Johnson Creek Water Quality

2009 to 2014

Johnson Creek Watershed Council

Acknowledgements

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Johnson Creek Watershed Council

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Executive Summary

Many jurisdictions conduct monitoring within Johnson Creek. However, there has not been a recent effort to assemble this information across jurisdictional boundaries and create a watershed-wide picture of water quality conditions. This project assembled data from multiple jurisdictions for the period 2009 to 2014. The objectives of the study were to develop an assessment of current conditions and to create a baseline that could be used to measure changes in the future. The interpretive criteria used in this study were State Water Quality Standards criteria and a three-tiered condition classification system established by the authors. The three categories were labeled Good, Fair, and Poor and the criteria for the categories are generally more stringent than State water quality standards. The three-tiered classification was developed in order to assess pollution levels at concentrations below State Water Quality Standards.

The monitoring data exhibit great spatial variability in water quality. There are tributaries in the watershed with few water quality limitations and good water quality. This is seen in the chemical/physical monitoring as well as in the biological (macroinvertebrate and fish) monitoring. However, the mainstem and the majority of tributaries exhibit degraded water quality.

Three water quality parameters had violations of State Water Quality Standards -- **water temperature**, ***E. coli***, and **total mercury**. However, there were only five sites with exceedances of the mercury standard.

There were no exceedances of State Water Quality Standards for **zinc**, **copper**, and **lead**. There are no State Water Quality Standards for **total suspended solids**.

In addition to comparing the monitoring data to State Water Quality Standards, we compared the data to a generally more stringent three-tiered classification of Good, Fair, or Poor. This analysis allowed assessment of conditions in ranges of pollution below State Water Quality Standards. The criteria for the three-tiered classification system were set by the authors.

High **water temperature** is a widespread problem within the watershed and may be the most significant limitation on aquatic communities. Even the upper reaches of many tributaries are in “poor” or “fair” condition for water temperature primarily due to loss of riparian shading. The headwaters of Botefuhr, Butler, Chastain, and Kelley Creeks were the only significant areas of the Johnson Creek stream network meeting the “good” criterion. All of the Johnson Creek mainstem and nearly all of the tributaries exceed the State Water Quality Standard (64.4°F/18°C) at some point during the year, and much of the watershed exceeds the State Water Quality Standard for the majority of the summer. There are, however, some areas of cool water refuge in a few small tributaries in the mid-watershed.

Dissolved zinc concentrations are well below State Water Quality Standards. Zinc concentrations in the Johnson Creek watershed appear slightly elevated, with multiple exceedance of the “Good” criterion even at average concentrations. Sampling locations were limited to the lower reaches of the watershed,

and focused on the mainstem and the Veteran's Creek, Powell Butte, and Kelley Creek tributaries. Further analysis is required to definitively determine the risk to aquatic life from these zinc levels (particularly to adjust criteria for hardness). The headwaters of Veteran's Creek (PAWMAP site 1084) and a site on Middle Johnson Creek (PAWMAP site 0428) appear to have zinc concentrations significantly higher than the rest of the watershed, and may warrant further investigation.

Total mercury concentrations in the Johnson Creek watershed tend to average between "Fair" and "Poor." Most of the "Poor" samples occurred during storm events. Violations of State Water Quality Standards were infrequent (7 samples out of 257) and five sites exceeded the Standards in at least one sample. These exceedances occurred during storm events. Mercury contamination of Johnson Creek is relatively widespread, with hotspots that may indicate accumulation of mercury from upstream sources near the lower mainstem sites. These sites may reflect cumulative impacts of the drainage area as particulate mercury is flushed through the stream network. Mercury appears to be a pollutant of concern for Johnson Creek, although data on concentrations in fish and invertebrates would be more indicative of potential impacts to wildlife and human health than the values for concentrations within the water itself. No point sources are suggested by the data. Atmospheric deposition of particulate mercury onto urban landscapes, followed by transport to streams during storm events is a common route of contamination in urban areas.

Dissolved copper concentrations in the Johnson Creek watershed are generally within an acceptable range and rank in the "Good" or "Fair" categories for all sites. Of 298 samples only one sample exceeded the threshold for the "Poor" category and that sample was taken during an extreme storm event. There were no observed violations of State Water Quality Standards.

Dissolved lead concentrations in the Johnson Creek watershed are generally within an acceptable range and rank in the "Good" category for all but one site. Of the 297 samples collected at all sites, only one sample was in the "Fair" category and one sample was the "Poor" category. These fair and poor samples both occurred at one site. There were no observed violations of State Water Quality Standards.

Total suspended solids in the Johnson Creek watershed show a mixture of "Fair" and "Good" conditions on average. However, the maximum concentrations are usually many times the median value at each site, and are typically in the "Poor" range. This pattern of low concentrations most of the time with episodic high concentrations is typical of storm-driven runoff pollution or re-suspension of sediments. High concentrations of suspended solids occurred throughout the watershed, including mainstem and tributaries. Suspended solids are often increased in agricultural and urban areas due to increased surface runoff, erosion, and channel incision caused by storm flows interacting with impervious surfaces and drainage networks. This mechanism could explain the disparity between low mean total suspended solids concentrations and high peak concentrations.

E. coli is an indicator bacterium widely used in water quality assessment to provide an estimate of the level of general sanitation and water pollution due to bacterial contamination of waters related to warm-blooded organisms. While most forms of *E. coli* do not directly cause disease, they can be found in association with more virulent species of bacteria, and serve as an indicator of the potential for wider contamination by disease-causing bacteria. *E. coli* contamination of the Johnson Creek mainstem appears to be significant and widespread. Average values are predominantly in the "Fair" range, while the maximum values at each site sampled were in excess of the "Poor" criterion, and in violation of single-value maximum criterion for Oregon water quality standards by 2-3 orders of magnitude. Only five sites of the 39 had average values in the "Good" range, although none of the average values were in the "Poor" range. Exceedances of the "Fair" and "Poor" thresholds occurred year round, and were not confined to any particular seasons. The source of *E. coli* contamination is not readily determined. The primary sources are probably wildlife and/or domestic animals and biofilms, although it is possible that malfunctioning or poorly maintained septic or sewer systems could also be a source.

Macroinvertebrate community sampling shows that conditions are moderately to severely degraded throughout most of the watershed. However, there are areas within the watershed with healthy macroinvertebrate communities. Of the 60 sites sampled, three sites rated "no impairment" and 3 sites rated "slight impairment." These sites are all in forested headwaters. Fourteen sites were rated "moderately impaired." The remaining 40 sites were "severely impaired."

Fish community sampling shows that conditions are marginally to severely impaired throughout the watershed. All of the sites or reaches surveyed had F-IBI scores that fell in the Marginally Impaired or Severely Impaired ranges. This reflects low fish diversity. No sites had F-IBI scores in the Not Impaired range. Although the fish community throughout the watershed is impaired, it is not dominated by invasive species. Non-native fish species such as Bluegill, Pumpkinseed, and Largemouth Bass are present in the watershed but they do not dominate the fish community and constitute less than 1% of the community by number of individuals. Native species such as Redside Shiner, Reticulate Sculpin, Speckled Dace, and Cutthroat Trout dominate the fish communities and are found in the smallest tributaries. In addition, Coho Salmon, Steelhead, and Pacific Lamprey can be found in many reaches.

The monitoring data indicate that the mainstem and the major tributaries exhibit degraded water quality. The most significant water quality problems are temperature, *E. coli*, and total suspended solids. In addition, there may be potential pollution problems with mercury. The macroinvertebrate community sampling also shows impacts to the biological community in the mainstem and major tributaries. However, the macroinvertebrate sampling indicates healthy conditions in several of the less developed upper tributaries. The fish community sampling shows marginally impaired to severely impaired communities throughout the watershed. However, non-native fish species are not a significant problem and native salmonids are present in many reaches.

1 Introduction

This document provides an overall watershed-wide assessment of the water quality condition of Johnson Creek based on monitoring data collected between 2009 and 2014. Monitoring data were compiled from several organizations into a common database for analysis. Various aspects of watershed condition were analyzed by developing summary statistics and comparing measured values to State Water Quality Standards criteria and to other condition criteria. Condition criteria were used to evaluate conditions as “good,” “fair,” or “poor.” The interpretive criteria were established by the authors and are somewhat based on preliminary criteria being considered by the City of Portland’s Watershed Indicators program at the time.

Selected Parameters

There are approximately 50 specific parameters that are collectively monitored by the various entities that have ongoing monitoring programs in the watershed. We did not attempt to analyze all 50. Some parameters have a very limited amount of data. We focused the analysis on those parameters that have a reasonable amount of data and are known or potential problems. The parameters that were analyzed in this study were as follows:

Water Temperature

Total Suspended Solids

Dissolved Copper

Dissolved Zinc

Total Mercury

Dissolved Lead

Coliform Bacteria (*E. coli*)

Macroinvertebrate Community Assemblage (B-IBI)

Fish Community Assemblage (F-IBI)

Sources of monitoring data

This assessment is based on monitoring data assembled from several jurisdictions. There are approximately 2,000 individual observations taken every year by the jurisdictions working in Johnson Creek. The various monitoring programs are summarized in this section. Not all programs described below contributed data to this study. The organizations that are active in monitoring Johnson Creek are listed below.

Johnson Creek Inter-Jurisdictional Committee

Johnson Creek Watershed Council

City of Portland

City of Gresham

City of Milwaukie

City of Damascus

Clackamas County Service District #1/Water Environment Services

Multnomah County

Clackamas County Soil and Water Conservation District

East Multnomah Soil and Water Conservation District

Metro

Oregon Department of Environmental Quality

Oregon Department of Fish and Wildlife

U. S. Geological Survey

Portland State University

Reed College

Xerces Society

Johnson Creek Inter-Jurisdictional Committee (IJC)

The IJC is made up of technical staff from the JCWC, jurisdictions, and agencies that manage portions of the watershed, including the U.S. Geological Survey, Oregon Department of Environmental Quality, Oregon Department of Agriculture, the Cities of Damascus, Gresham, Milwaukie and Portland, Multnomah and Clackamas Counties, the East Multnomah and Clackamas Soil and Water Conservation Districts, volunteer retired scientists, and active Portland State University graduate students.

Watershed-Wide Summertime Continuous Stream Temperature Monitoring

Since 2009, summertime, continuous stream temperature data has been collected at the watershed scale. The number of monitoring units deployed by year has been as follows: 11 sites in 2009, 11 sites in 2010, 27 sites in 2011, 16 in 2012, 37 in 2013 and 40 in 2014. These sites include the four Gresham fixed sites, the Portland PAWMAP sites (6 to 9 a year), and the East Multnomah SWCD’s two fixed sites. A focus of the 2012-2013 monitoring was at the mouths of tributaries and documenting the heating effects of in-line ponds.

Watershed-Wide Macroinvertebrate Monitoring

Since 2009, August macroinvertebrate samples have been collected throughout the watershed and the taxonomic analysis paid for by multiple jurisdictions. Site selection is based on the Oregon Master Sample developed by the EPA lab in Corvallis, Oregon. This is a sampling design using a generalized random tessellation stratified design – or GRTS approach which produces a set of points that are spatially balanced in a probabilistic random sampling design. Each year, ~8 sites are sampled to complement the sites being sampled by the City of Portland through their PAWMAP study for a total of 15-17 per year throughout the watershed. The next year a different 15-17 sites are sampled. After four years the sampling plan will return to the first year "panel" and repeat. Thus a total of approximately 60 sites are sampled over four years. The variables used in the analysis included a suite of macroinvertebrate metrics including the individual metrics from the Index of Biotic Integrity. We also look at functional feeding groups and the results from the DEQ's predictive model known as PREDATOR.

Watershed-Wide Summertime Bacteria Monitoring

In 2012 and 2013, the IJC collaborated on a watershed-wide bacteria sampling blitz with assistance from DEQ to get a handle on human sources of fecal contamination in Johnson Creek and exploration of alternative indicators of fecal contamination to *E. coli.* 70 sites throughout the watershed were sampled for *E. coli* in August 2012 and 2013 after several weeks of no rain to determine summertime bacteria levels. In 2012, 50 of the sites were also tested for general Bacteroides and a Human Bacteroides Indicator using qPCR. Fourteen of these fifty tested positive for human fecal contamination.

Johnson Creek Watershed Council

In addition to contributing to the IJC efforts described above, the Council also conducts the following monitoring efforts.

Annual Coho spawning surveys. Volunteers conduct weekly surveys of several one-mile-long reaches in the fall to look for spawning salmon, carcasses of spent salmon, and redds.

Mussel Surveys. Volunteers are used to conduct recognizance surveys of mussel presence. Future surveys will focus on the success of mussel transplant efforts associated with the Westmoreland Park stream channel reconfiguration project.

Implementation Project Tracking (the Conservation Registry). The Council established and maintains a database of information on all restoration projects that have occurred within the watershed.

Tributary hydrology citizen science with USGS. To better understand the hydrology of ungauged tributaries, the Council established hydrology monitoring sites and trained volunteers to read staff gauges. The project was coordinated by USGS.

Pit-tag antenna at JCWC Office for tagged lamprey. In partnership with a private company, a detection system was installed in the creek next to the Council offices to detect when lamprey that had been tagged with transmitters passed by on their annual migration.

City of Portland

The City of Portland has three monitoring efforts focused on Johnson Creek. The principal monitoring effort is the Portland Area Watershed Monitoring and Assessment Program (PAWMAP). Some additional information is collected to supplement the PAWMAP data to support determining a Watershed Health Index (WSHI). The third effort is to conduct project effectiveness monitoring for several large restoration projects.

PAWMAP

The objective of the Portland Area Watershed Monitoring and Assessment Program (PAWMAP) is to assess the health of Portland watersheds by evaluating the biological, chemical, and physical condition of watersheds in Portland, and compare the relative importance of chemical, physical, and biological stressors. The goal is to determine the overall health of the streams within a fairly large geographic area such as within the boundaries of the City or within the portion of the City covered by a basin. Within the geographic area, specific sampling points are randomly selected. By using a random sampling design, the data collected are statistically representative of all waters within the geographic area. The design will allow general conclusions about condition to be made (e.g., 83% of Portland's stream reaches have impaired macroinvertebrate communities) without sampling every reach.

The program has randomly selected 128 sites within the City boundaries. These are sampled on a four year rotational schedule. Thus, 32 sites are sampled in a year. Within the Johnson Creek basin (that portion of it that falls within the City boundary), there are 25 monitoring sites. In any single year six to nine Johnson Creek sites are monitored. The same schedule of monitoring then repeats every four years.

This program design is the same as used by the USEPA nationally but adapted to the area of Portland. The strength of the design is the ability to make conclusions about conditions over a broad area without having to monitor the entire area. The drawback is that the randomly selected sites may not be appropriate for monitoring a particular problem or source. Also, measuring trends is possible but only after several four-year rotational cycles have been completed. How many cycles would be needed to detect trends depends on the inherent variability of the conditions in the basin being studied and varies by parameter.

The parameters collected at each sampling point are quite comprehensive. Standard EPA sampling and analysis methods are used. The parameters are summarized as follows:

- Instream and riparian habitat – sampled once in summer
- Water quality – sampled quarterly, with an additional sample collected during a rain event to characterize stormwater impacts on stream water quality
- Macroinvertebrates – sampled once in the summer
- Fish – sampled quarterly
- Birds – sampled once in May

The program began sampling in 2010 and is now in its fifth year of sampling. In 2014 the second four-year cycle began and sites that were sampled in 2010 were sampled again. Data flows into an in-house data base maintained by BES.

This is a well-designed monitoring program that is being actively supported. Staff anticipates funding to continue for the next ten years. Reports are available at the following web site: http://www.portlandoregon.gov/bes/article/493159.

Watershed Health Index (WSHI)

Portland also has an effort to determine an Index value for each watershed in the City. This effort is separate from the PAWMAP program but uses data from PAWMAP. The PAWMAP data are supplemented with largely GIS-derived data. The index is composed of the following indicators:

Hydrology

Effective Impervious Surface (GIS)
Stream Connectivity (% piped) (GIS)

Water Quality

Total Suspended Solids (TSS)
Total Phosphorus
Temperature
Total Mercury
Dissolved Oxygen
E. coli
Ammonia-Nitrogen
Dissolved Copper

Biological Communities

Aquatic Communities – Fish
Aquatic Communities – Benthic macroinvertebrates
Terrestrial Communities – Avian

Physical Habitat

Tree Canopy (% canopy cover city-wide) (GIS)
Floodplain Condition (% vegetative cover) (GIS)
Bank Condition (% bank hardening)
Depth Refugia (% of channel <20 feet deep) Willamette only (GIS)
Stream Accessibility (% of stream accessible)
Riparian Integrity (% canopy cover)
Large Wood Volume
Substrate Composition (% fines and gravel in riffles)

Project Effectiveness Monitoring

The third type of monitoring that the City of Portland conducts is follow-up monitoring on major restoration projects. There are currently fifteen Johnson Creek projects being monitored:

Phase I

Powell Butte Ponds
Luther Road project
Veterans Creek
Tideman Johnson
Foster Floodplain Natural Area
Crystal Springs
- Tenino – Umatilla
- Westmoreland
- Golf Course
- RxR (photo monitoring only because the property is not owned by the City)
- Tenino

Phase II

Schweitzer Natural Area
Kelley Confluence
Errol Confluence
Errol Wetland
Brookside (Also phase III since it's recruiting large wood from trees that were there pre-project)

Monitoring intensity varies with the time from project completion. The first five years is considered Phase I, five to 20 years is Phase II, and beyond 20 years is Phase III. Phase I projects are monitored two times per year. The following data are collected (there is some variation site to site based on the project):

- Photo Monitoring
- Aquatic Habitat (unit frequency, total habitat area, pool availability, large wood, substrate composition)
- Winter high-flow refuge (quantify off-channel availability to salmonids)
- Flood storage (aerial photo, field investigations, staff gauges and crest gauges)
- Pebble counts
- Channel Survey (cross-sectional and longitudinal surveys)
- Canopy Cover

Data are managed by BES. One report for Johnson Creek projects covering 1997 to 2010 has been issued. BES is committed to continuing project effectiveness monitoring for major restoration projects that the City implements.

City of Gresham

The City of Gresham has two monitoring efforts, both within the Department of Environmental Services. The Watershed Division conducts water quality monitoring. And the Natural Resources Group conducts a program of biological and habitat surveys.

Water Quality Monitoring

The objective of this effort is to monitor water quality status and trends to support compliance with the City's storm water NPDES permit. The monitoring design consists of quarterly grab samples taken at four fixed monitoring stations. The list of parameters monitored is fairly comprehensive and includes DO, pH, temperature, conductivity, turbidity, *E. coli*, hardness, BOD,TSS, chlorophyll-*a* (May-Oct); nutrients (nitrate, ammonia, Total P, ortho-P); total recoverable and dissolved metals (copper, lead and zinc); and legacy pesticides. Data are stored locally in Excel spreadsheets. Reports are prepared and submitted to DEQ annually. Every five years a trend analysis is conducted and a report on trends is prepared as part of the stormwater permit renewal. An in-depth report on trends over 15 years was prepared in 2008.

In addition to the water quality monitoring, macroinvertebrate community sampling is conducted once a year at the four fixed stations. The City is supporting two USGS streamflow gauges and conducts occasional project-oriented flow studies. The City also conducts stream temperature monitoring using automated continuous monitors (approximately seven long-term temperature monitors in Johnson Creek and additional monitors for short term studies). Multnomah County helps fund the temperature monitoring.

Biological and Habitat Surveys

The City conducts a variety of biological and habitat monitoring. The objective is to estimate conditions over large geographic areas to support project planning and compliance with the Endangered Species Act. Most data collection is more observational and less quantitative. Some habitat surveys are conducted using GIS and remote sensing such as aerial photography.

There are several ways this work is carried out:

1. Updating the Natural Resources Master Plan. As opportunities arise, City biologists conduct surveys in order to update previous surveys. The field data sheets from these surveys are loaded to a GIS data system. The information from the surveys is used to update project sheets.
2. Biodiversity Surveys. Every year a specific ecosystem type or biological community is selected and a comprehensive survey is conducted to estimate conditions for all land within the City. This effort began in 2003 with upland vegetation as the subject. Each year for the subsequent ten years a different flora or fauna has been targeted. Targeted communities for biodiversity surveys have included amphibians and birds. The program is now in the eleventh year and the program managers will start cycling through the same topics in order to assess changes over a ten year period. Data from these surveys goes into Access databases. The work is carried out primarily using volunteers and AmeriCorps interns.

3. Short term studies. As needed, special studies are carried out. For example, there is currently a Habitat Study underway. This is mostly a GIS/remote sensing study of areas upstream of culverts. This Habitat Study is expected to be completed this year. Another example is a fisheries study that was conducted with Multnomah County in 2011-12 under a grant. The information from that fisheries survey was compared to an ODFW fisheries study that was done in 1999-2000.

The Biological and Habitat Survey program is very cost-effective through the use of volunteers and AmeriCorps. The use of volunteers also helps educate and engage the public. Because of the sensitive nature of information on the occurrence of endangered species, much of the data is not released to the public.

City of Milwaukie

Milwaukie monitors flows from their storm water system into and out of their Roswell Detention Pond. Flow from this pond joins Johnson Creek at Ochoco St. This sampling occurs three times per year as required by the City's NPDES permit.

During the summer the City will inspect outfalls of the storm system for illicit discharges, some of which discharge directly to Johnson Creek.

The City of Milwaukie also contributes to the USGS Cooperative Agreement for streamflow gages, turbidity and temperature monitoring, primarily focused on the Milport Road streamflow gage.

City of Damascus

Damascus contributes to the USGS Cooperative Agreement and plans to into the future.

Clackamas County Service District #1/Water Environment Services

CCSD#1 (which includes the City of Happy Valley) pays for a share of the USGS Cooperative Agreement. The District has opted to partner in a larger, coordinated monitoring effort in the Johnson Creek watershed rather than a separate effort, given that only a tiny percentage of the watershed is in their service area.

CCSD#1 performs annual dry weather field screening for illicit discharges at five outfalls in the Johnson Creek watershed.

Multnomah County

Multnomah County contracts their monitoring work through the City of Gresham. The county currently is supporting temperature loggers in the stream as part of their regular Johnson Creek monitoring. They do not have a regular ambient monitoring program for Johnson Creek, aside from contributing to the USGS Cooperative efforts. They rely on the work of the EMSWCD and USGS for upper watershed data.

