum scores and 10-year seasonal Kendall trends. Abbreviations in column headings described in the Water Quality Results section of this report. See pages 5 to 8 for parameter abbreviation explanations.

Location	Site ID	WQI	pH	DO	BO D	TS	N	P	Bact
Lower Willamette River		↗	-	-	↘	-	↗	↗	-
Portland, St Johns Br	10332	↗	-	-	-	-	↗	↗	-
Portland, Hawthorne Br	10611	-	-	-	-	-	↗	↗	↘
Canby	10339	↗	-	↗	↘	-	↗	↗	-

Location	Site ID	WQI	pH	DO	BO D	TS	N	P	Bact
Mid Willamette River		↗	-	↗	↘	-	↗	↗	-
Wheatland	10344	-	-	↗	↘	-	↗	↗	-
Salem	10555	↗	-	↗	↘	-	↗	↗	-

Location	Site ID	WQI	pH	DO	BO D	TS	N	P	Bact
Upper Willamette River		↗	-	↗	-	↘	↗	↗	-
Albany	10350	↗	-	↗	-	-	↗	↗	-
Corvallis	10352	↗	-	-	-	-	↗	↗	-
Harrisburg	10355	↗	-	↗	-	-	↗	↗	↗
Springfield	10359	-	-	↘	-	↘	↗	↗	↗

Condition Grade Scale

Condition	OWQI Scoring	Report Card Scoring System	Condition Description
Very Good	90 - 100	80 - 100%	Expectation for healthy waters are almost always met.
Good	85 - 89	60 - <80%	Expectation for healthy waters are frequently met.
Fair	80 - 84	40 - <60%	Expectation for healthy waters are occasionally met.
Poor	60 - 79	20 - <40%	Expectation for healthy waters are frequently not met.
Very Poor	10 - 59	0 - 20%	Expectation for healthy waters are rarely met.

Condition trending

Trend	Description
↗	Significantly improving trend
-	No change trend
↘	Significantly declining trend

Figure 2. Willamette River annual OWQI scores with 3-year reach average and reach trend.