Clackamas Soil & Water Conservation District

Their Oregon Department of Agriculture (ODA) focus area includes the portions of Johnson Creek upstream of Gresham in Clackamas County, including Sunshine and Badger Creeks. This means that they concentrate on riparian buffers and erosion control in these subwatersheds. For riparian reforestation, they are working with JCWC on the CreekCare program. The riparian monitoring involves visual assessments of riparian buffer quality using an ODA protocol (Streamside Vegetation Assessment tool). The erosion control efforts involve outreach to agricultural producers to reduce sediment contributions to streams and other erosion. They plan to calculate benefits of this work using a soil erosion estimate (USLE or RUSLE2).

East Multnomah Soil and Water Conservation District

EMSWCD has a program of fixed station water quality monitoring. ODA paid for three years of monitoring to establish a baseline (2010-2013). EMSWCD is continuing the monitoring program.

EMSWCD collects the following in the field at six sites each month:

- turbidity
- pH
- total dissolved solids
- conductivity
- *E. coli*
- Nitrate
- Phosphorous
- Total suspended solids

They also have continuous temperature loggers at two sites each summer.

In 2010, they had samples analyzed for some currently used pesticides that are known to be problems in other watersheds – atrazine, simazine, chlopyrifos, and phosmet. As none of the results were above the EPA criteria and the testing was prohibitively expensive, it has been discontinued.

Metro

Metro primarily conducts ecological monitoring to guide site restoration planning and monitor the effects of restoration activities. They use a Key Ecological Attributes framework to assess changes to riparian buffers, canopy cover, etc. and to characterize ecological conditions. Staff indicated that they would be open to discussing streamflow, temperature, or other parameters that directly relate to their site restoration and stabilization work.

Oregon Dept. of Environmental Quality

From 1972 to present, ODEQ has monitored a site at the SE 17th Avenue Bridge over Johnson Creek, near the confluence of Johnson Creek and the Willamette, monthly or quarterly for temperature, conductivity, pH, DO, TP, N, alkalinity, hardness, chloride, color, BOD, COD, potassium, fecal coliform, sulfate, total coliform, TS, and TSS. From these parameters, an Oregon Water Quality Index (OWQI) is calculated to assess general water quality. The OWQI includes several sub-indices for this site, including temperature, dissolved oxygen, biochemical oxygen demand, pH, total solids, bacteria, nitrogen and phosphorus (see http://www.deq.state.or.us/lab/wqm/wqimain.htm).

Oregon Department of Fish & Wildlife

Periodic Aquatic Habitat and Fish Surveys

A habitat assessment was conducted in 1999-2000 for Johnson Creek mainstem and a number of tributary streams. Fish surveys were conducted for Johnson Creek and parts of Crystal Springs and Kelley Creek in 2001 and in 2009.

Statewide OASIS, Aquatic Habitat Inventory, and Juvenile Salmonids Monitoring

Eric Brown, Ryan Jacobsen, and Sharon Tippery with ODFW in Corvallis provided information on the number of sites planned to be surveyed over the next decade for each of three ODFW monitoring programs in Johnson Creek: Spawning Surveys, Habitat Assessments, and Snorkel Surveys. Like PAWMAP, they use rotating panels for EMAP-selected sites. There are plans for many years of snorkel surveys for coho and steelhead in Johnson Creek, although ODFW has never found coho carcasses or live adults in Johnson Creek, only a few in Crystal Springs over all the years surveyed (2006-present). One live steelhead was found in upper Johnson Creek in 2006 by ODFW. However, JCWC volunteers have found coho carcasses and live fish every year surveyed (2010-present).

Plans for future habitat surveys are uncertain due to current budget discussions; however, the survey locations are re-surveyed on rotating panels and include snorkel surveys where possible.

Oregon Department of Agriculture

ODA assists SWCDs with riparian, water quality, and erosion control monitoring as needed/requested.

U. S. Geological Survey

USGS has a long history of studying Johnson Creek hydrology. There are flow data going back 70 years. There have been several major groundwater studies over the years. In addition, USGS has done water quality monitoring studies. The USGS work falls into three areas: surface water hydrology; groundwater hydrology; and water quality.

Surface water hydrology

USGS maintains four continuous stream flow stage monitors (pressure transducers) that also record temperature (see http://waterdata.usgs.gov/or/nwis/current/?type=flow&group_key=basin_cd). They are maintained under a joint funding agreement. Under the agreement USGS also carries out additional flow measurements and conducts short term studies. All data are housed in web accessible data bases. The current level of effort for this work is about 200K per year (both USGS and partner funds).

In addition, under a 319 grant from DEQ, USGS worked with the JCWC in 2013 to set up manually-read staff plates, train volunteers to conduct streamflow measurements, installed two additional pressure-transducer gages, and analyzed tributary streamflow data for six sites.

Groundwater hydrology

USGS maintains six wells for monitoring ground water levels on a continuous basis. There are an additional 23 wells that are read quarterly for water level. All data flows to web-accessible data bases. The last data analysis and report was in 2009. A major ground water study, the Portland Basin Study, was completed about 20 years ago.

Water quality monitoring

USGS has conducted various water quality studies in the past. Sediment contaminants were studied in the late 1980's. Legacy organochlorine esticides were monitored in the mid-1990's. USGS National Water-Quality Assessment (NAWQA) Program sampled the basin for nutrients, pesticides, and trace elements during the 1990's and early 2000's, and is currently planning a major water quality sampling effort under the NAWQA program for 2015. The focus area is the Willamette Basin and Puget Sound. There is the possibility that one or two sampling sites will be in Johnson Creek. The sampling design calls for weekly grab sampling for ten weeks. The list of parameters to be analyzed is extensive. Ecological monitoring would then occur for two weeks following the chemical sampling period.

Portland State University

Portland State University does not conduct long term monitoring in Johnson Creek. However, there is great interest in identifying studies that could be carried out by students in time periods ranging from six months to three years. Several professors have had a long term interest in riparian management and effects on water quality. There is currently at least one doctoral student interested in analysis of historical water quality data to look for trends and their relationship to potential driving factors.

Student Watershed Research Program (SWRP)

From 2002-2012 water quality monitoring was conducted at two sites: 1) Johnson Creek Park in Crystal Springs Creek, and 2) just upstream of Westmoreland Pond in Crystal Springs Creek. These sites were sampled for phosphorus, NO3-N, Turbidity, Dissolved Oxygen, Temperature, turbidity, dissolved oxygen, temperature, pH, and alkalinity. In addition, macroinvertebrates were monitored from 2008 through 2013 at these sites. Data for these and other sites is available at http://www.swrp.esr.pdx.edu/student_data/student_data.htm. However, plans for the future are uncertain as the program may be cut due to budget shortages at PSU.

As of 2013 four sites were monitored in the Johnson Creek watershed: Crystal Springs at Johnson Creek (Cleveland High School), Johnson Creek in Gresham Woods (Alpha High School), Johnson Creek at Ambleside (Multnomah Youth Corps, Reynolds School District), and Johnson Creek above and below the confluence with Crystal Springs Creek (PSU Capstone students). Students visit the stream sites twice a year, in October and April. They measure pH, DO, temp, turbidity, alkalinity, nutrients (nitrate, ammonia, soluble reactive phosphorus), stream flow, in-stream habitat (if there's time during the field trip), and conduct macroinvertebrate monitoring to family, using a non-lethal method. Duplicate samples from these sites are analyzed by PSU Capstone students.

Reed College

In Reed Canyon and Crystal Springs Lake, which are owned by Reed College, ongoing water quality monitoring is conducted. Crystal Springs Lake feeds Crystal Springs, a tributary to Johnson Creek. Zac Perry, Canyon Restoration Manager, has taken seasonal measurements of nitrate, phosphate, dissolved oxygen, and temperature since 1999. Reed College samples four sites: 1) the eastern end of canyon at the springs; 2) west end of lake at fish ladder; 3) at the old drama building downstream of the fish ladder; and 4) near the culvert under SE 28th Ave. All samples are taken on the same day within a few hours of each other. Zac would be interested in partnering to standardize monitoring protocols and frequency. He generally analyzes them to see whether the values fall within State benchmarks for salmon-bearing streams. They occasionally monitor *E. coli* levels as part of a microbiology course curriculum. Occasionally, amphibians are also monitored throughout Reed Canyon as well.

Xerces Society

The Xerces Society for Invertebrate Conservation has conducted surveys of freshwater mussels in Johnson Creek and is actively monitoring the results of salvage and replanting efforts that were part of restoration projects in Crystal Springs. They are interested in establishing an Odonate (dragonfly/damselfly) monitoring effort.

Summary of ongoing fixed-station monitoring

Fixed station monitoring by multiple organizations occurs at approximately 30 sites per year. If one considers multiple years, the number of stations increases to around 50. The frequency of monitoring is fairly low ranging from once a year for some parameters and programs to monthly for one program. The cumulative number of observations made in a year is on the order of 2,000 observations.

Data interpretation criteria used in this study

Monitoring results were compiled from all jurisdictions and consolidated into a single database. The temporal distribution of sampling was not consistent. Some sites were sampled regularly (usually once per quarter) but other sites were sampled for only one year. The data were summarized in two ways. First, all data were pooled to develop summary statistics such as the number of samples, median, range, minimum and maximum, and number of samples exceeding various thresholds. Second, data for specific sites were analyzed to calculate both average concentration for a site and maximum concentration. These site values were then compared to Oregon State Water Quality Standards and to the three-tiered classification criteria described below.

The Oregon DEQ's statewide aquatic life standards for copper, lead, and zinc vary based on a calculation that takes into account changes in toxicity due to water hardness of a sample. The Oregon DEQ applies a base hardness of 100 mg/L as a benchmark when concurrent hardness data for a metal sample is not available. Since the value of metals criteria change depending on the concentration of hardness in a sample, and we do not have hardness data for all metal samples evaluated in this report, we applied the base hardness of 100mg/L to metals criteria in order to provide a consistent level of comparison, regardless of whether hardness data for a specific sample may have been available. Actual hardness levels may differ for individual samples and locations.

In addition to using State Water Quality Standards to evaluate the monitoring data, we also compared the site values to a three-tiered classification system in order to assign an overall condition rating for that site of "Good, Fair, or Poor." In general, the criteria used in the three-tiered condition classification were more stringent than the State Water Quality Standards criteria. The three-tiered classification was developed in order to assess pollution levels at concentrations below State Water Quality Standards. Results for both compliance with Water Quality Standards and condition based on the three-tiered classification are presented in maps.

The three-tiered condition classification criteria used to classify monitoring results are provided in Table 1. These interpretive criteria were established by the authors from a variety of sources. Three categories are defined (Good, Fair, and Poor). In general, the three-tiered classification criteria are more stringent than State water quality standards.

Table 1. Three-tiered classification criteria used to interpret monitoring results.

Parameter	Units	Condition Classes		
		Good	Fair	Poor
Temperature	°C	< 15.1	15.1 – 21.2	> 21.2
Total Suspended Solids (TSS)	mg/L	< 10	10 – 43	> 43

Parameter	Units	Condition Classes		
		Good	Fair	Poor
Zinc, dissolved	mg/L	< 0.85	0.85 – 4.9	> 4.9
Copper, dissolved	µg/L	< 0.88	0.88 – 4.2	> 4.2
Mercury, total	ng/L	< 0.85	0.85 – 4.9	> 4.9
Lead, dissolved	µg/L	< 0.85	0.85 – 4.9	> 4.9
E. coli	mpn/100mL	< 100	100 – 930	> 930

Chapter 2 Stream Temperature

Stream temperature is affected by a combination of air temperature, direct solar exposure, groundwater influxes, and changes to vegetation and land cover. Water heats up when it is in direct sunlight and when air temperatures increase. Artificial ponds and channel widening along the stream network are particularly susceptible to increased water temperature from solar exposure because of their large surface area and lack of shade away from banks. Runoff can also pick up heat from surfaces warmed by the sun, such as bare soil or concrete, but typically is not a major heat source in the Pacific Northwest because summers tend to be dry and precipitation occurs in the cooler months . Shade provided by vegetation and inflows of cooler groundwater help to reduce stream temperatures. Large streams heat and cool slower than small streams. The temperature at a given location is also affected by the temperature of water flowing downstream from other areas, so temperature is not only related to the conditions at a given site, but the condition in tributaries and headwaters upstream as well.

Ample, cool stream flow is essential for fish and wildlife. Warm water carries less dissolved oxygen, and direct sunlight can cause algal blooms. During the summertime, Johnson Creek is often hotter than state water quality standards for rearing salmon and trout (64.4°F / 18°C). The maximum mainstem stream temperature for 2008-2014 was in July 2009, when it reached 83°F / 28°C; the air temperature measured at PDX at that time exceeded 104°F/40°C, the highest air temperature recorded during the assessment period.

Historically, streams were kept cool by the dense forests that shaded the stream channels and by complex interaction with their hyporheic zone through channel morphology. The impact of changes in channel morphology, such as in-line ponds and channel widening and straightening, on temperature have not been addressed in the Johnson Creek Total-Max Daily Load (TMDL), a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that load among the various sources of that pollutant. There is not sufficient information to address them in this report. However, in 2002, the average effective shade over mainstem Johnson Creek was just under 40%. Analysis has shown that to keep Johnson Creek cool enough for trout and salmon to thrive in the future, an average of 80% effective shade over the stream channel will be required. To meet this goal, trees must be planted along streambanks wherever possible. Even a narrow creekside forest buffer in a backyard makes a big difference. Since it can take up to 30 years for a tree to grow large enough to provide substantial effective shade to the creek, it will be a long time before we will be able to detect a stream temperature response to planting efforts. In the meantime, fish may find refuge in small, shaded tributaries and areas with groundwater springs.

The 7-Day Average Daily Maximum (7-DADM) is a stream temperature metric that measures a moving average of the maximum temperature over a consecutive 7-day period. It provides a more comprehensive measure of the extreme temperatures that might be experienced by fish by examining the maximum temperature in a given day and accounting for a longer duration of time of exposure. While fish can survive short spikes of high temperatures, prolonged exposure leads to an increase in mortality.

This analysis of temperature conditions in the Johnson Creek watershed is centered on the State of Oregon temperature standard for juvenile rearing of salmon of 64.4°F/18°C. Maximum temperatures are measured to determine whether streams are meeting the standard. High water temperatures affect juvenile fish by interfering with fry development, growth, disease prevalence, and smoltification. High water temperatures are typically encountered during the summer months. It is possible to evaluate the daily maximum temperatures in each stream, or the daily average temperature to determine how warm the waters are. The severity of the exceedance of the standard can be identified by the number of days during the summer that maximum water temperatures are higher than the standard. If a stream exceeds the standard for only a short time, there is opportunity for fish to find refuge in cool areas nearby and withstand or avoid the high temperatures. The standard accounts for this in part by using a 7-day average of the maximum temperature on each day, rather than the instantaneous temperature at any given time. If high temperatures persist for many days during the summer, the chances of fish dying or migration being blocked in the stream are higher. The presence of cool tributaries, where the water temperature does not exceed the standard, or only does so for a short time, can enhance the probability that fish can persist in the Johnson Creek Watershed despite high temperatures elsewhere. However, it is still critical that that the temperature in the mainstem does not create a thermal barrier that blocks access to the cooler tributaries.

Monitoring

Water temperature was measured at 91 sites in the Johnson Creek Watershed from 2009-2014, using small temperature sensors (Figure 2.1, Table 2.1). Because temperatures can vary significantly throughout the day, from season to season, and from place to place, temperature loggers were placed at many different locations in order to capture the spatial and temporal variability of water temperature in the stream network. Six of the monitoring sites were measured continuously during this period. These sites are located at Crystal Springs at Bybee and at the mouth, Johnson Creek at Milport in Milwaukie, at Regner, and at Sycamore, and the mouth of Kelley Creek at 159th Ave. Many of the other sites have records that span from 1 to 5 years in order to maximize the number of locations measured in the watershed, and only measure in the summer months, when temperatures are likely to exceed the standard (Table 2.2).

Compliance with the 64.4°F / 18°C Temperature

Almost all of the streams in the Johnson Creek watershed experienced temperatures in excess of the 64.4°F / 18°C standard during some portion of the summer months from 2009-2014 (Fig. 2.2). However, there are some small refuge areas where temperature remained below the standards for the entire period of record. These are the headwaters of Butler Creek, Jenne Creek, Botefuhr Creek, and Miller Creek. These cooler streams tend to be headwaters located in heavily shaded parks or natural areas, and may be influenced by cool groundwater springs.

Magnitude and Duration of Warm Stream Temperatures in Johnson Creek

While almost all monitored stream reaches in Johnson Creek exceed the standard at some point during the summer, the severity and duration of the exceedance of the standard varies considerably throughout the watershed. Maximum summer temperatures vary considerably across the Johnson Creek Watershed (Fig. 2.3). Headwaters are typically cooler, with maximum summer temperatures near the standard, between 18°C and 21°C. Larger tributaries and the Johnson Creek mainstem tend to be warmer, with temperatures above 23°C during the peak of summer. Several portions of the watershed such as Clatsop Creek and Mitchell Creek reach extremes of over 30°C due to extreme low summer flows that are barely more than a trickle and may lead to exposure of the temperature probe to warmer air temperatures.

The duration of time stream temperatures exceed the standard has a similar pattern to the summertime maximum temperatures (Fig. 2.4). Headwater areas, even especially warm tributaries to the Johnson Creek mainstem east of Hwy 26, tend to exceed the standard for fewer days during the summer than the lower mainstem of Johnson Creek. The mainstem of Johnson Creek west of I-205 and near Foster Rd, Crystal Springs, and the Hogan Creek tributary exceed the standard for much of the summer, between 80 and 113 days. The exceedances at Crystal Springs Creek are related to large in-line ponds, one of which was removed in 2013.

Stream Condition Assessment

We assessed the condition of streams at our temperature monitoring locations in the Johnson Creek watershed based on the average 7-DADM at each monitoring site, and coded them as good, fair, or poor based on the three-tiered qualitative assessment methodology (Fig. 2.5). The criteria for classifying sites into the three tiers were set by the authors and are different from State Water Quality Standards. Sites in “Good” condition had an average 7-DADM temperature below 15.1°C, and sites in “Poor” condition had 7-DADM temperatures above 21.2°C.

Analysis of stream condition indicated that the headwaters of Butler Creek were the only significant areas of the Johnson Creek stream network meeting the “Good” criterion. Many of the headwater tributaries throughout the stream network, as well as Upper Johnson Creek, are in “Fair” condition. Hogan Creek is an exception, being a headwater tributary but scoring “Poor” on the condition assessment. The other “Poor” condition areas are Crystal Springs, and the mainstem of Johnson Creek, especially in the western portion of the watershed where the landscape is more urbanized, and where the stream is more likely to have received already warmed water from upstream “Fair” areas.

The effect of In-line Ponds

Human-created ponds and widened channels are features of the stream network that play an important role in affecting stream temperatures. Solar exposure on un-shaded pond surfaces can lead to heating of surface water that is then passed downstream. In July-November 2014, temperature sensors were placed above the inlet and below the outlet of Centennial Pond, an in-line pond that discharges from the surface, on Mitchell Creek (Fig. 2.6). The data from these sensors illustrates the effect of in-line ponds on altering the temperature in streams over short distances. The red line shows the temperature of Mitchell Creek at 162nd Ave, above the pond. The temperature of the creek at the pond inlet is only a few degrees higher than the upstream portion of Mitchell Creek in July and August. However, temperatures at the pond outlet, shown in green, are ~10°C warmer than the inlet stream in July and August, and remain significantly warmer than the inlet and upstream reach by ~5°C until temperatures converge again in November.

Conclusions

The factors that contribute to high stream temperature are 1) location within zones of high impervious surface coverage, 2) low riparian vegetation cover, 3) receiving warm water from upstream tributaries, and 4) the location of in-line ponds subject to heating.

All of the Johnson Creek mainstem and nearly all of the tributaries exceed the 64.4°F/18°C State Water Quality Standard at some point during the year, and much of the watershed exceeds the standard for a majority of the summer. There are, however, some areas of cool water refuge in a few small tributaries to Butler Creek near the center of the mainstem.

Management for reducing of stream temperatures will require a landscape perspective. Restoration of vegetation to stream banks to provide shade wherever possible will be one of the most effective management interventions. However, management effort will be most successful in headwater areas away from the mainstem where stream reaches are smaller, so that increased shade can have maximum impact, and the cooling effects will not be undermined by warm waters flowing from upstream. Eliminating or by-passing in-line ponds, or conversing warm surface-discharging outlets to cooler deep-water outlets, where ponds are deep enough to display thermal stratification, are additional restoration strategies for reducing high water temperatures.

Figure 2.1 Location of temperature monitoring sites in the Johnson Creek Watershed.

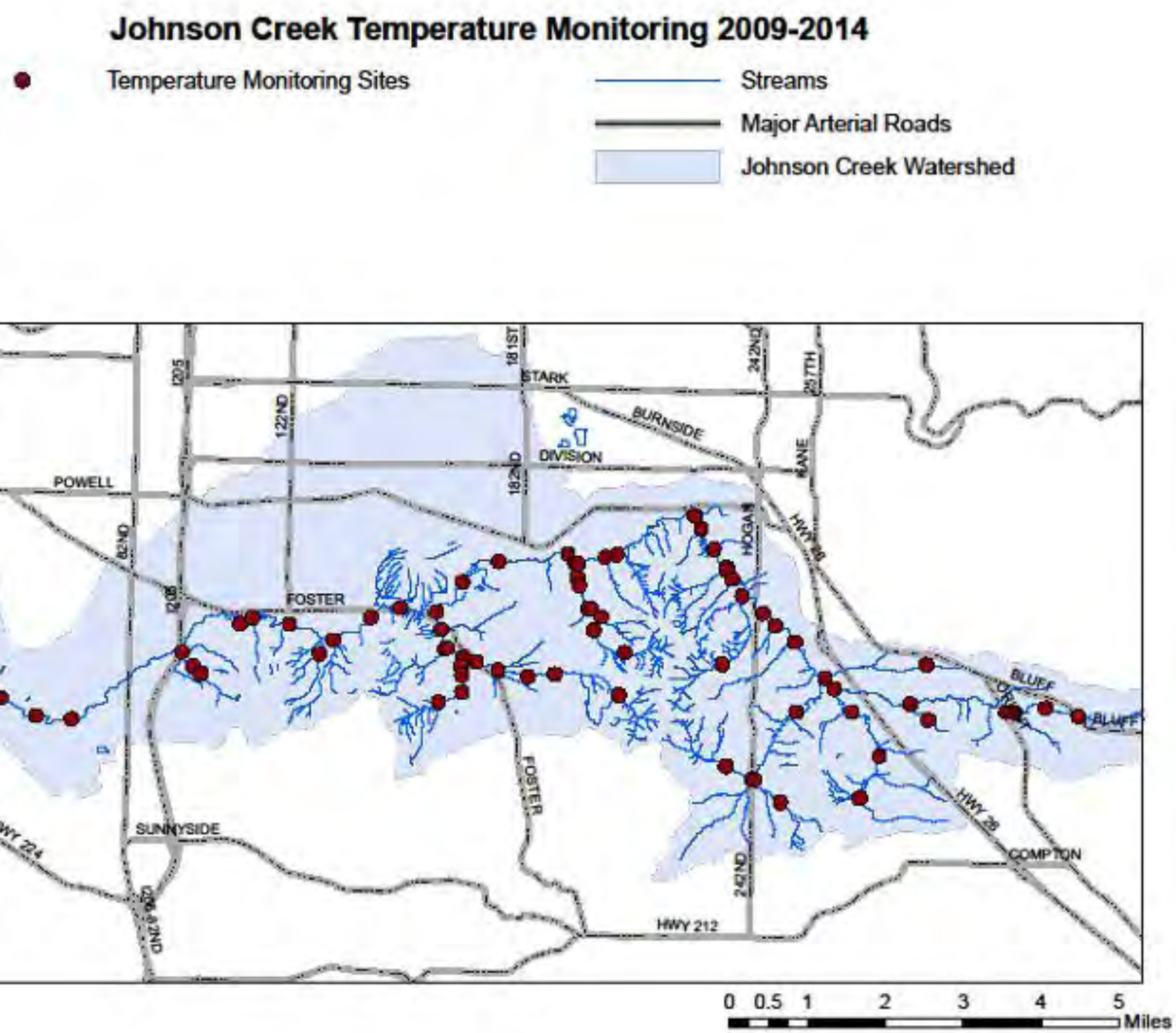


Figure 2.2 Monitored reaches meeting or exceeding the 18.0°C rearing standard at summer maximum temperatures.

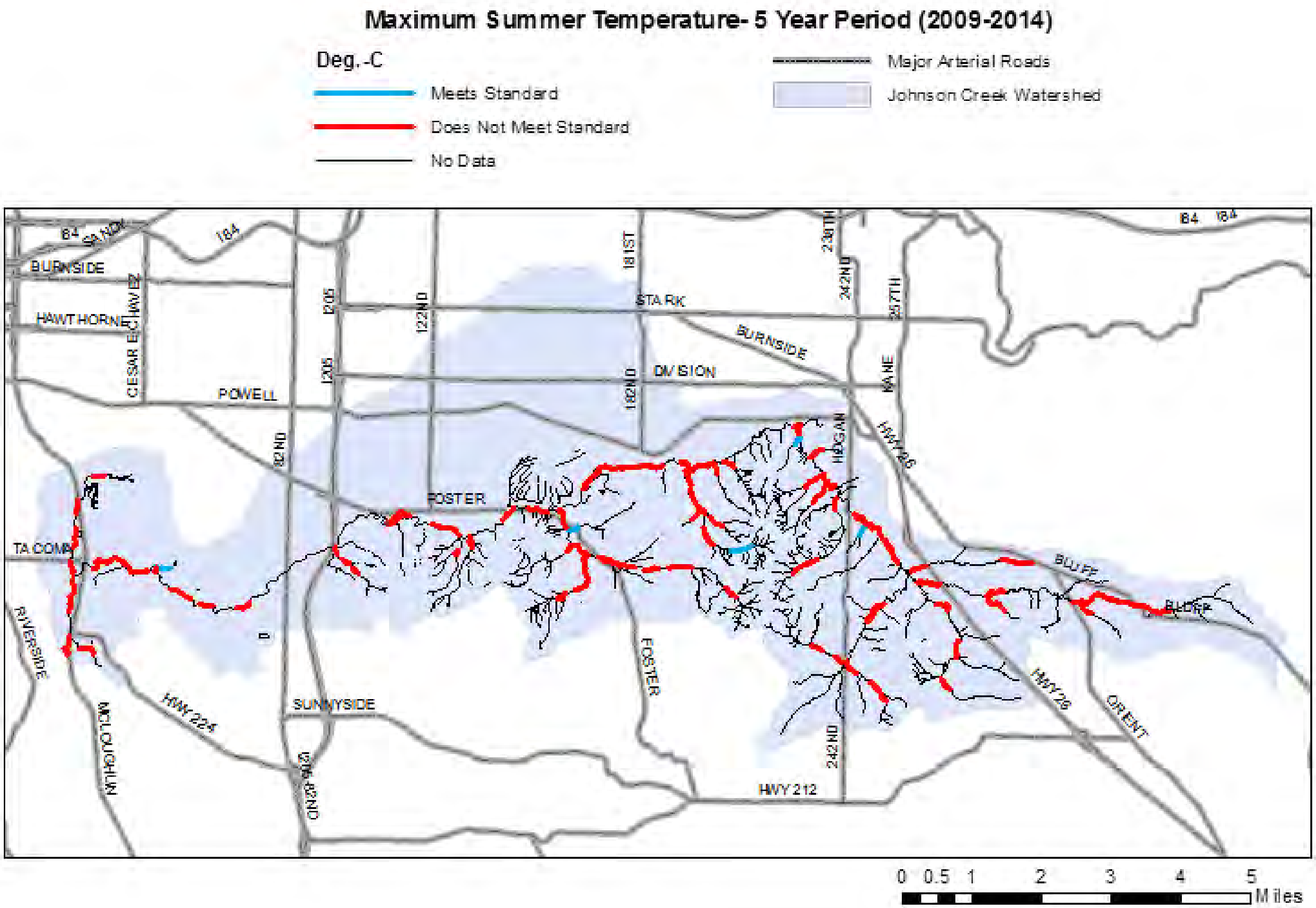


Figure 2.3 Maximum recorded summer temperature for the assessment period 2009-2014.

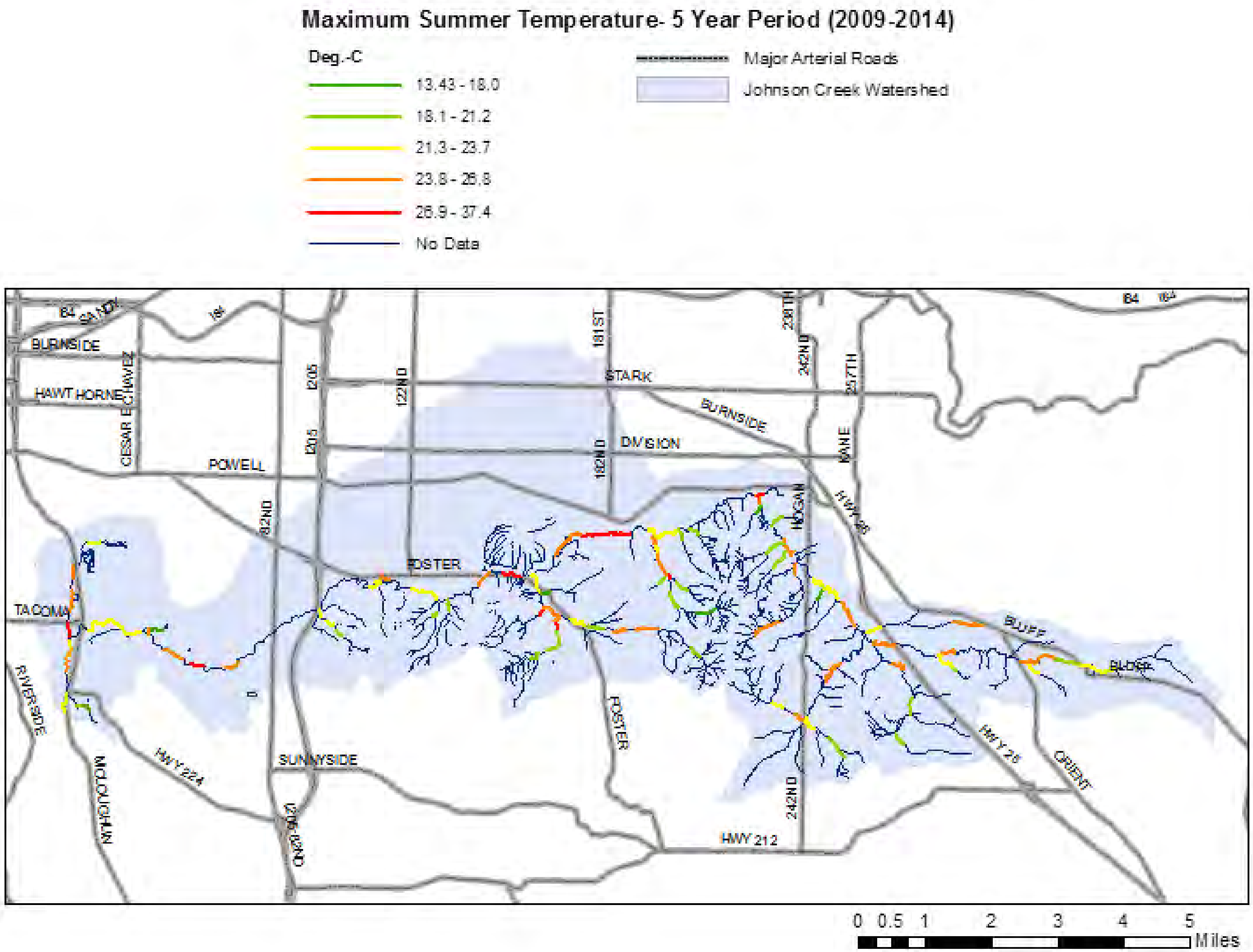


Figure 2.4 Number of days streams exceed the 18°C temperature standard in the summer months, July-August.

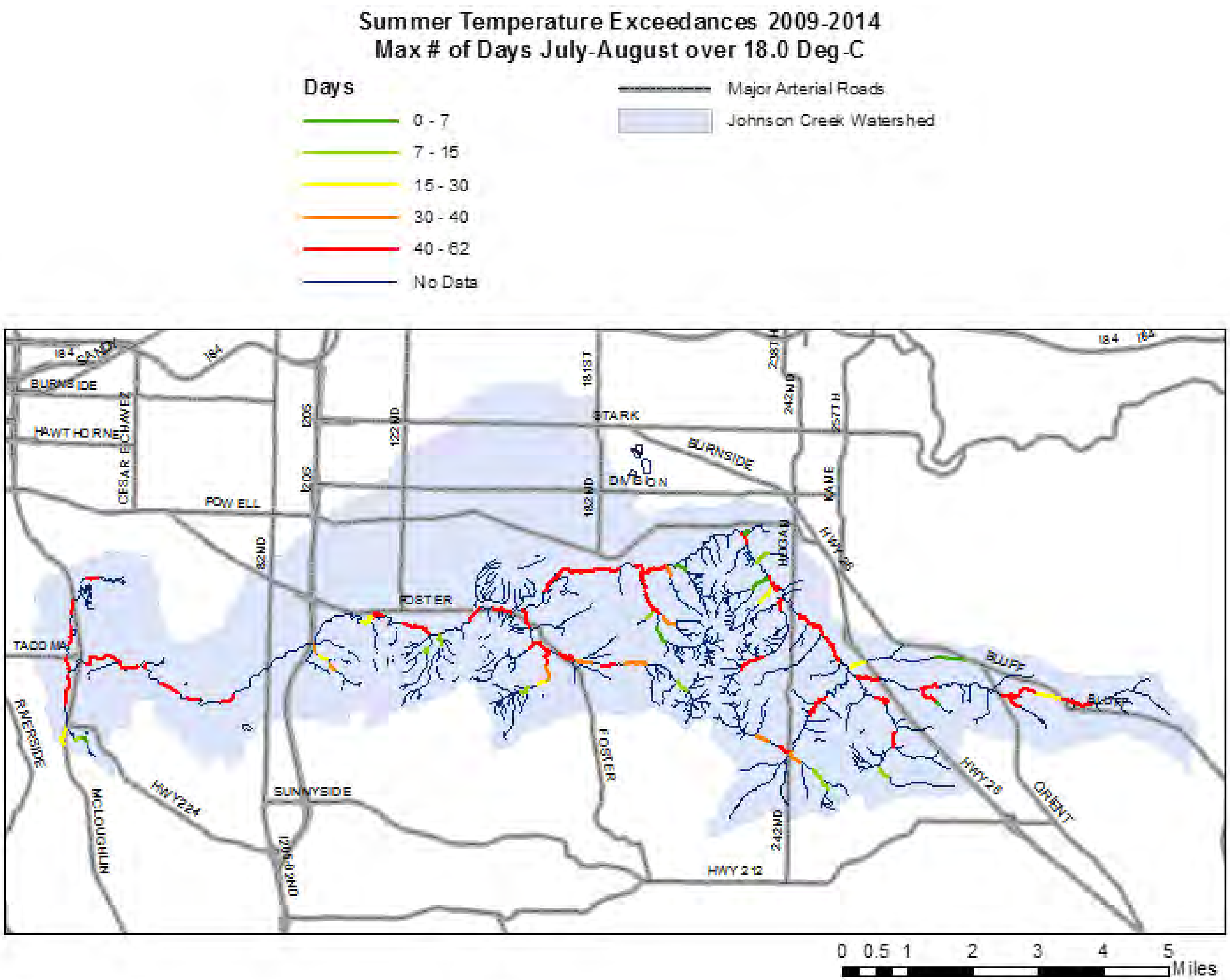


Figure 2.5 Stream condition-using 7-Day Average Daily Max and the three-tiered interpretation criteria

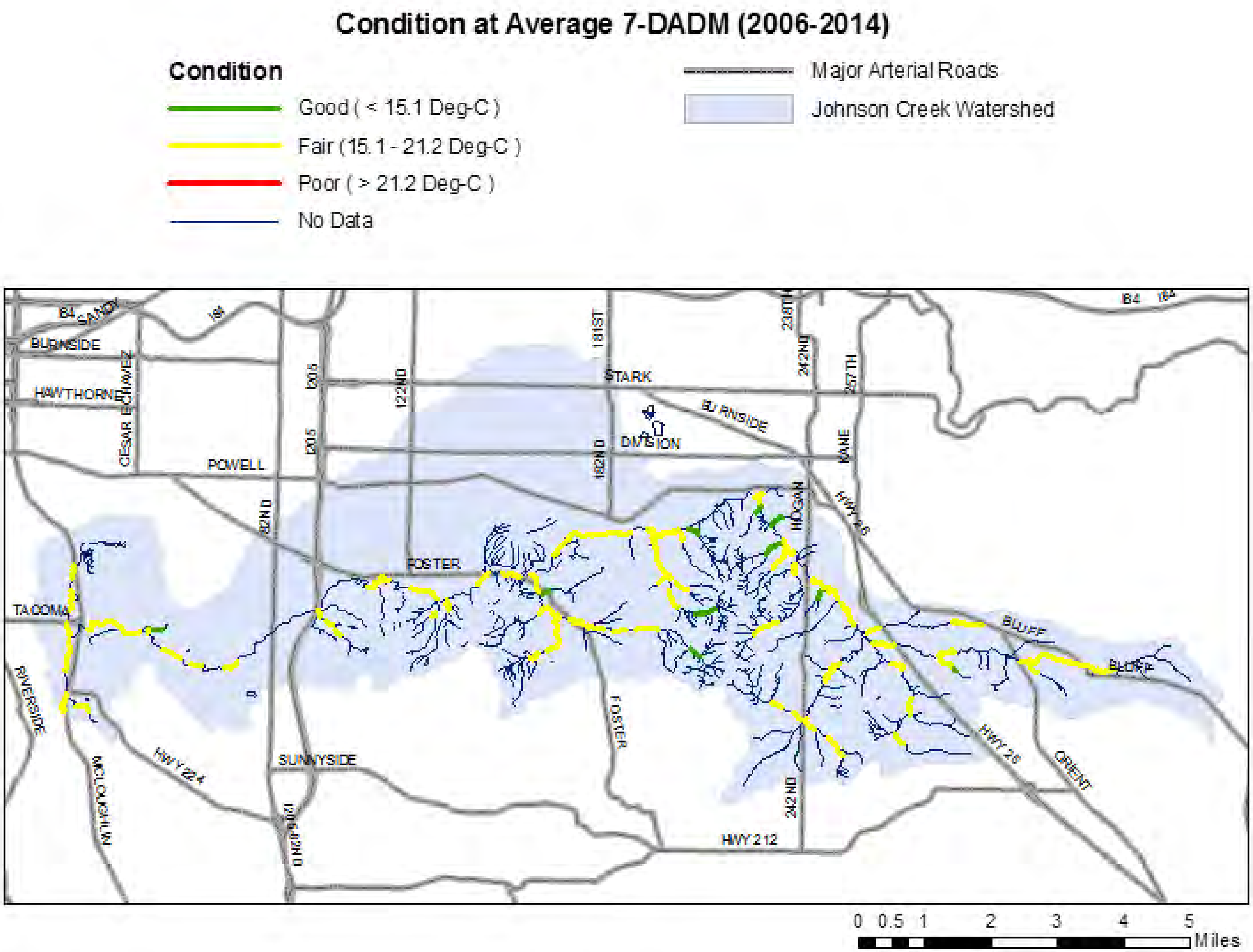
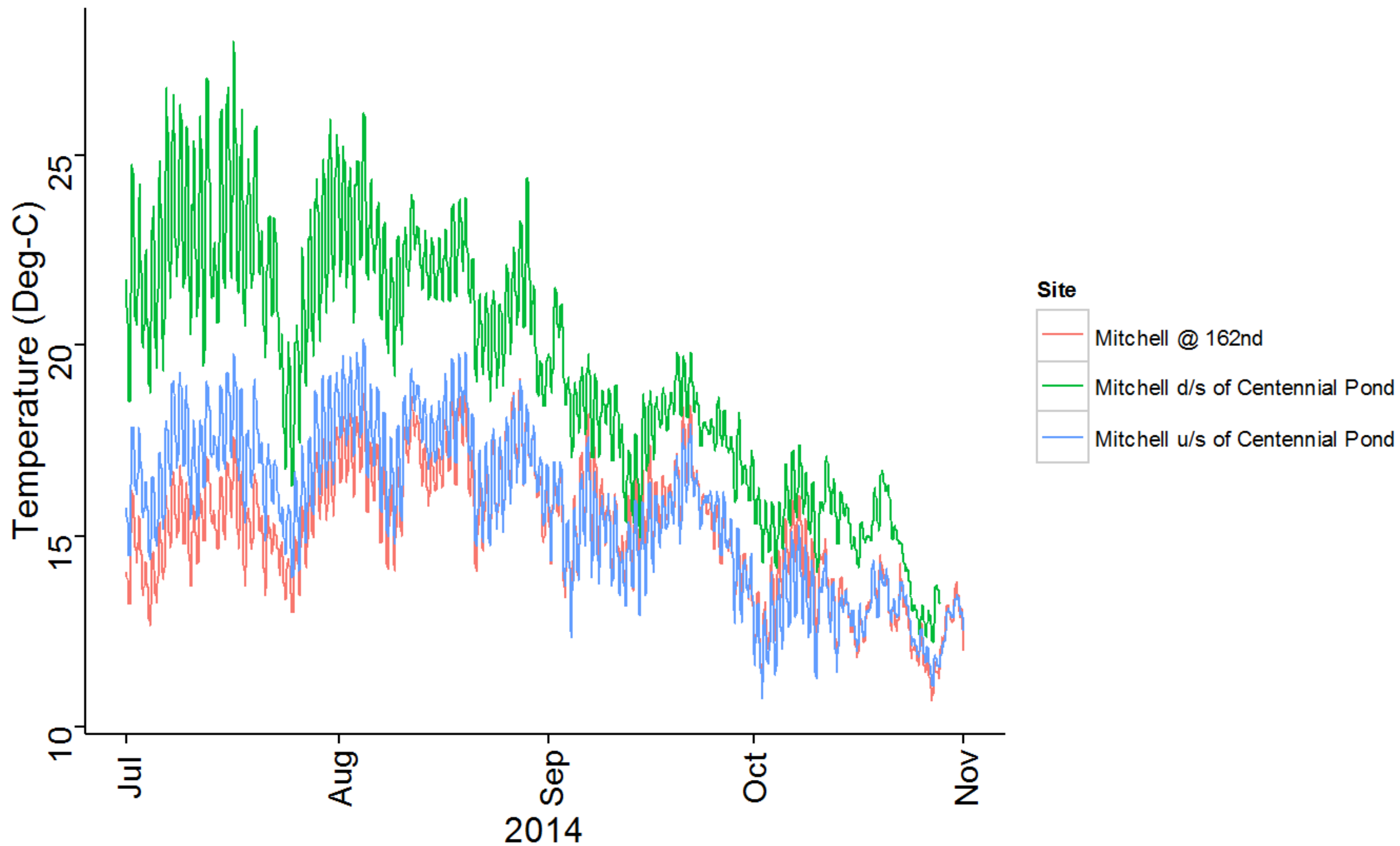


Figure 2.6 Temperature differences in Mitchell Creek, upstream and downstream of Centennial Pond. 7-Day Average Daily Maximum temperatures recorded at two sites upstream (blue and red) and one site downstream (green) of Centennial Pond.



Chapter 3 Water Quality

3. A. Dissolved Zinc

Dissolved zinc is an aquatic pollutant of concern in urban watersheds. The primary anthropogenic sources of zinc in urban environments the production and use of zinc-bearing alloys such as brass, bronze, die cast metal, tire rubber, and paints. Automobiles make use of zinc in brake linings and engine parts, where it can become incorporated in road particulates. Zinc is also an ingredient is some common herbicides. Like copper, zinc is an effective biocide, and can be toxic to algae, bacteria, and invertebrates.

Dissolved zinc was measured at 33 sites in the Johnson Creek watershed between 2009 and 2014. The number of samples was highest at four long-term monitoring sites in Gresham, at 174th Ave (n=92) and 252nd Ave/Palmblad (n=94), Kelly Creek at Foster Rd. (n-41) and Rondlun Rd. (n=41) and two PAWMAP monitoring sites for the City of Portland at Milport (n=39) and Sycamore (n=42). Sampling of zinc at other sites was infrequent, with 5 samples or less at any of the other monitoring locations in the Johnson Creek watershed. The predominant agency collecting zinc samples was the City of Portland, with only the Oregon DEQ providing a few additional samples. Samples were collected quarterly at the fixed site, with PAWMAP sites measured 5 times for one year duration at each site. Two Oregon DEQ sites were sampled only once in 2009 and corresponded to the Gresham site on the Johnson Creek mainstem.