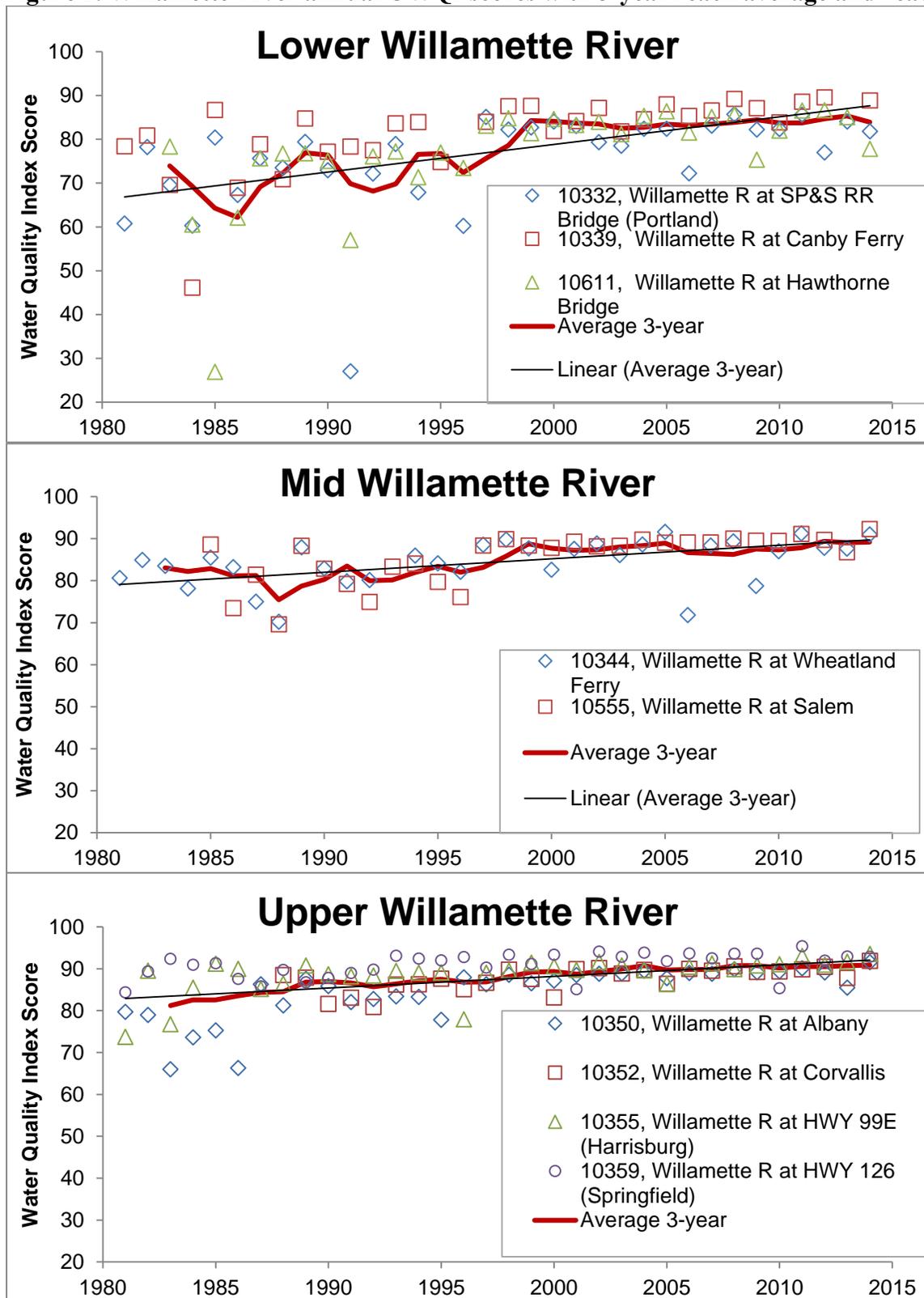
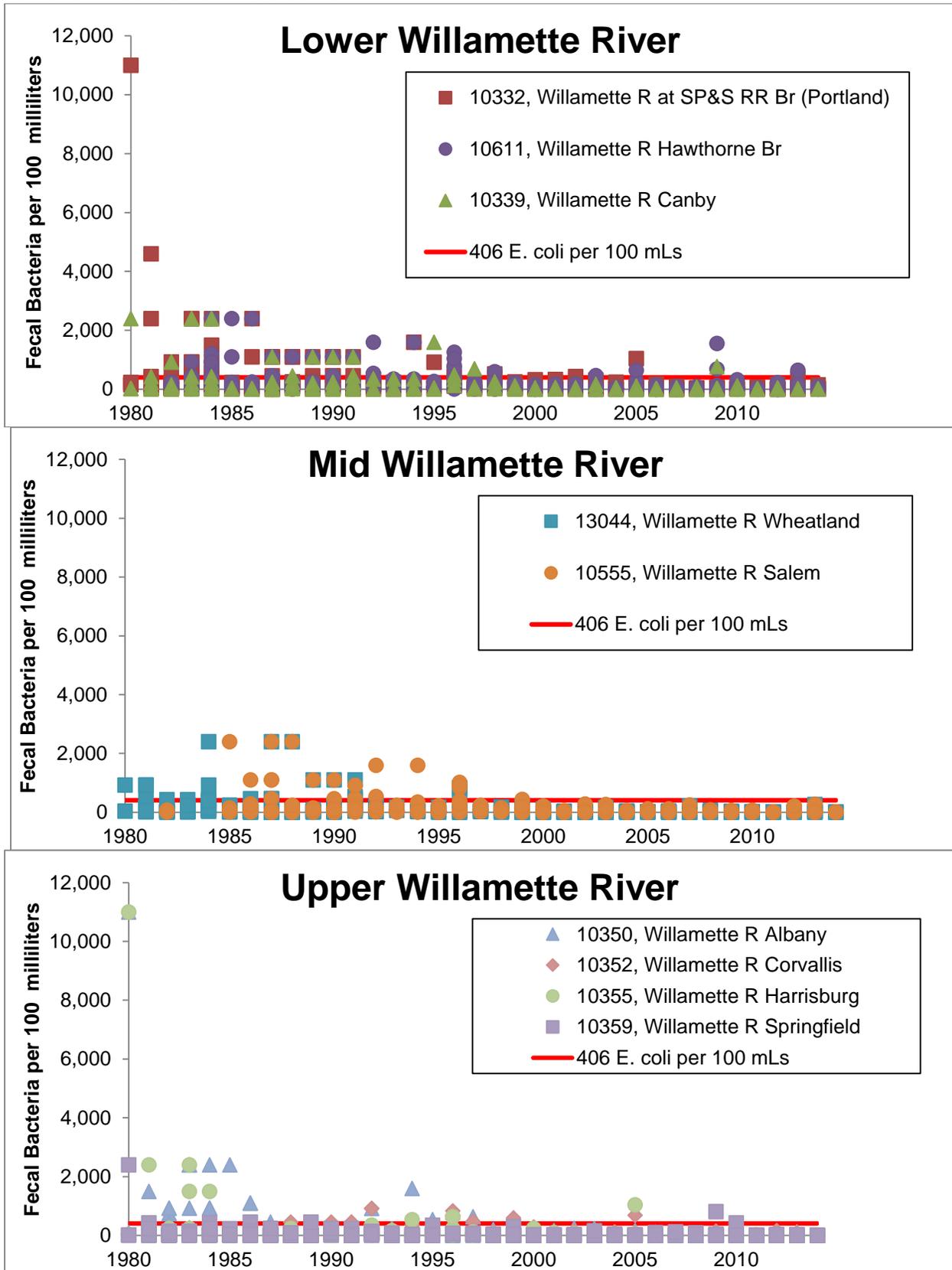


Figure 3. Willamette River fecal bacteria 1980-2014. Data 1980 to 1999 are fecal coliform bacteria, from 2000 to 2014 data are *E. coli* bacteria. Fecal coliforms are a group of bacteria that include *E. coli*. The method was changed in 2000 because *E. coli* is a better indicator of human risk than fecal coliform bacteria.



References

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