The state of Oregon uses a hardness-based calculation to establish acute and chronic environmental toxicity criterion for zinc. Using a base hardness of 100 mg/L, the acute exposure criterion of zinc is 117 µg/L, and the chronic exposure criterion is 118 µg/L. We also used a condition range criteria to determine the general water quality of sites in relation to dissolved zinc concentrations based on interpretive range criteria. This rates the concentration as “Good” “Fair” or “Poor” depending on a pre-determined threshold (see Table 3.A.3). Note that our three-tiered interpretive criteria are more than an order of magnitude lower than the State water quality criteria for acute and chronic exposure. Of the 189 samples collected at all sites, only 26 samples meet or are below the “Good” criterion. The “Fair” criterion was the largest with 139 samples. There were 24 samples that exceeded the “Poor” criterion during the time window of the assessment.

Conclusions

Although none of the samples exceeds the benchmark for the state water quality criteria for dissolved zinc, concentrations in the Johnson Creek watershed appear slightly elevated, with multiple exceedance of the “Good” criterion even at average concentrations. Sampling locations were limited to the lower reaches of the watershed, and focused on the mainstem, and the Veteran’s Creek, Powell Butte, and Kelley Creek tributaries. Hardness data is required to definitively determine the risk to aquatic life from these zinc levels, but impairment appears likely. The headwaters of Veteran’s Creek (PAWMAP site 1084) and a site on Middle Johnson Creek (PAWMAP site 0428) appear to have zinc concentrations significantly higher than the rest of the watershed, and warrant further investigation.

Tables

Table 3.A.1 Summary Statistics

Dissolved Zinc, µg/L	
n	456
Mean	2.69
Standard Error	0.20
Median	2.13
Standard Deviation	4.16
Minimum	0.50
Maximum	74

Table 3.A.2 Individual sample events by condition range

Condition, n

Condition*	Mainstem, n	Mainstem, %	Tributary	Tributary, %
Poor	29	6%	5	1%
Fair	260	57%	96	21%
Good	44	9%	21	5%
Total	333		122	

Samples collected quarterly at each of 36 sites from 2009-2014.
* See ranges defined in table 3.A.3.

Table 3.A.3 Condition ranges

Index	*Quantity, µg/L*
Good	< 0.85
Fair	0.85 – 4.9
Poor	> 4.9

Figure 3.A.1 Mean sample concentrations of dissolved zinc in µg/L. The horizontal bar at the center of each box represents the sample mean. The vertical box ends represent the 25th and 75th quantiles. Whisker bars represent the range of 1st and 4th quartiles. Points represent outlier values. Dashed lines across the figure represent the condition range thresholds (see Table 3.A.3). Reaches are ordered from downstream (left) to upstream (right).

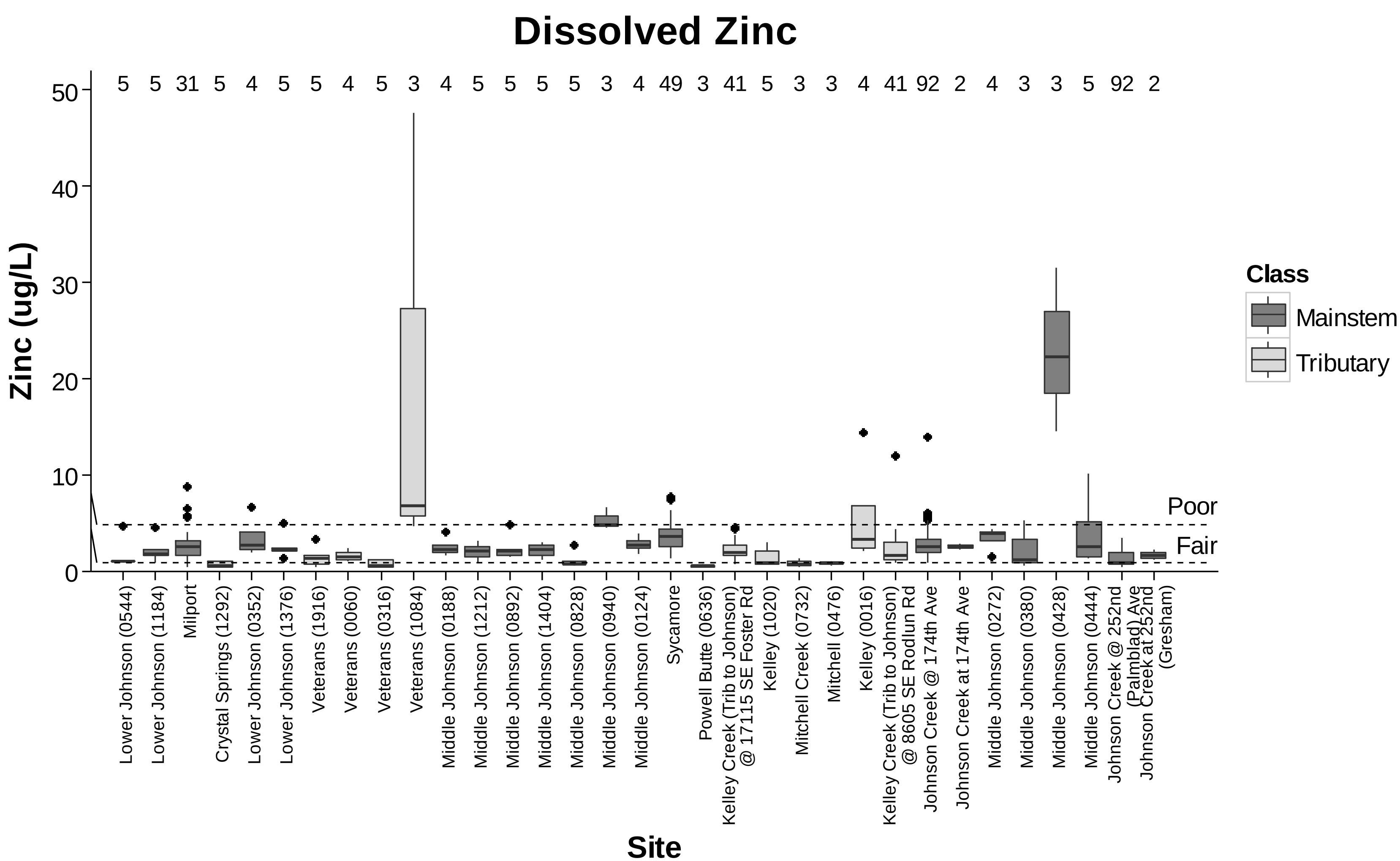


Figure 3.A.2 Maximum dissolved zinc compliance with DEQ chronic zinc standard (assumes 100 mg/L hardness)

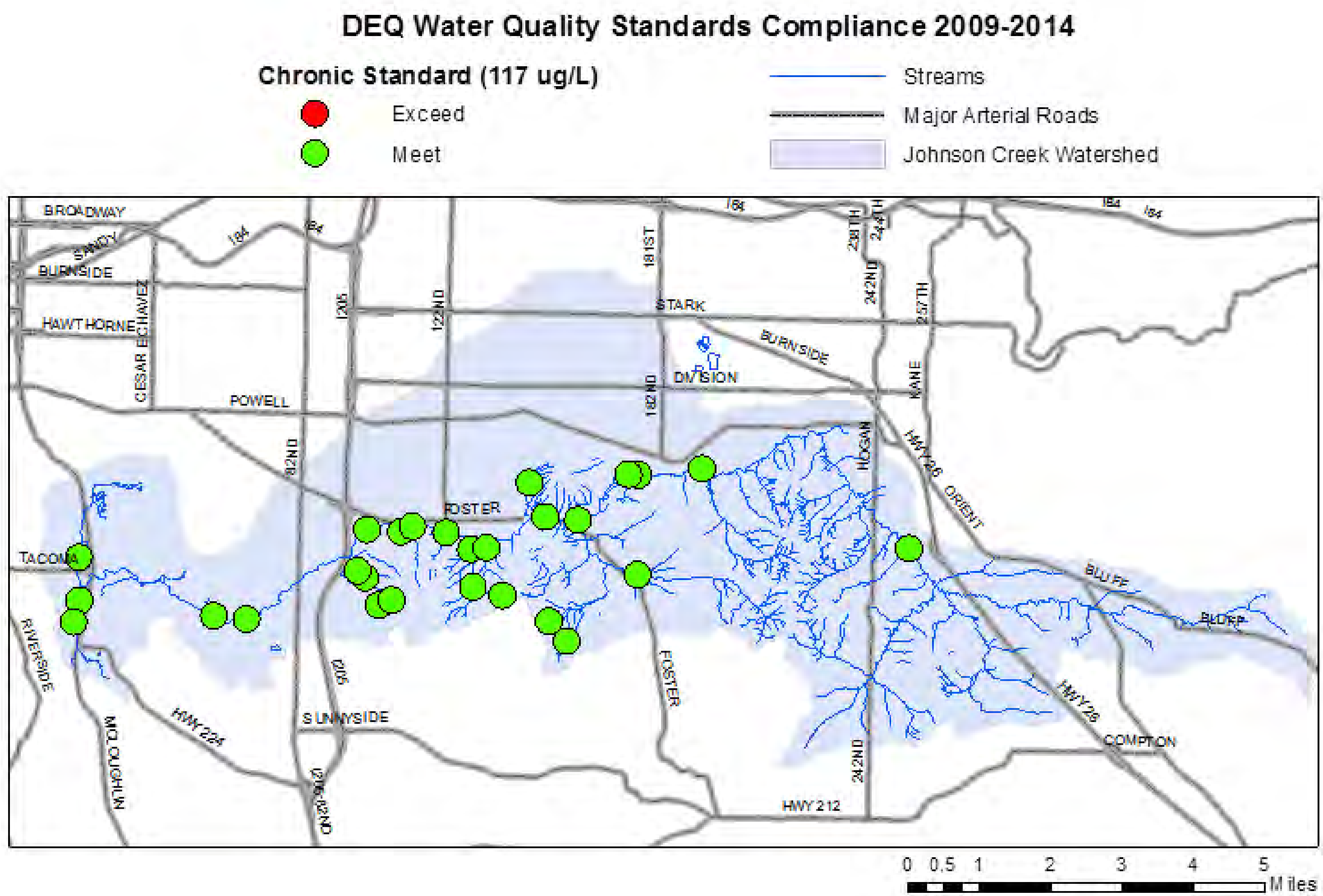


Figure 3.A.3 Mean dissolved zinc concentrations for the assessment period 2009-2014

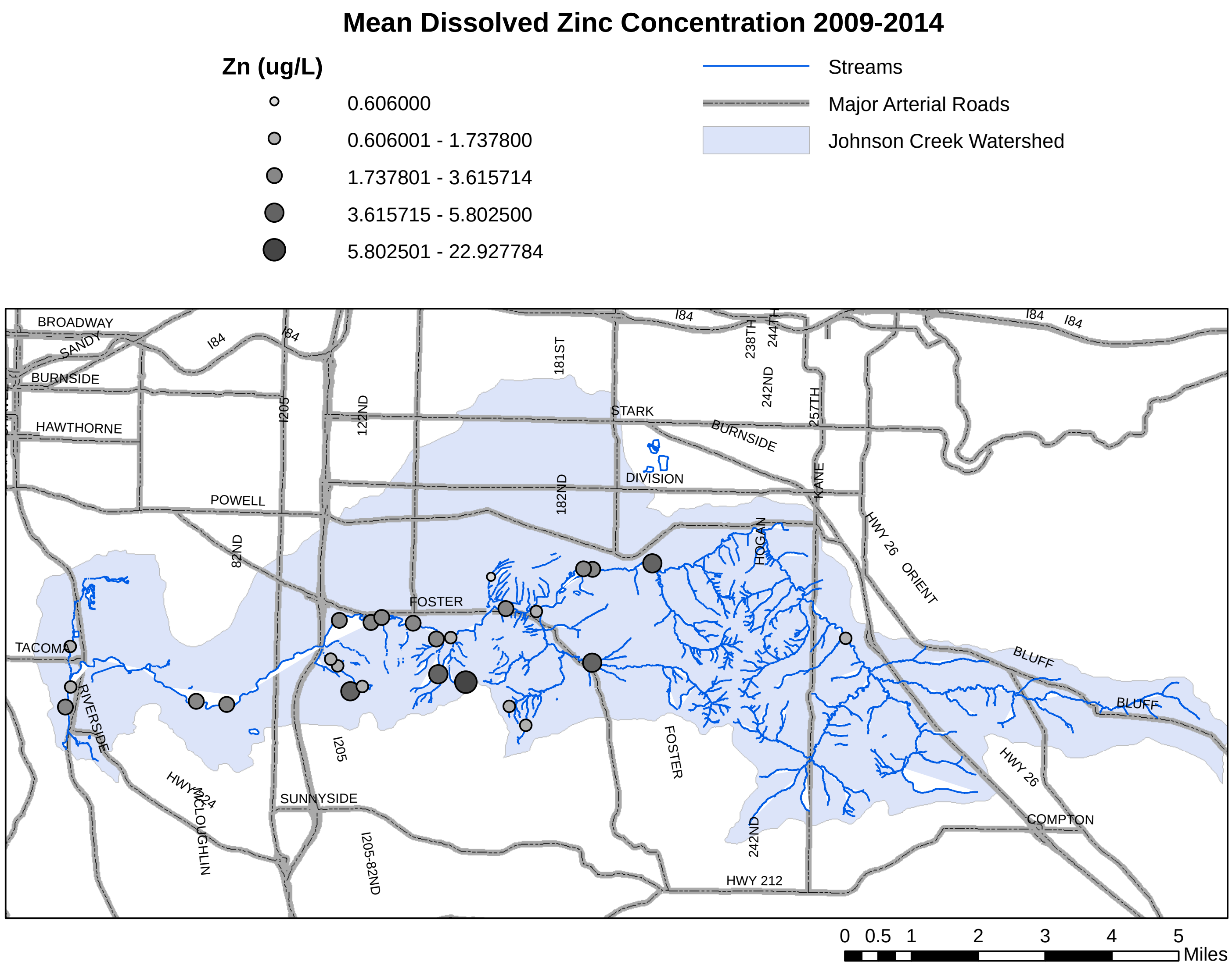


Figure 3.A.4 Stream condition using mean dissolved zinc concentrations compared to three-tiered interpretation criteria

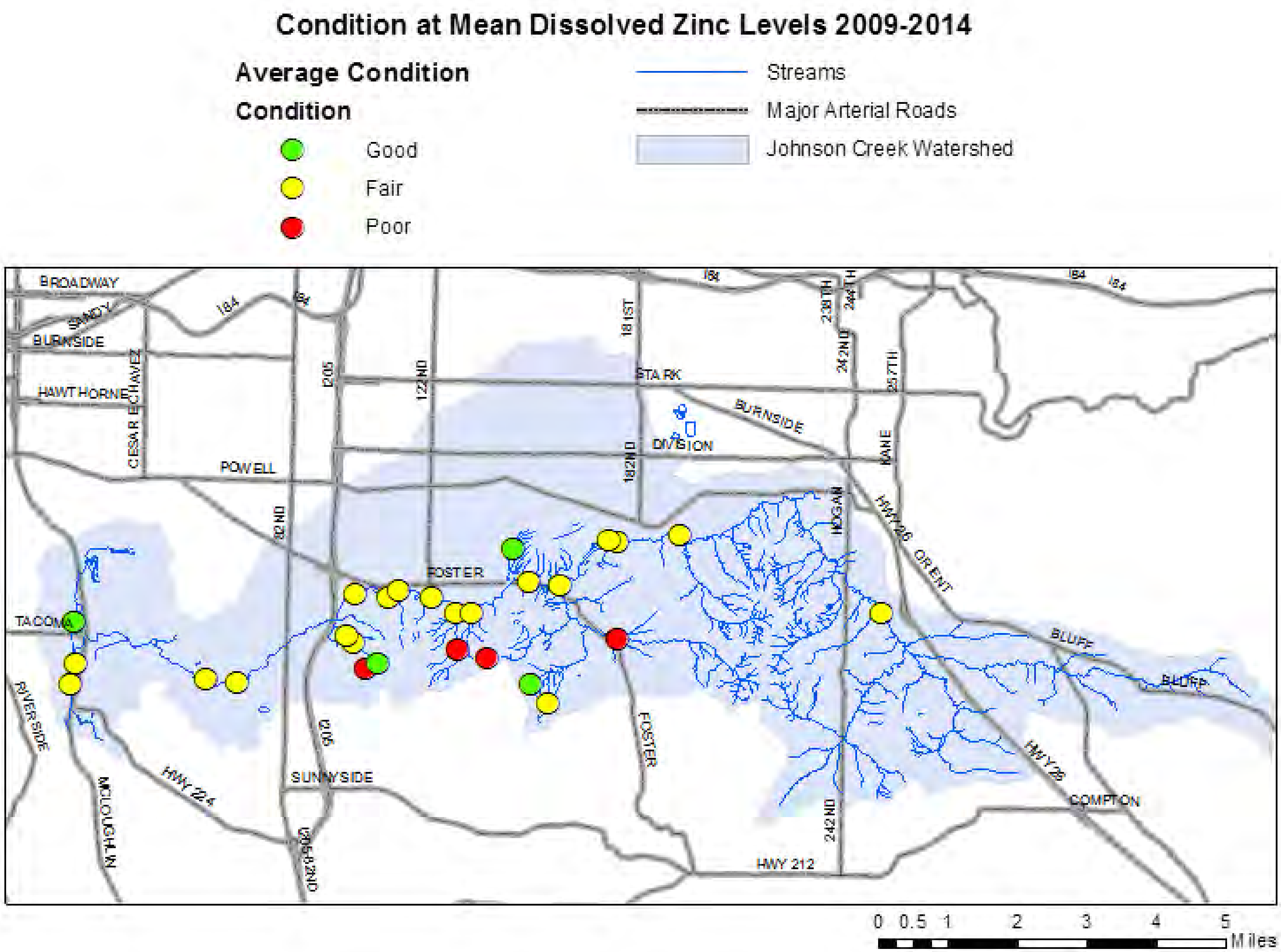
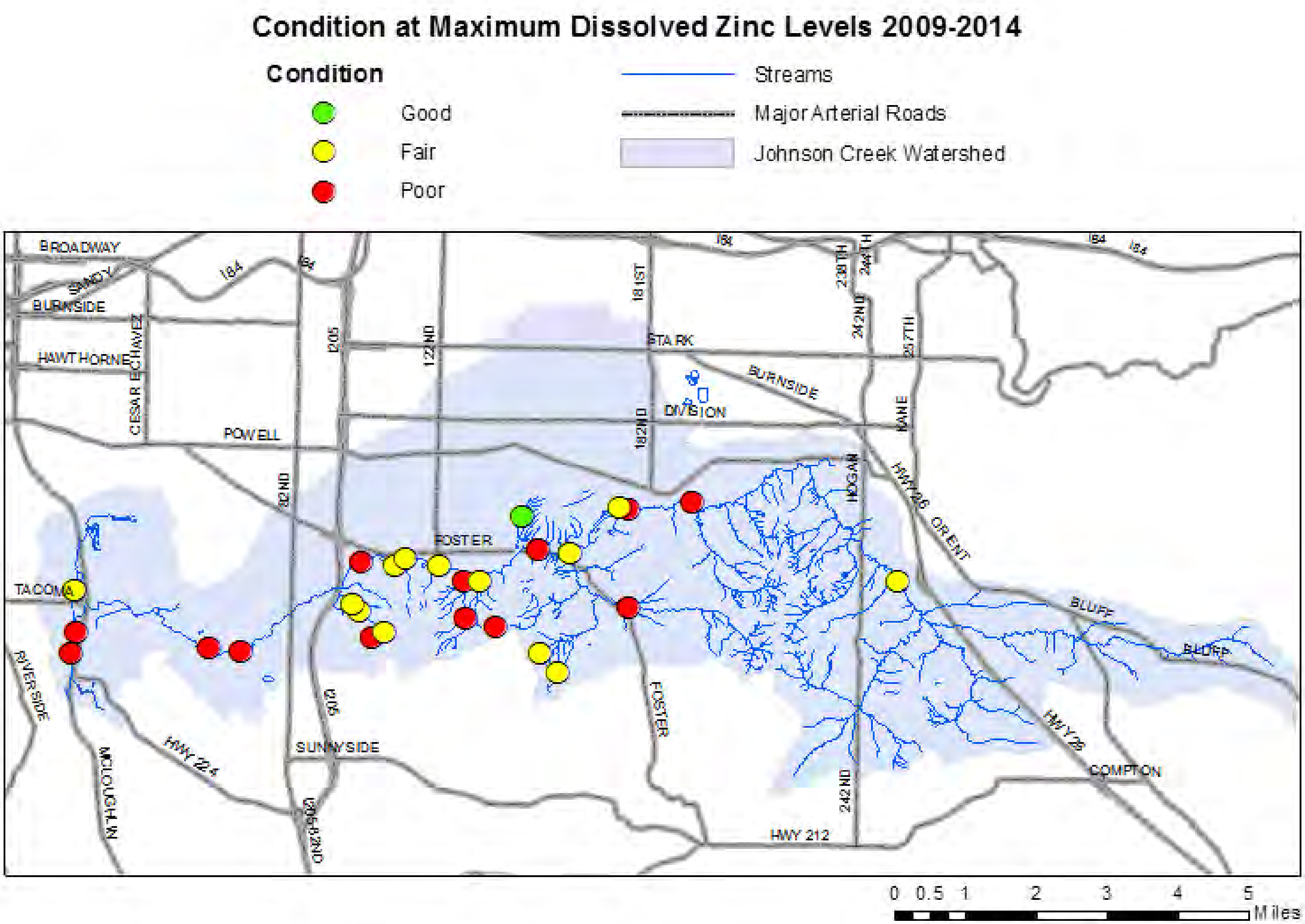


Figure 3.A.5 Stream condition using maximum dissolved zinc concentrations compared to three-tiered interpretation criteria



3.B. Total Mercury

Mercury is a highly toxic metal, especially when it complexes with organic material to form methylmercury compounds. Although mercury may be used in some industrial processes, the most important sources of mercury to the environment are from mining activities and as a component of fossil fuel emissions from coal-burning power plants. Absent any industrial sources, most mercury in urban environments is deposited with particulates from coal emissions in the atmosphere, or from erosion of soils. Mercury is acutely toxic and exposure at high levels can harm the brain, heart, kidneys, lungs, and immune system of adults, children, and wildlife. Mercury bioaccumulates in the food chain, especially in high level predators such as salmon, largemouth bass, northern pikeminnow, and water fowl, where it can cause physical deformities and abnormal behavior.

Total mercury was measured at 33 sites in the Johnson Creek watershed between 2009 and 2014. The number of samples was greatest in the upper portion of the Johnson Creek mainstem at 174th and 252nd Ave (n=27 each), and Kelley Creek at Foster and Rodlun Roads (n=27). The Portland fixed sites at Milport and Sycamore also had a large number of samples (n=17). Agencies contributing data for total mercury are the City of Portland, City of Gresham, and the Oregon Department of Environmental Quality (DEQ). Samples were collected quarterly.

The State of Oregon aquatic life criterion for mercury is 0.012 µg/L in fresh water. Oregon does not have a human health standard for the concentration of mercury in fresh water. Instead, it limits consumption to fish with tissue mercury concentrations of less than 0.040 milligrams per kilogram (mg/kg). A condition range criterion was also used to determine the general water quality of sites in relation to total mercury concentrations. The criteria used were the three-tiered interpretive criteria rating the concentration as “Good” “Fair” or “Poor” depending on a pre-determined threshold (see Table 3.B.3). Note that our three-tiered interpretive criteria are an order of magnitude lower than the State water quality criteria. Of the 257 samples collected for all sites, none of them meet or are below the “Good” criterion. Most of the mainstem samples, 84%, were above the “Fair” condition; and 88% of the tributary samples were above the “Poor” condition.

The mean sample concentration for all sites was below the Oregon statewide aquatic life criterion of 0.012 µg/L. However, a number of sites have at times exceeded the DEQ aquatic life criteria for mercury (Fig. 3.B.2). Most samples that exceed the statewide criteria and the “Poor” condition criteria are outliers to the distribution of concentration measurements, and represent infrequent or extreme events. Only 7 of the 257 mercury samples from 2009-2014 exceeded the statewide aquatic life criteria. These were in Johnson Creek at Palmblad in Nov. 2009 and Jan. 2013, Kelley Creek at Rodlun Rd in Jan. 2013, Lower Johnson (PAWMAP 0352) in Dec. 2010, Johnson Creek at 174th in Jan. 2013, and Johnson Creek at 17th Ave in Feb. 2009. The dates of these high samples coincide with large rain events. For instance, the rainfall for the 24hr period preceding Jan. 29th 2013, when 3 of these exceedances occurred, was 0.95 inches.

Conclusions

Total mercury concentrations in the Johnson Creek watershed tend to average between “Fair” and “Poor.” Due to mercury’s high toxicity, there is a narrow range between the limits of the aquatic life criteria at 0.012 µg/L and the detection limits of the methods used to measure mercury, approximately 0.002 µg/L. While the mean concentration of mercury was below the state standard for aquatic life criteria, five sites exceeded the standard in at least one sample. Low-level mercury contamination of Johnson Creek is relatively widespread, with hotspots that may indicate accumulation of mercury from upstream sources near the lower mainstem sites. These sites may reflect cumulative impacts of the drainage area as particulate mercury is flushed through the stream network. Mercury appears to be a pollutant of concern for Johnson Creek, although data on concentrations in fish and invertebrates would be more indicative of potential impacts to wildlife and human health than the values for concentrations within the water body itself. No point sources are suggested by the data. However, atmospheric deposition of particulate mercury onto landscapes, followed by flushing to streams during storm events is a common route of contamination.

Tables

Table 3.B.1 Summary Statistics

Total Mercury, µg/L	
n	257
Mean	0.0033
Standard Error	0.0002
Median	0.0021
Standard Deviation	0.0026
Minimum	0.0015
Maximum	0.017

Table 3.B.2 Individual sample events by condition range

Condition, n				
Condition*	Mainstem, n	Mainstem, %	Tributary	Tributary, %
Poor	25	16%	85	88.5%
Fair	136	84%	11	11.5%
Good	0	0%	0	0%
Total	161		96	

Samples collected quarterly at each of 32 sites from 2009-2014.
* See ranges defined in table 3.B.3.

Table 3.B.3 Condition ranges

Index	*Quantity, µg/L*
Good	< 0.00085
Fair	0.00086 – 0.0049
Poor	> 0.0049

Figure 3.B.1 Mean sample concentrations of total mercury in µg/L. The horizontal bar at the center of each box represents the sample mean. The vertical box ends represent the 25th and 75th quantiles. Whisker bars represent the range of 1st and 4th quartiles. Points represent outlier values. Dashed lines across the figure represent the condition range thresholds (bottom, see Table 3.B.3), and the Oregon Aquatic Life Criteria (top). The number of observations in each sample are shown at top.

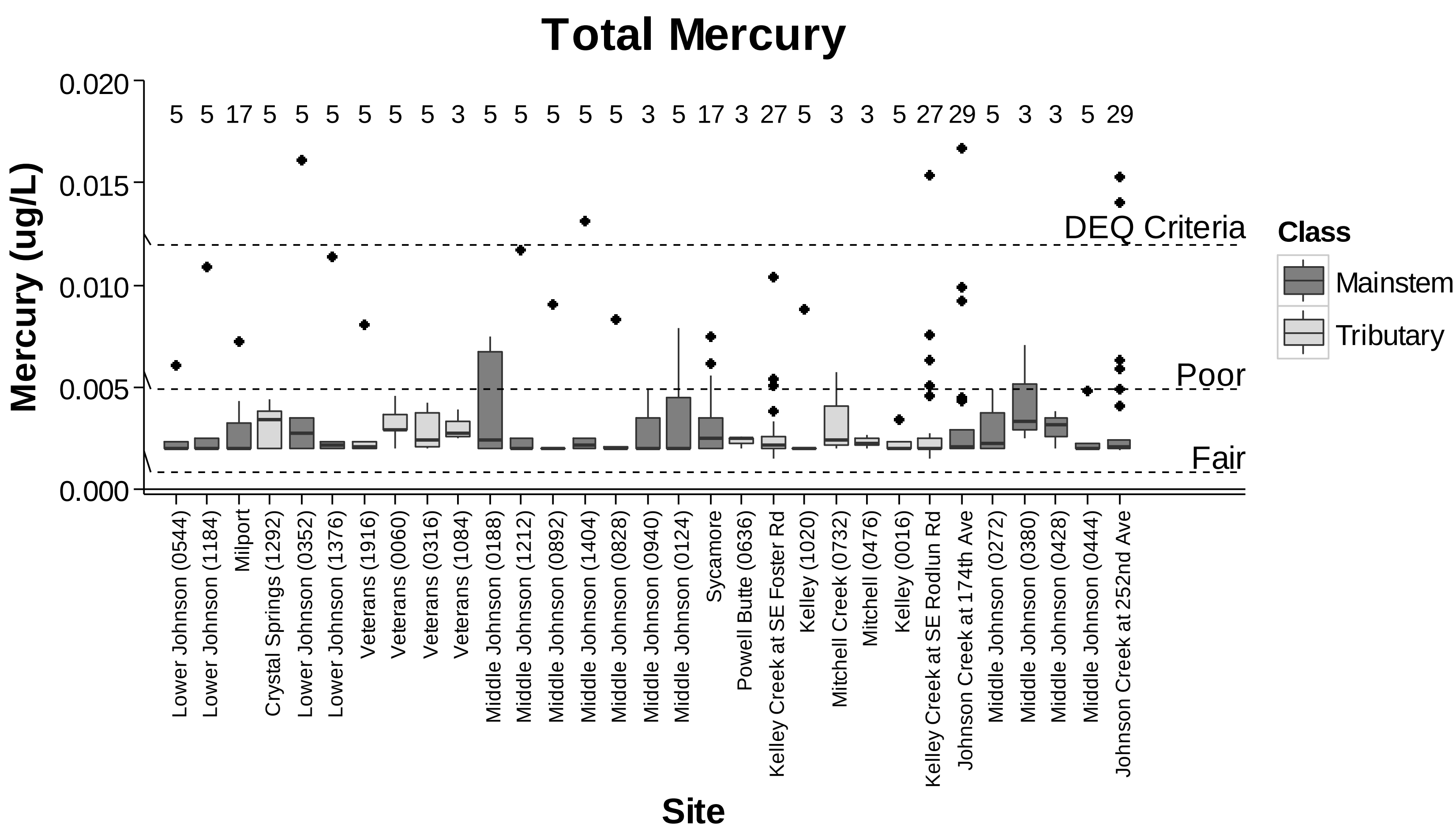


Figure 3.B.2 Maximum total mercury compliance with DEQ chronic standard. Note that the exceedances were associated with large rainfall events.

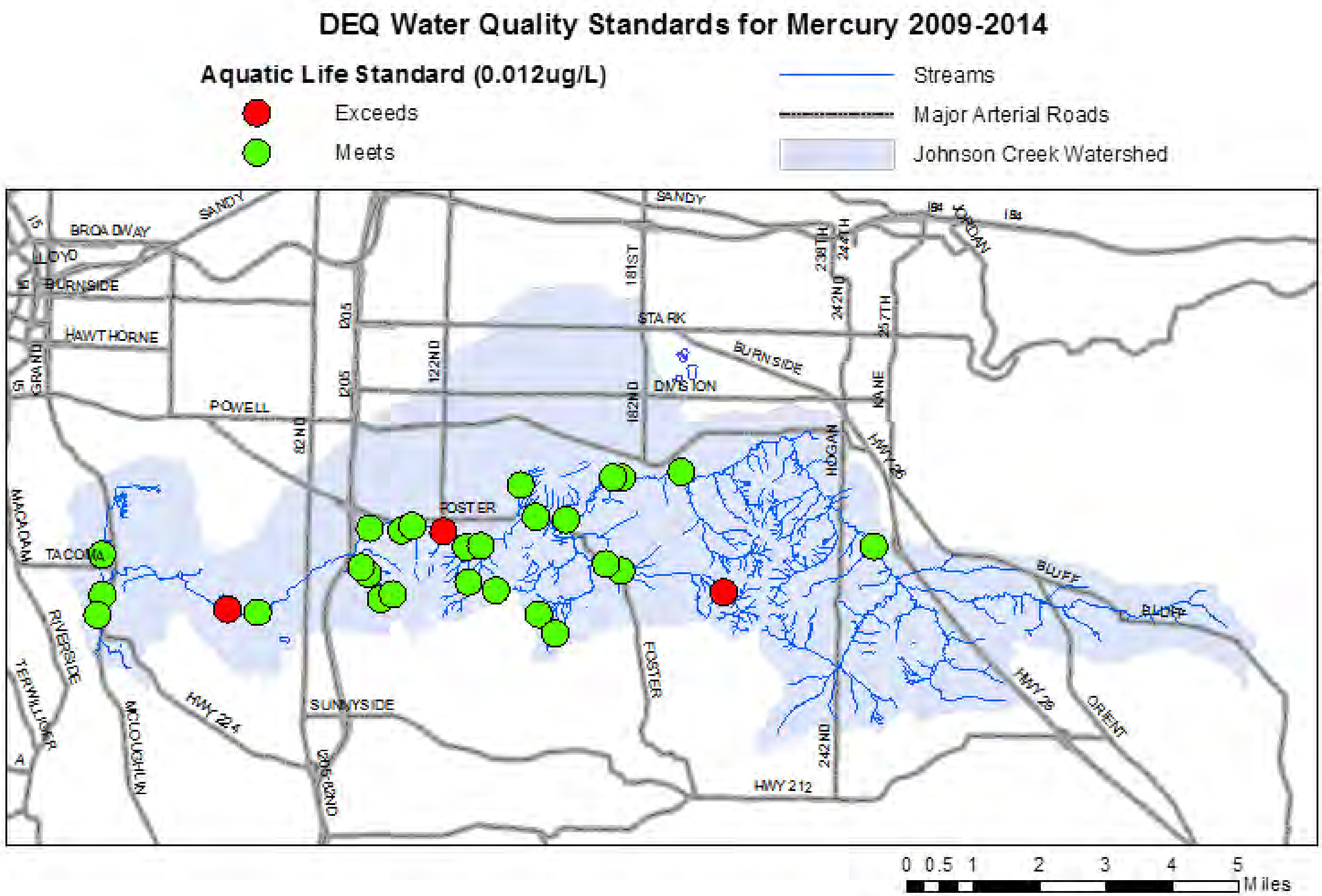


Figure 3.B.3 Mean total mercury concentrations for the assessment period 2009-2014

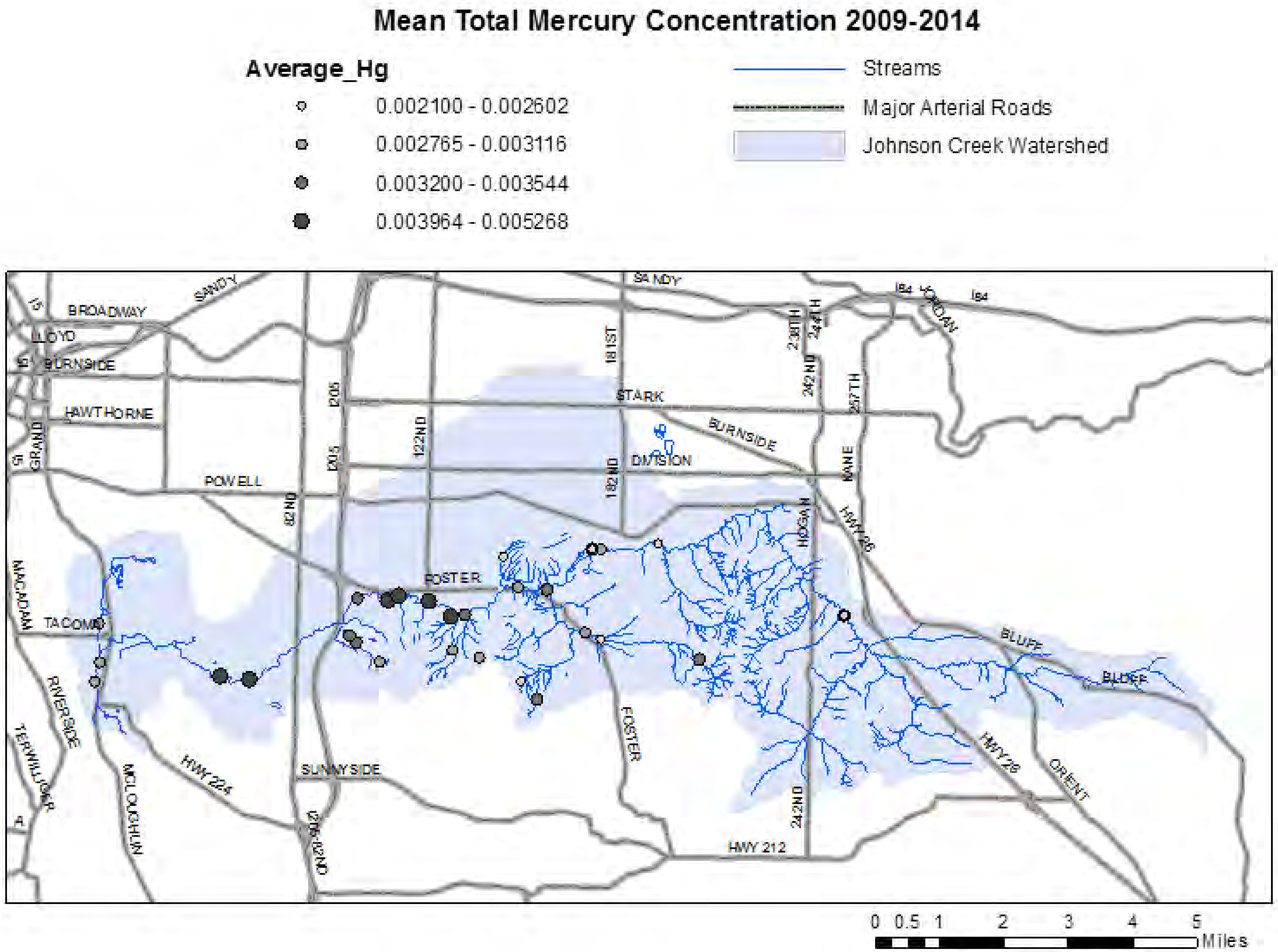


Figure 3.B.4 Stream condition using mean total mercury concentrations compared to three-tiered interpretation criteria

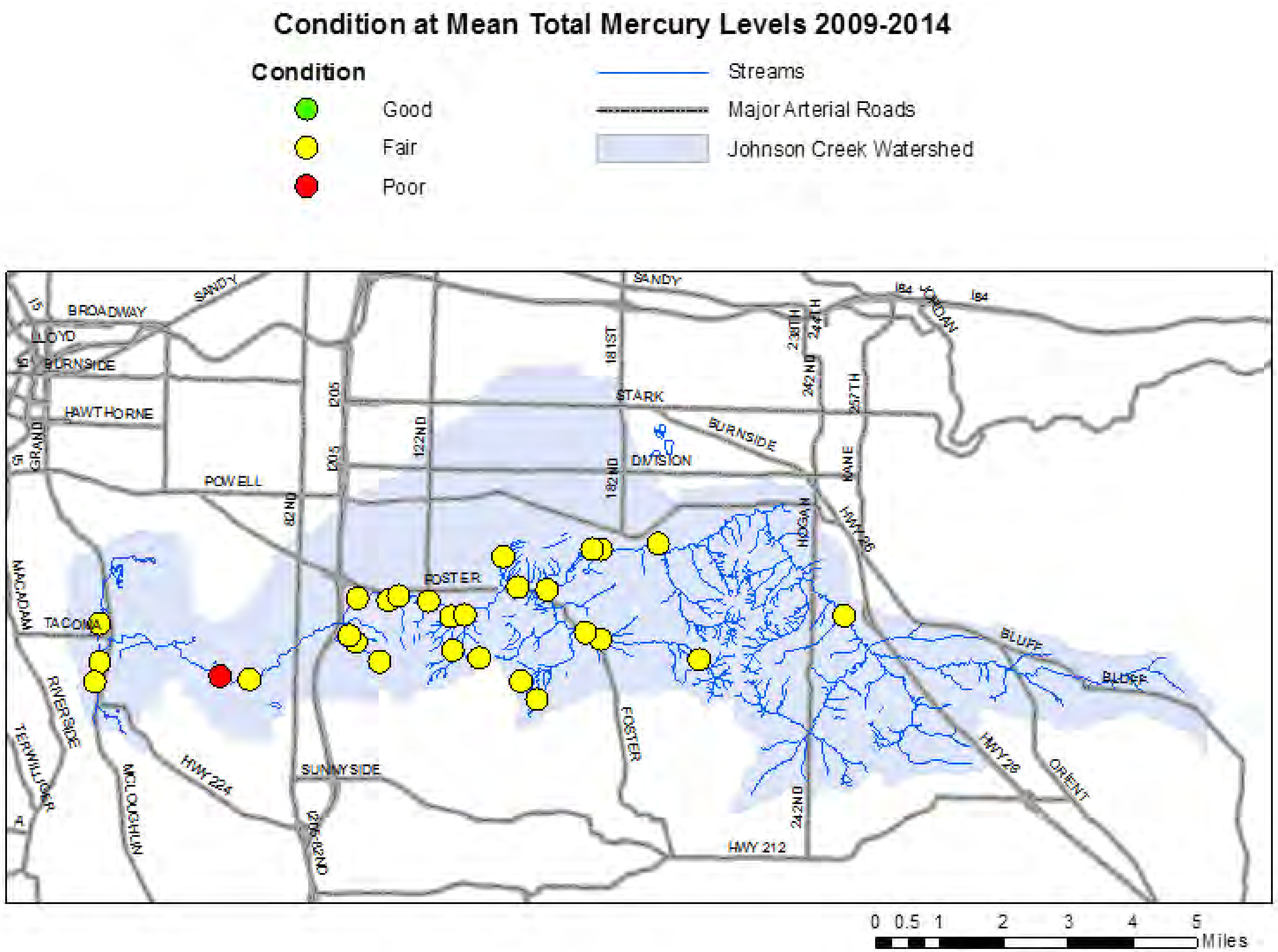
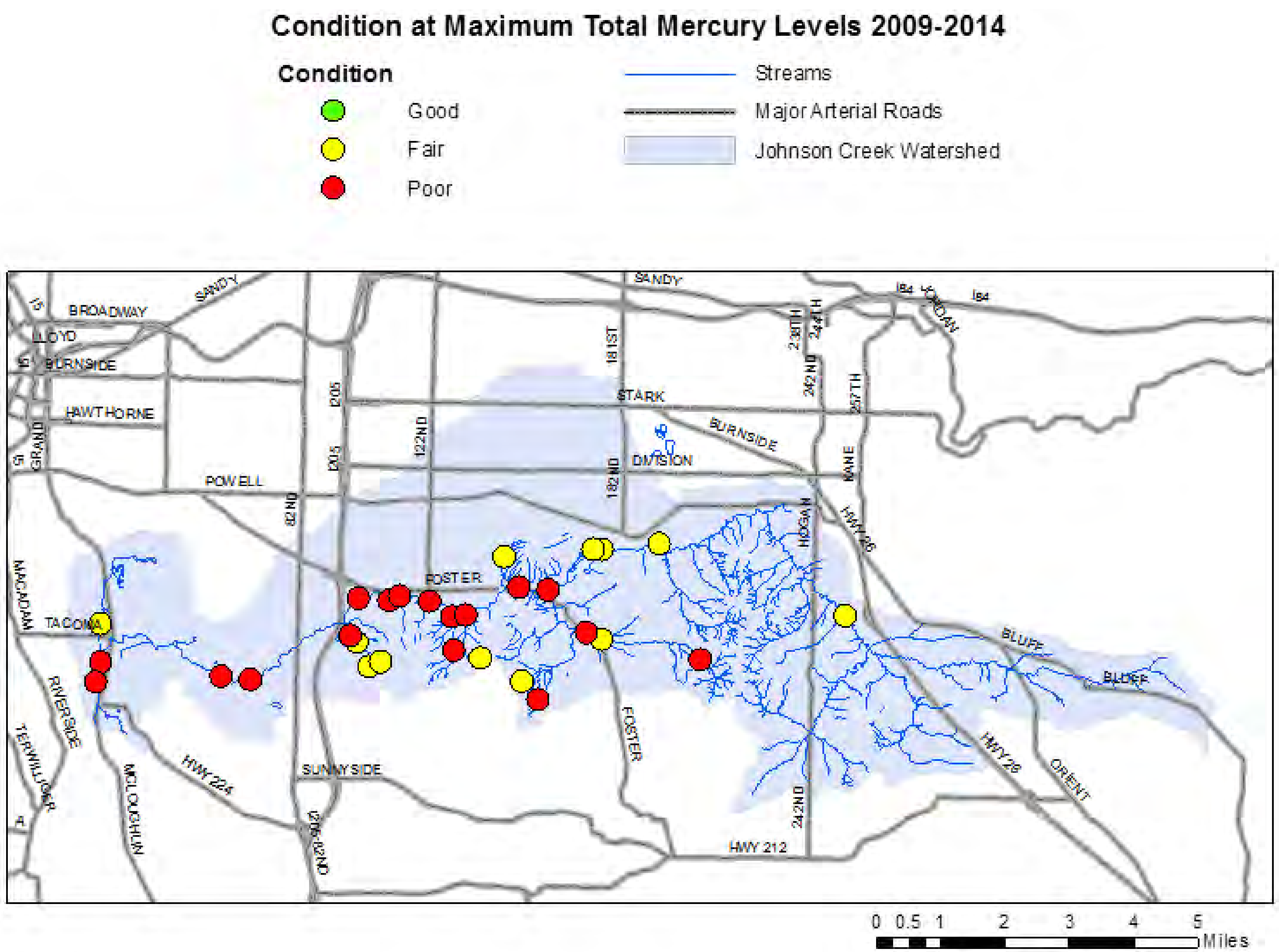


Figure 3.B.5 Stream condition using maximum total mercury concentrations compared to three-tiered interpretation criteria



3.C. Dissolved Copper

Dissolved copper is a metal pollutant of concern in urban watersheds. Copper enters streams in particulate and dissolved forms from industrial point sources and dispersed non-point sources primarily related to automobile traffic. Specifically, non-point source copper contamination is linked to the wear of engine parts and brake pads containing copper metal. Copper acts as a biocide in the environment, and can be toxic to algae, bacteria, and aquatic invertebrates. Copper is acutely toxic to salmonids, and there are significant sub-lethal effects of lower concentrations. Even very low concentrations of copper can negatively impact the olfactory senses of salmonids; interfering with predator avoidance, feeding, and other behavior. The Oregon DEQ currently determines copper toxicity using a hardness-based calculation. Using a base hardness of 100 mg/L, the acute exposure criteria of copper is 18 µg/L, and the chronic exposure criteria is 12 µg/L.

Dissolved copper was measured at 34 sites in the Johnson Creek watershed between 2009 and 2014. The number of samples was greatest west of SE 182nd Ave; including mainstem and major tributary streams. Tributary streams and headwaters east of SE 182nd Ave are not typically represented. Twenty-three sites were on the mainstem of Johnson Creek. The remainder was distributed among tributaries with one site at Crystal Springs, two sites on Mitchell Creek, and four sites each on Kelley Creek and Veteran's Creek. Agencies contributing data for dissolved copper are the City of Portland, City of Gresham, and the Oregon Department of Environmental Quality (DEQ).

Samples were collected quarterly, although the years of coverage for each sample differ by site and jurisdiction. The City of Gresham and City of Portland sampled in each quarter from 2009-2014. The City of Portland PAWMAP measured sites 5 times annually but only for one year duration at each site. The Oregon DEQ sites were sampled only once in 2009.

A condition range criterion was used to determine the general water quality of sites in relation to dissolved copper concentrations. The three-tiered interpretive criteria rating the concentration as "Good" "Fair" or "Poor" were used (see Table 3.C.3). Note that our three-tiered interpretive criteria are about an order of magnitude lower than the State water quality criteria for acute and chronic exposure. Of the 298 samples collected at all sites, 127 samples meet or are below the "Good" criterion, 170 samples are "Fair", and only 1 sample at one site exceeded the "Poor" criterion during the time window of the assessment.

Conclusions

Dissolved copper in the Johnson Creek watershed are generally within an acceptable range and rank below the "Good or "Fair" criteria for all sites. The only instance of an exceedance of these criteria was a single sample collected on Veteran's Creek on 11/19/2012 of 4.64 µg/L. This date was the wettest day of 2012, with 2.2 inches of precipitation. Because outliers in copper concentration were related to large storm events, it is possible that extreme runoff events may lead to exceedance in susceptible watersheds. However, the impact from copper across the entire Johnson Creek watershed appears acceptable relative to current water quality standards. Copper in all streams was well within compliance with Oregon DEQ standards.

Tables

Table 3.C.1 Summary Statistics

Dissolved Copper, µg/L	
n	297
Mean	0.95
Standard Error	0.03
Median	0.85
Standard Deviation	0.55
Minimum	0.2
Maximum	4.64

Table 3.C.2 Individual sample events by condition range

Condition, n				
Condition*	Mainstem, n	Mainstem, %	Tributary	Tributary, %
Poor	0	0%	1	1%
Fair	111	54%	26	28%
Good	92	46%	67	71%
Total	203		94	

Samples collected quarterly at each of 32 sites from 2009-2014.
* See ranges defined in table 3.C.3.

Table 3.C.3 Condition ranges

Index	*Quantity, µg/L*
Good	< 0.88
Fair	0.88 – 4.2
Poor	> 4.2

Figure 3.C. Mean sample concentrations of dissolved copper in µg/L. The horizontal bar at the center of each box represents the sample median. The vertical box ends represent the 25th and 75th quantiles. Whisker bars represent the range of 1st and 4th quartiles. Points represent outlier values. Dashed lines across the figure represent the condition range thresholds (see Table 3.C.3). Note: the DEQ hardness-based chronic criterion of 12 ug/L is well above the scale of this figure. The number of observations in each sample is shown at top.

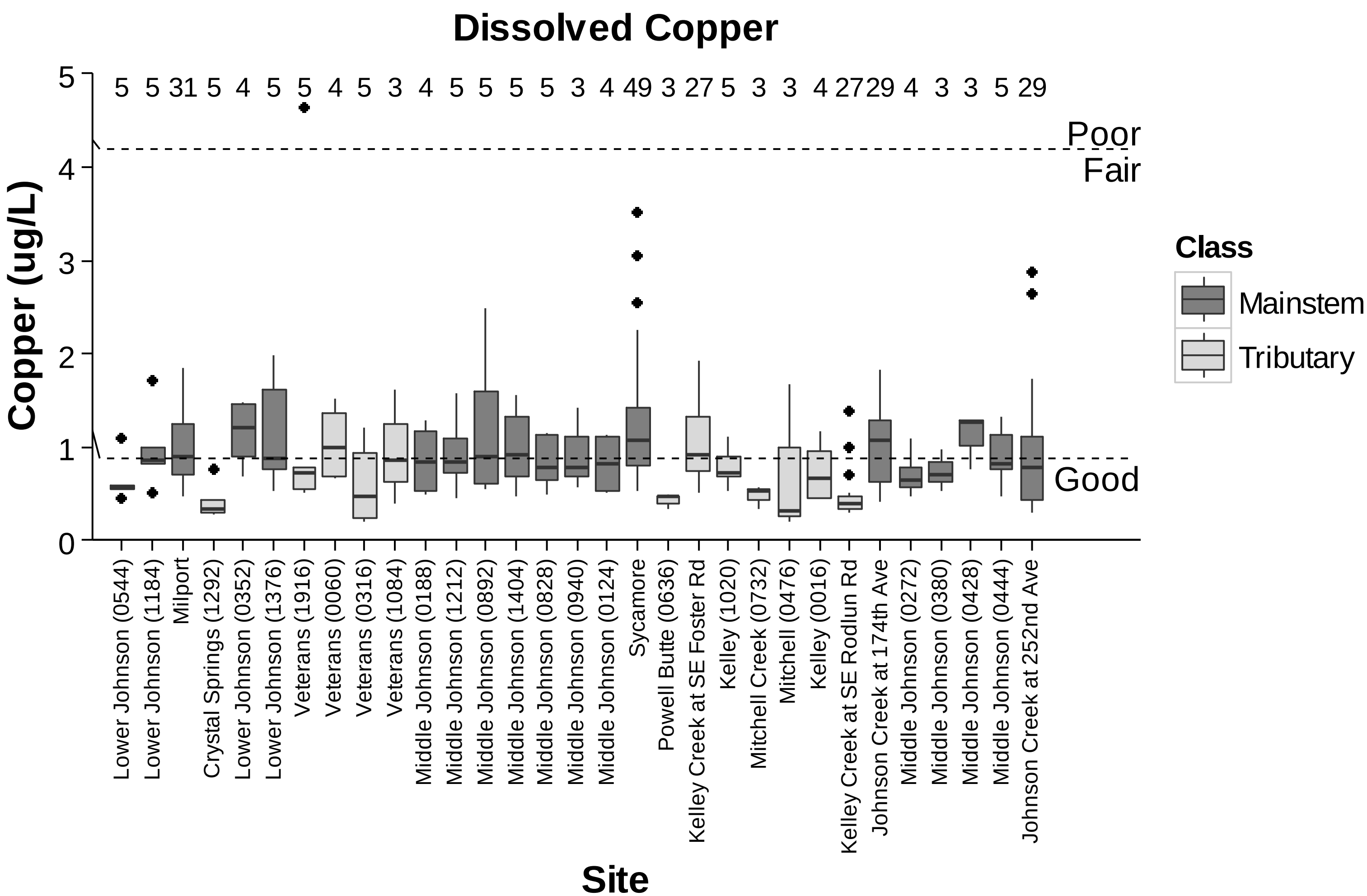


Figure 3.C.2 Maximum dissolved copper compliance with DEQ chronic standard (assumes 100 mg/L hardness)

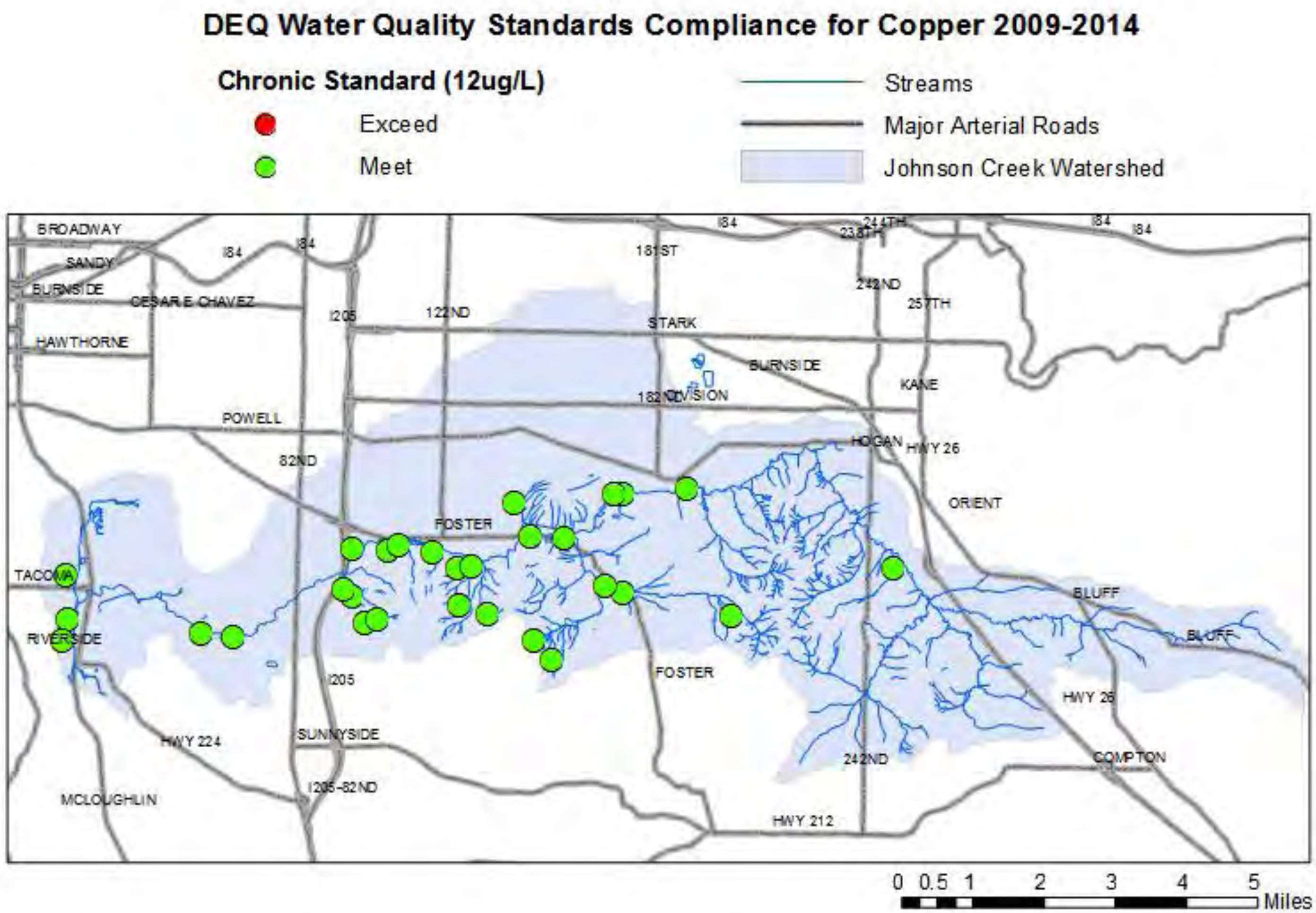


Figure 3.C.3 Mean dissolved copper concentrations for the assessment period 2009-2014

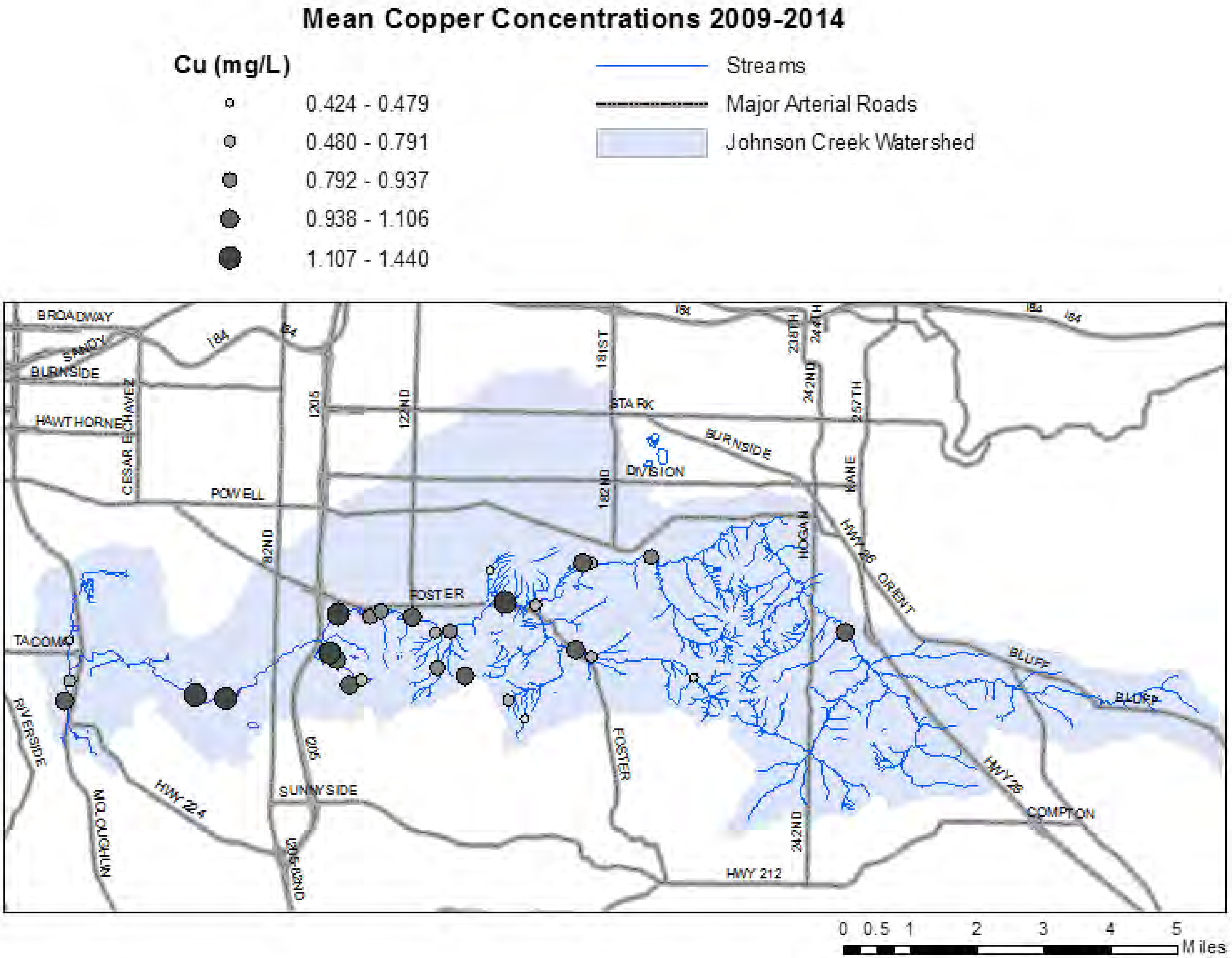


Figure 3.C.4 Stream condition using mean total copper concentrations compared to three-tiered interpretation criteria

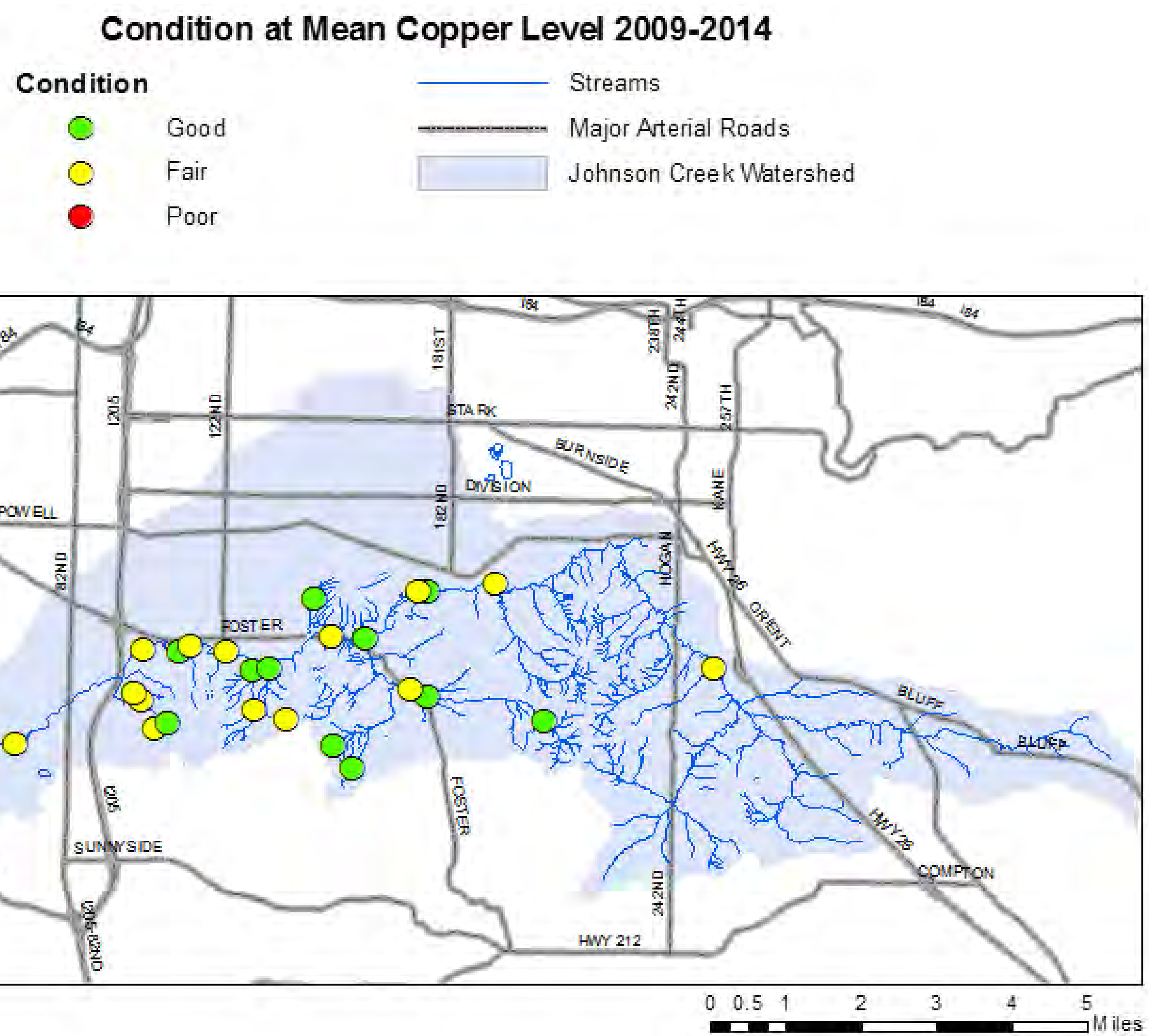
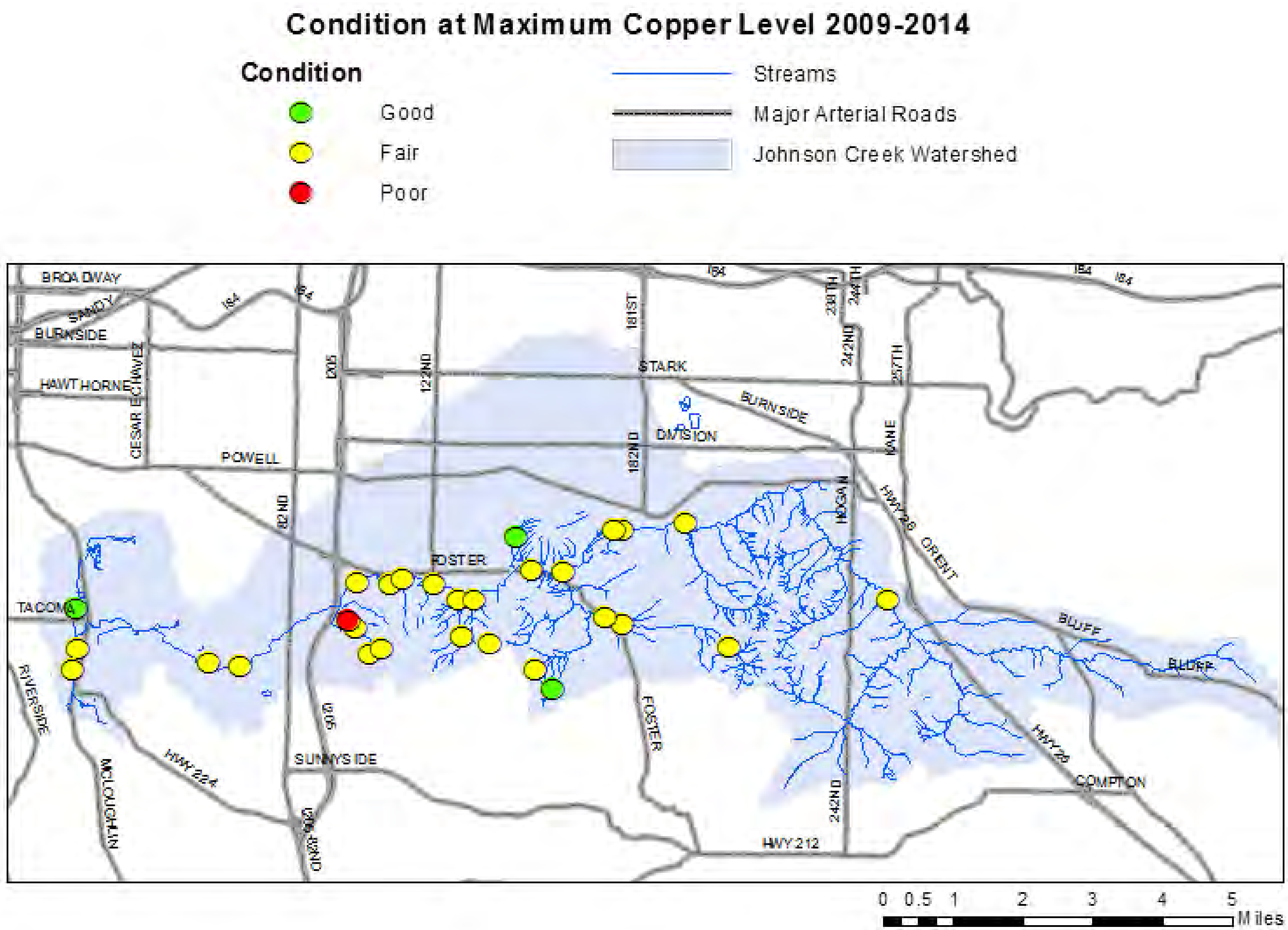


Figure 3.C.5 Stream condition using maximum total copper concentrations compared to three-tiered interpretation criteria



3. D. Dissolved Lead

In adults and children, lead exposure can cause damage to the brain and nervous system, liver and kidney damage, hearing and vision impairment, and reproductive problems. Children are especially vulnerable to lead, where exposure can cause fetal and childhood developmental delays, behavioral problems, and anemia. Major sources of lead exposure include lead from paint, gasoline, water distribution systems, food, and lead used in manufacturing and consumer goods. Although the most significant sources of lead to the environment, such as leaded gasoline and paint, were phased out of use in the U.S. between 1976 and 1990, contamination from these sources persists in urban soils, and many homes, buildings, and plumbing systems built before 1976. Lead reaches urban waterways during erosion of soils containing lead contamination, automobiles, industrial discharges, and through older sewage and plumbing systems containing lead components.

Dissolved lead was measured at 33 sites in the Johnson Creek watershed between 2009 and 2014. The number of samples was greatest at Sycamore (n=49), Milport (n=31), and 174th Ave, 252nd Ave (Palmblad), and Kelley Creek at Foster and Rodlun Rd (n=27 each). Agencies contributing data for dissolved lead were limited to the City of Portland fixed and PAWMAP sites, and the City of Gresham. Samples were collected quarterly.

The Oregon DEQ currently determines lead toxicity using a hardness-based calculation. Using a base hardness of 100 mg/L, the acute exposure criterion of copper is 65 µg/L, and the chronic exposure criterion is 2.5 µg/L. A condition range criterion was used to determine the general water quality of sites in relation to dissolved lead concentrations. The three-tiered interpretive criteria were used to rate the concentration as “Good” “Fair” or “Poor” depending on a pre-determined threshold (see Table 3). Note that our three-tiered interpretive criteria have the “Fair” threshold set lower than the State water quality criteria for chronic exposure. Of the 297 samples collected at all sites, only 2 exceeded the “Good” criterion, and only 1 of these samples also exceeded the “Poor” criterion during the time window of the assessment. The only exceedances were recorded at the City of Portland’s Sycamore site, with 1.10 µg/L on 03/18/2009, and 6.49 µg/L on 08/12/2009.

Conclusions

Dissolved lead in the Johnson Creek watershed is generally within acceptable ranges and rank below the “Good” criterion for all except 2 sampling events from 2009-2014. The only major exceedance occurred at Sycamore on 08-12-2009, following only a 48-hr total of 0.6 in of precipitation. Therefore, although the concentration of lead contamination in the majority of sites sampled is extremely low, there is the potential that increased sampling frequency may detect large spikes in lead concentration in the mainstem of Johnson Creek following even modest rain events.

Tables

Table 3.D.1 Summary Statistics

Dissolved Lead, µg/L	
n	297
Mean	0.13
Standard Error	0.02
Median	0.10
Standard Deviation	0.38
Minimum	0.10
Maximum	6.49

Table 3.D.2 Individual sample events by condition range

Condition, n				
Condition*	Mainstem, n	Mainstem, %	Tributary	Tributary, %
Poor	1	0.5%	0	0%
Fair	1	0.5%	0	0%
Good	201	99%	94	100%
Total	203		94	

Samples collected quarterly at each of 32 sites from 2009-2014.
* See ranges defined in table 3.D.3.

Table 3.D.3 Condition ranges

Index	*Quantity, µg/L*
Good	< 0.85
Fair	0.85 – 4.9
Poor	> 4.9

Figure 3.D.1 Mean sample concentrations of dissolved lead in µg/L. The horizontal bar at the center of each box represents the sample median. The vertical box ends represent the 25th and 75th quantiles. Whisker bars represent the range of 1st and 4th quartiles. Points represent outlier values. Dashed lines across the figure represent the condition range thresholds (see Table 3.D.3). The number of observations in each sample are shown at top.

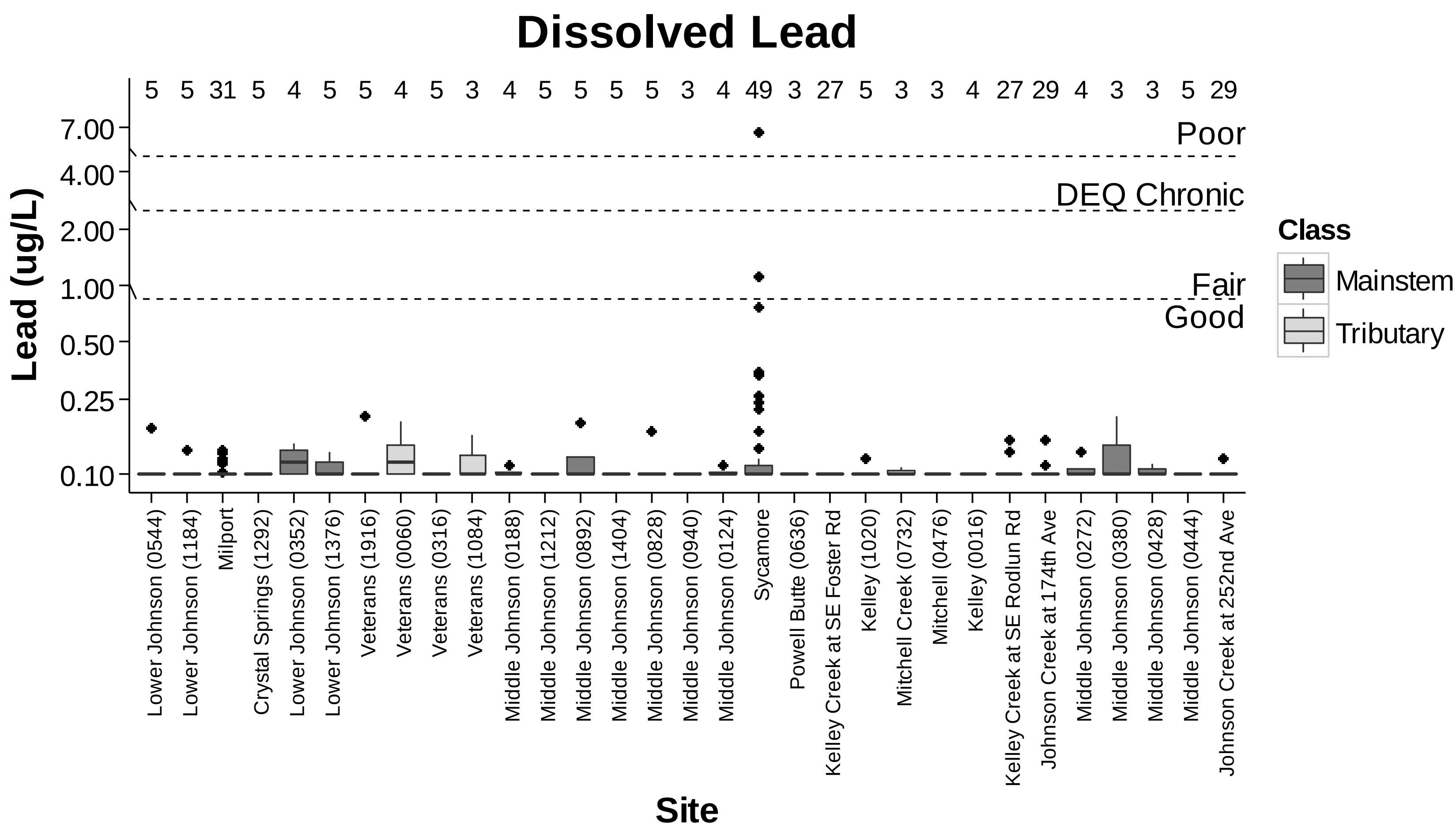


Figure 3.D.2 Maximum dissolved lead compliance with DEQ chronic standard (assumes 100 mg/L hardness)

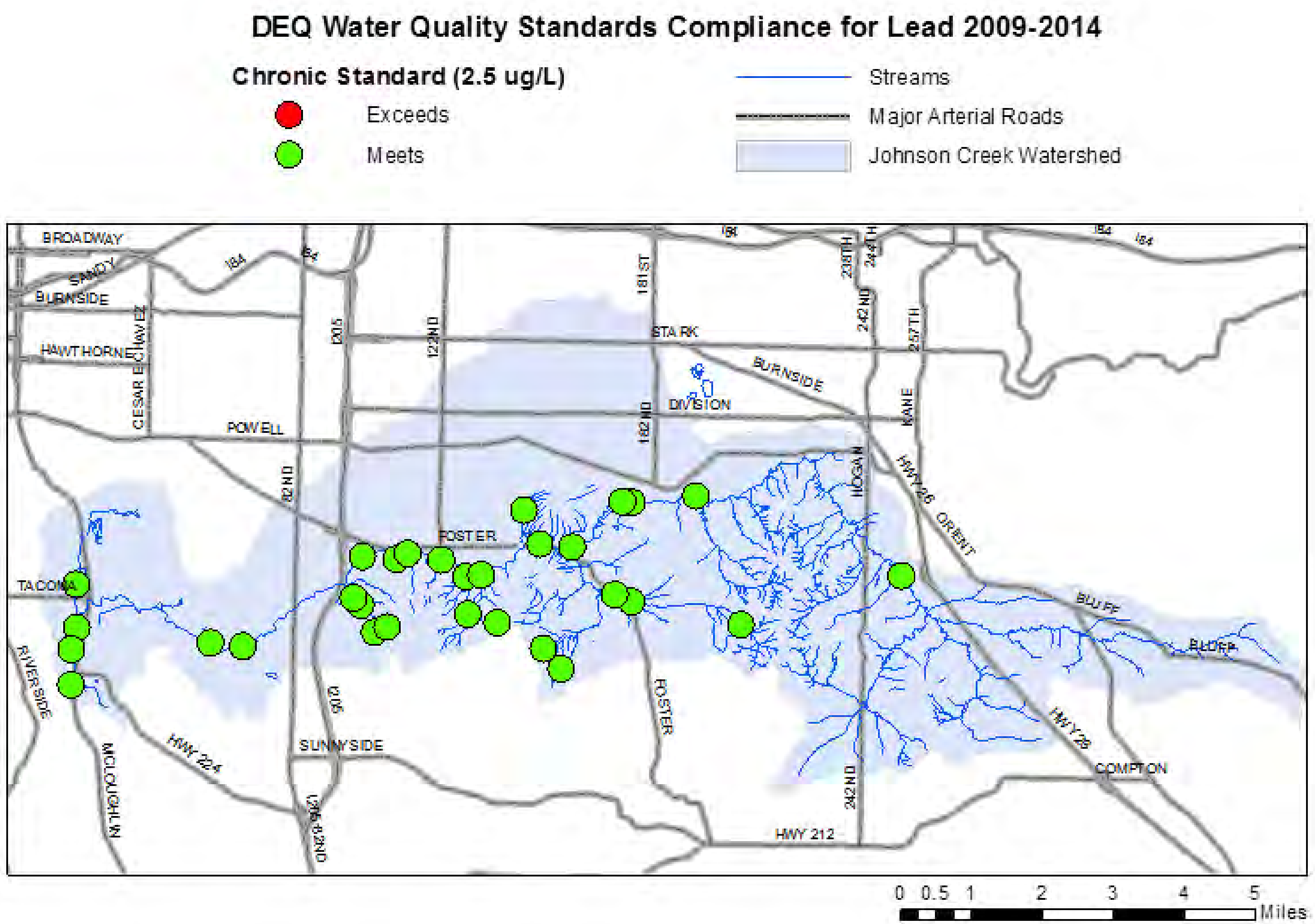


Figure 3.D.3 Mean dissolved lead concentrations for the assessment period 2009-2014

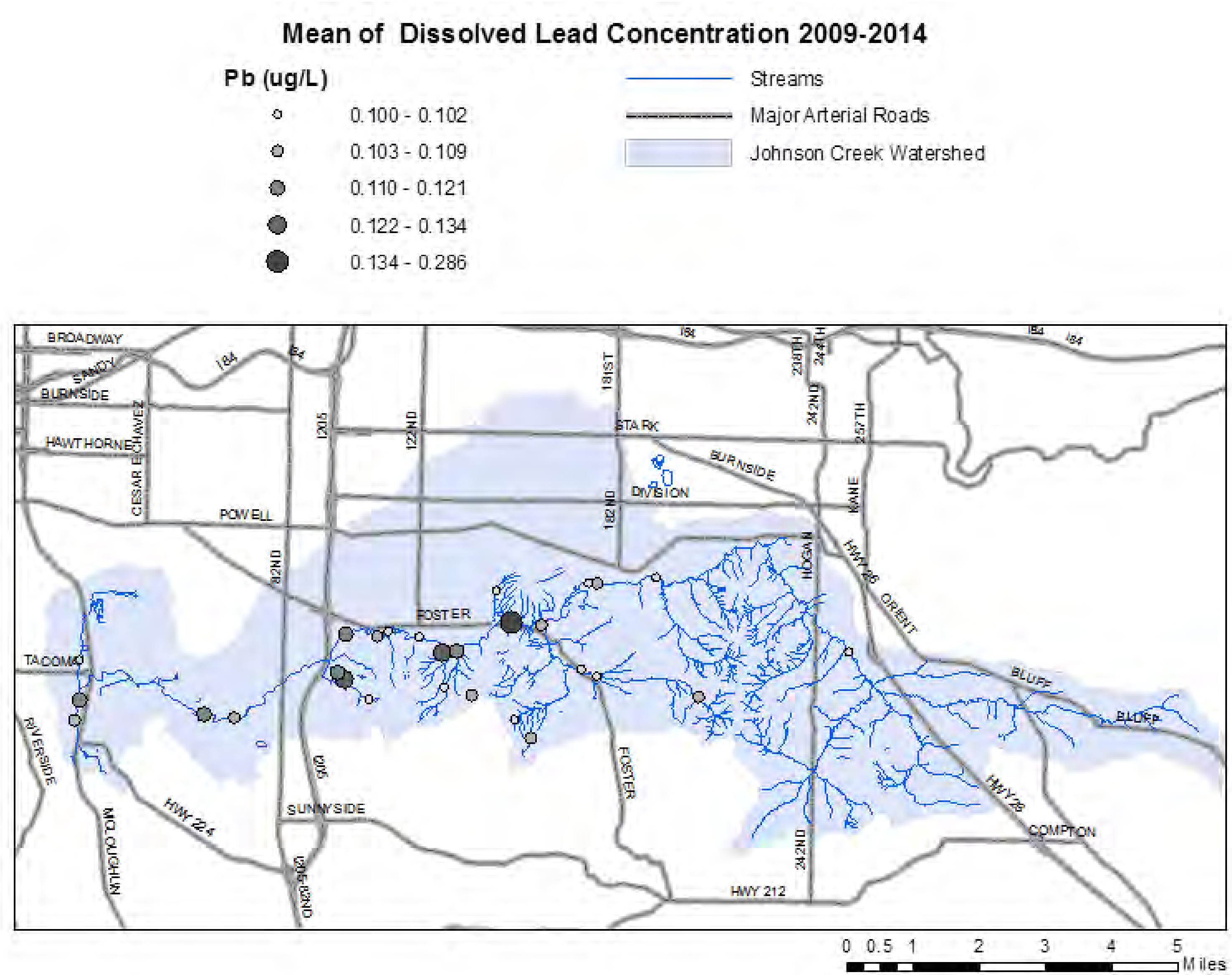


Figure 3.D.4 Stream condition using mean dissolved lead concentrations compared to three-tiered interpretation criteria

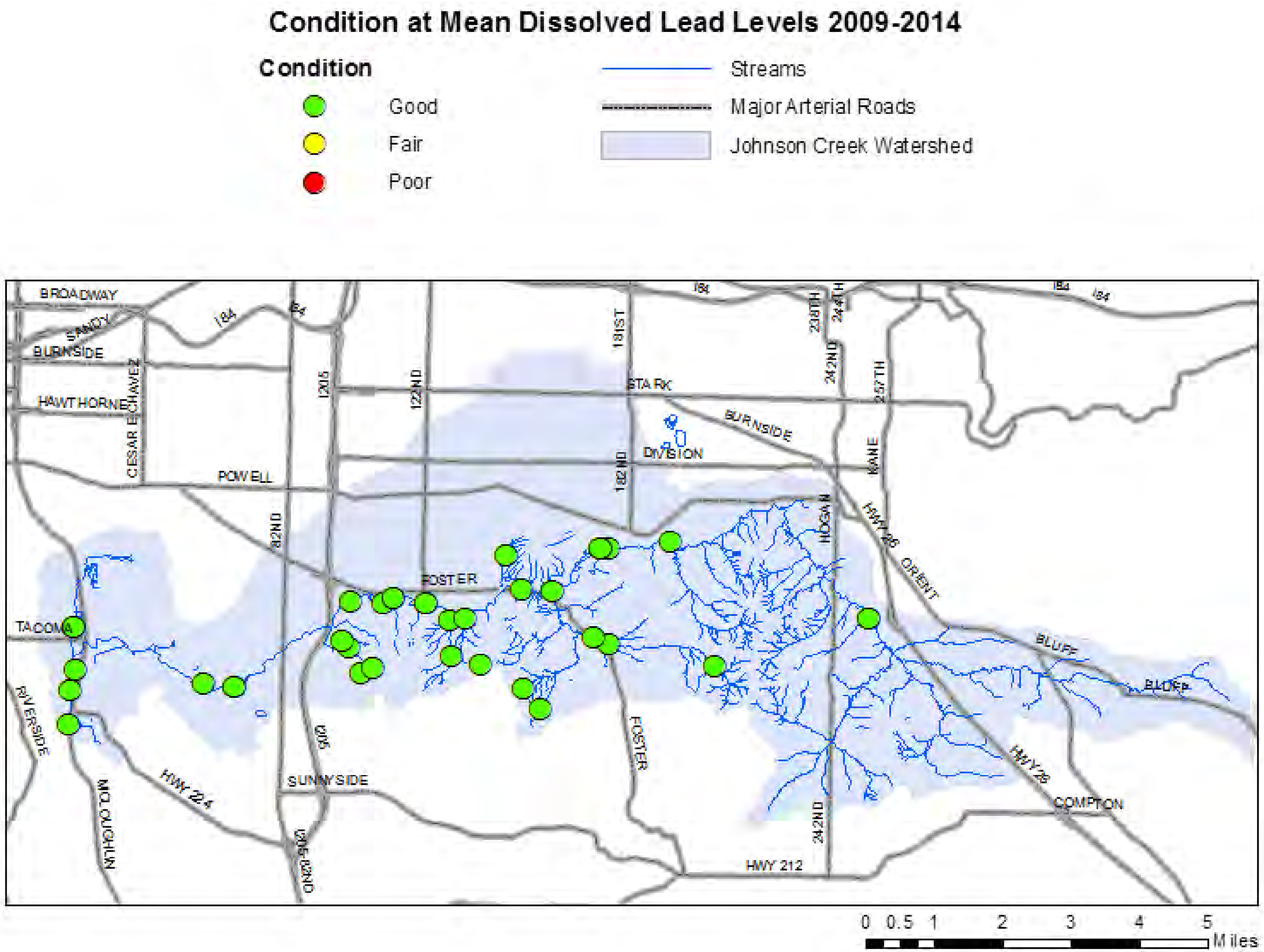
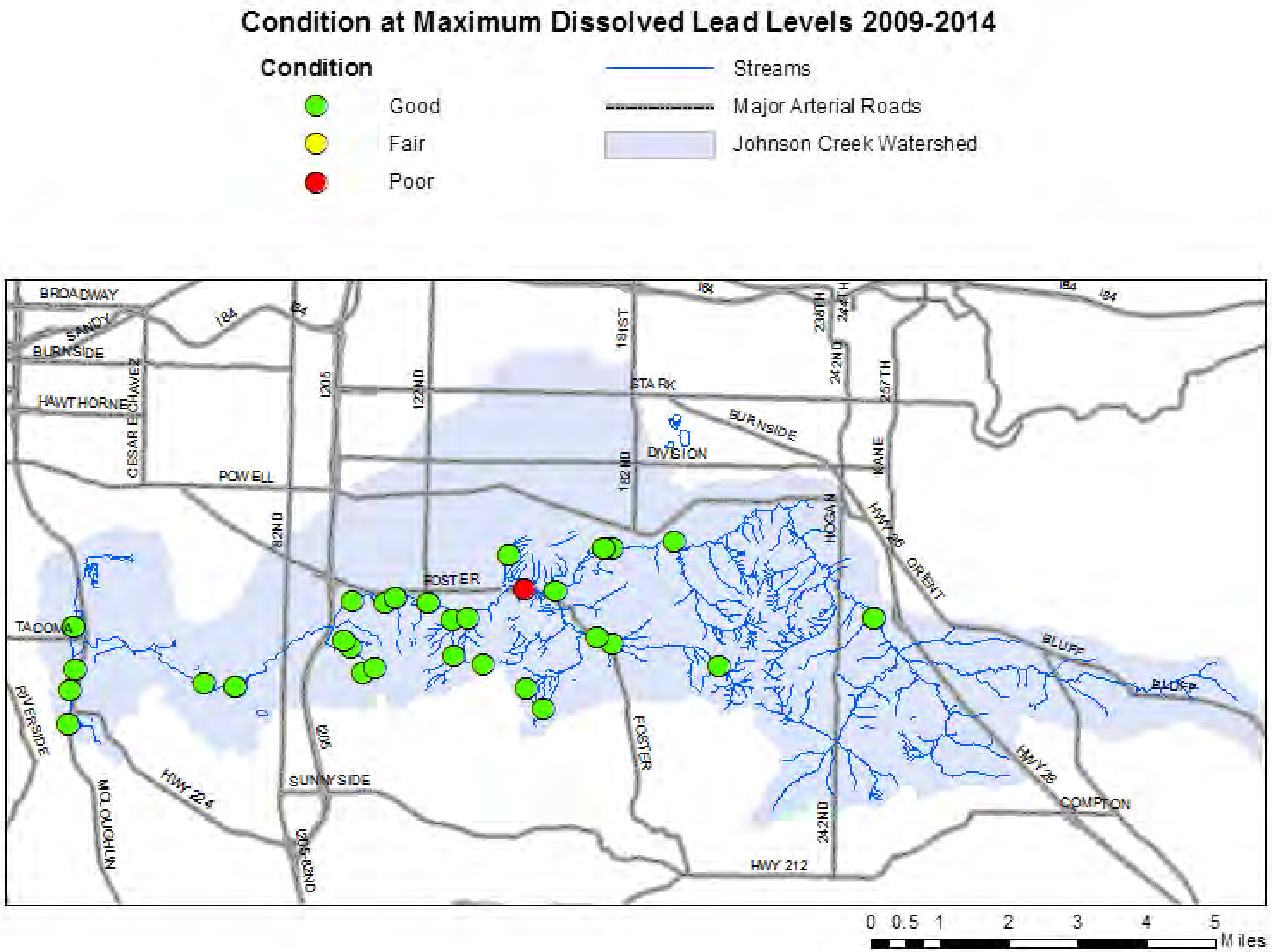


Figure 3.D.5 Stream condition using maximum dissolved lead concentrations compared to three-tiered interpretation criteria



3.E. Total Suspended Solids

Total suspended solids (TSS) are a measure of the particles larger than 2 microns found in the water column and is a measure of general water quality and visual clarity of a water body. Suspended solids are comprised of particulate matter that can include sediments, organic matter, algae and plankton. Suspended solids are often an issue in urban streams, where runoff carries eroded soils, pathogens, sewage, road particles, organic material into streams, or excess nutrients causes increased growth of algae and bacteria. Suspended solids affect multiple parameters of stream functioning. They can reduce the amount of light available to aquatic plants and reduce photosynthetic production, absorb heat thereby increasing water temperature and reducing dissolved oxygen, and can suffocate aquatic and benthic organisms by clogging gills. Although Oregon has no criteria established for TSS, suspended solids are often correlated with other forms of pollution that enter waterways through runoff, including metals and pesticides. The Johnson Creek TMDL uses suspended solids as a surrogate for DDT contamination and targets a limit of 15 mg/L.

Total suspended solids concentration was measured at 33 sites in the Johnson Creek watershed between 2009 and 2014. The number of samples was greatest at the Sycamore fixed monitoring site (n=49), at the 354th Ave. and North Fork sites (n=38 each), and Stone (n=37), 282nd, and Milport (n=31 each). Agencies contributing data for total suspended solids are the City of Portland, City of Gresham, the EMSWCD, and the Oregon Department of Environmental Quality (DEQ). EMSWCD samples were collected monthly, while Gresham and Portland collect samples quarterly.

The Oregon DEQ has not established criteria limiting total suspended solids. A condition range criterion was used to determine the general water quality of sites in relation to TSS concentrations. The criteria used were interpretive range criteria and rate the concentration as “Good” “Fair” or “Poor” depending on a pre-determined threshold (see Table 3.E.3). Of the 439 samples collected, 327 were at or below the “Good” concentration range, with 82 samples exceeding the “Fair” range and 29 samples exceeding the “Poor” range.

Conclusions

Total suspended solids in the Johnson Creek watershed show a mixture of “Fair” and “Good” conditions on average. However, the maximum concentrations are usually many times the median value at each site, and maximum values are frequently in the “Poor” range. High concentrations of suspended solids could be found throughout the watershed, including mainstem and tributaries. Suspended solids are often increased in urban and agricultural areas due to enhanced runoff and erosion and channel incision caused by storm flows interacting with impervious surfaces and drainage networks. This mechanism could explain the disparity between low mean total suspended solids concentrations and high peak concentrations.

Tables

Table 3.E.1 Summary Statistics

Total Suspended Solids, mg/L	
n	439
Mean	20.38
Standard Error	5.49
Median	2.96
Minimum	0.002
Maximum	590

Table 3.E.2 Individual sample events by condition range

Condition, n				
Condition*	Mainstem, n	Mainstem, %	Tributary	Tributary, %
Poor	20	7%	9	6%
Fair	53	19%	29	18%
Good	205	74%	123	76%
Total	278		161	

Samples collected quarterly at each of 32 sites from 2009-2014.
* See ranges defined in table 3.E.3.

Table 3.E.3 Condition ranges

Index	*Quantity, mg/L*
Good	< 10
Fair	10 – 43
Poor	> 43

Based on interpretive range criteria

Figure 3.E.1 Mean sample concentrations of total suspended solids in mg/L. The horizontal bar at the center of each box represents the sample mean. The vertical box ends represent the 25th and 75th quantiles. Whisker bars represent the range of 1st and 4th quartiles. Points represent outlier values. Dashed lines across the figure represent the condition range thresholds (see Table 3.E.3). The number of observations in each sample is shown at top.

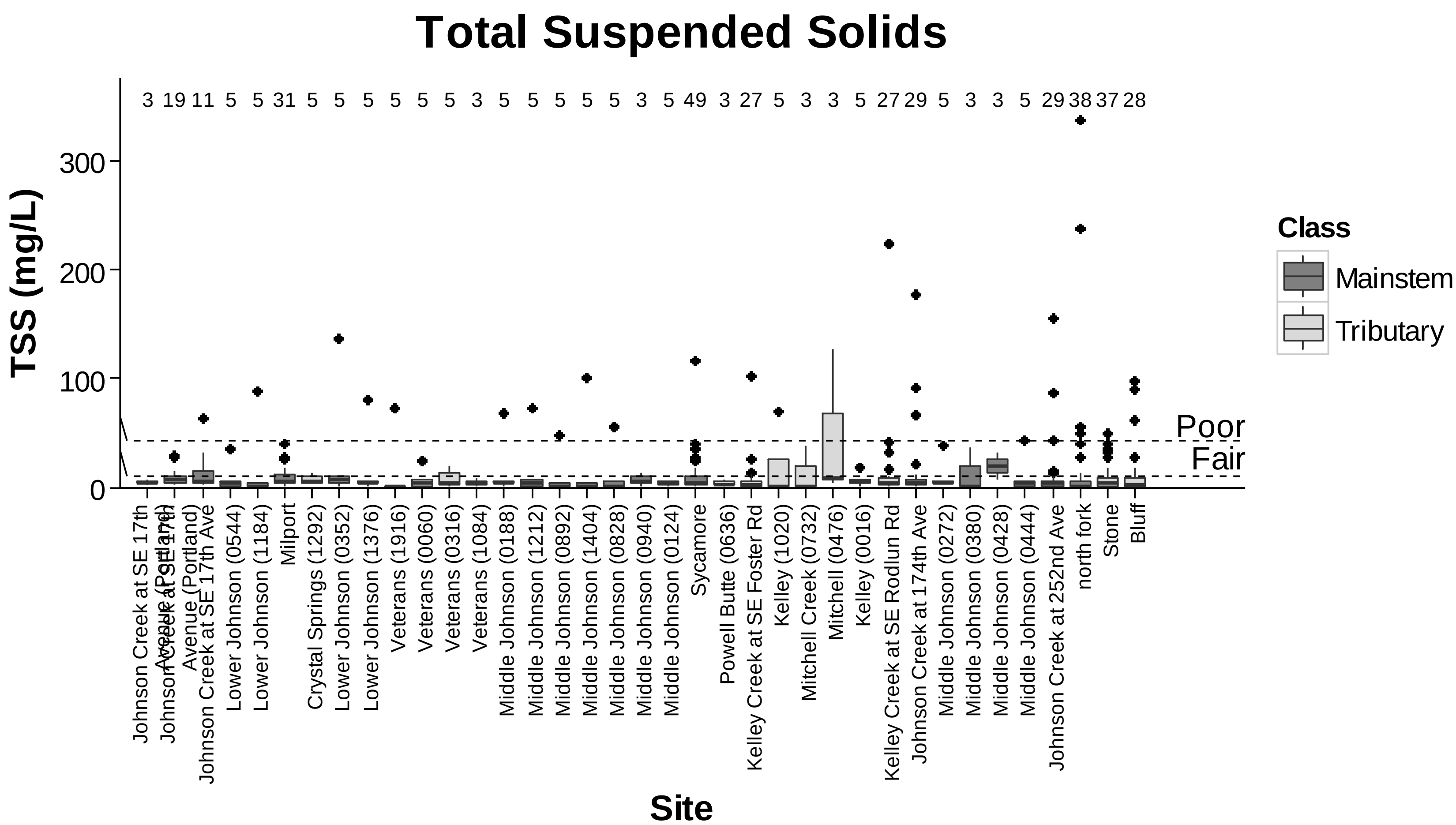


Figure 3.E.2 Mean TSS concentrations for the assessment period 2009-2014

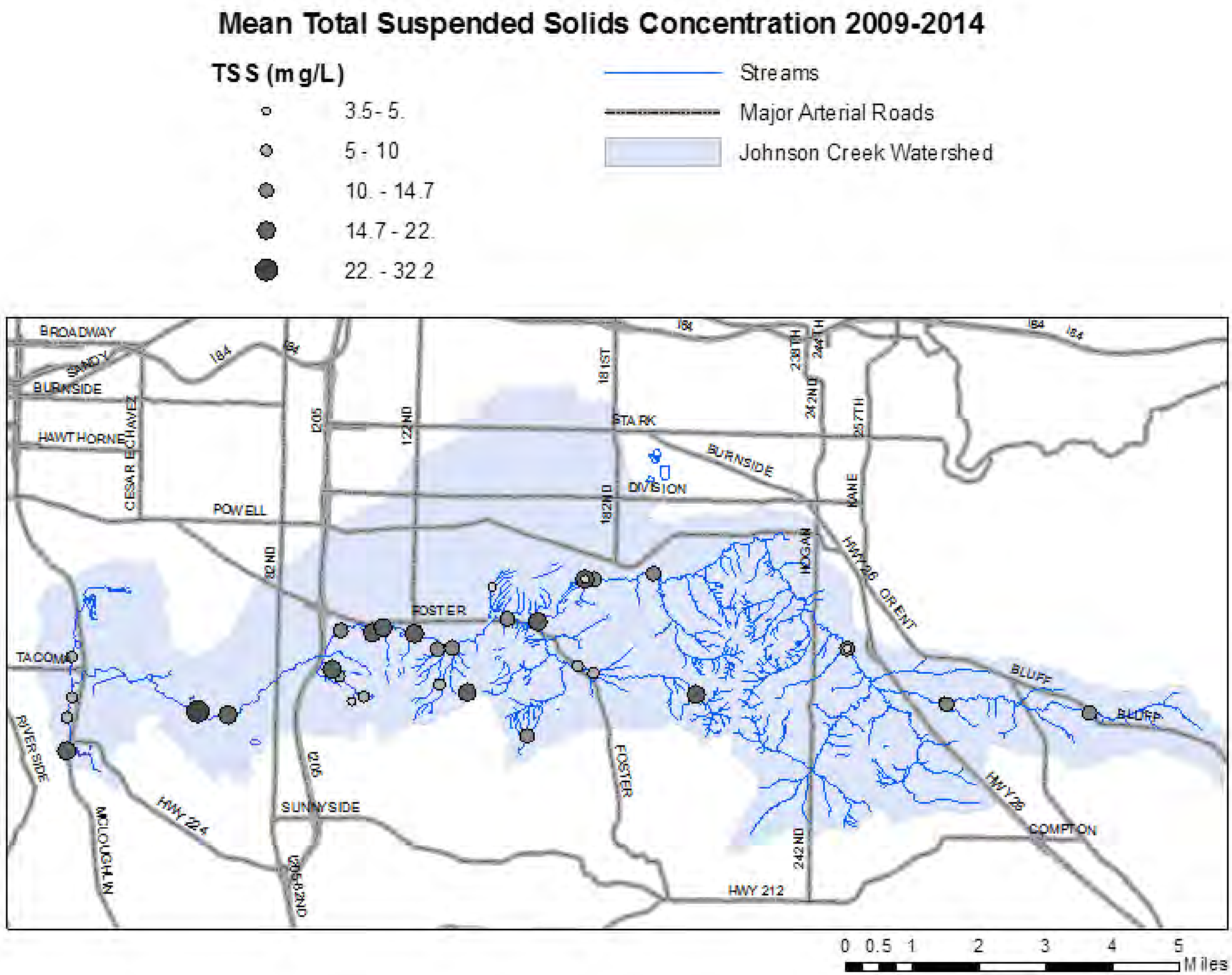


Figure 3.E.3 Stream condition using mean TSS concentrations compared to three-tiered interpretation criteria

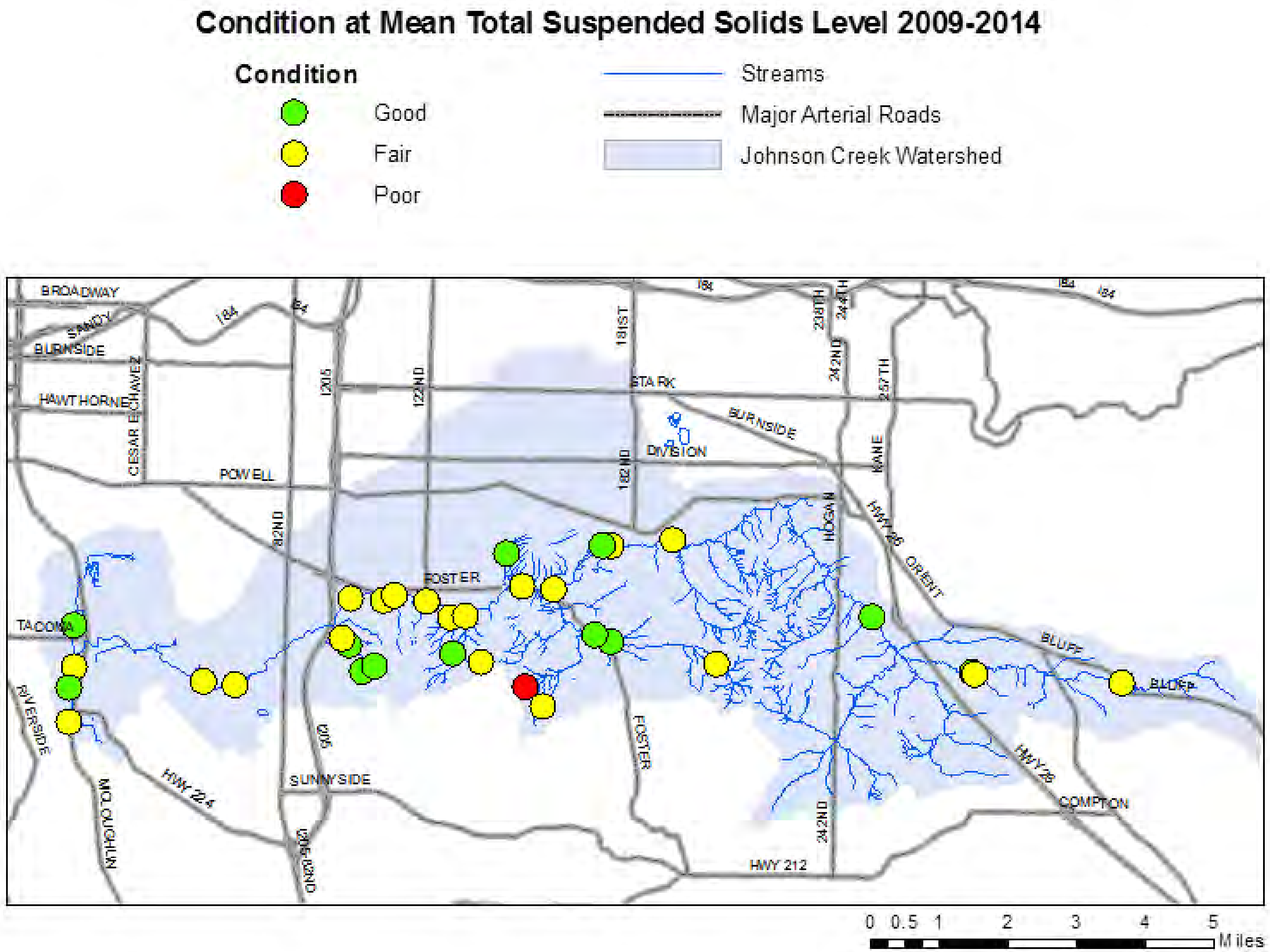
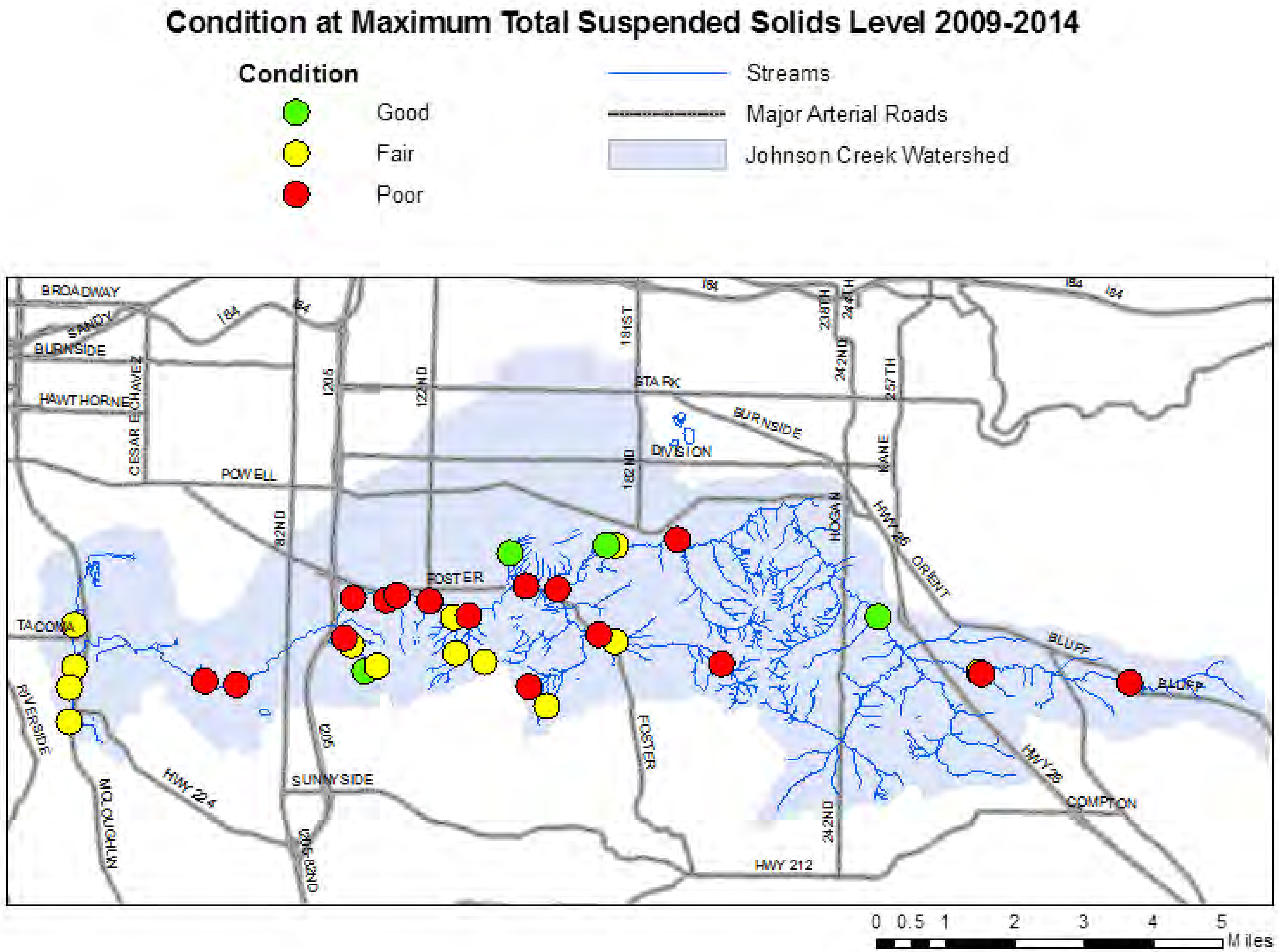


Figure 3.E.4 Stream condition using maximum TSS concentrations compared to three-tiered interpretation criteria



3.F. *E. coli*

E. coli is an indicator bacteria widely used in water quality assessment, and is a coliform bacteria associated with the intestinal tract of mammals. In water quality assessment, *E. coli* and other coliforms are measured to provide an estimate of the level of general sanitation and water pollution due to bacterial contamination of waters related to sewage leaks and animal waste. While most forms of *E. coli* do not directly cause disease, they can be found in association with more virulent species of bacteria and viruses, and serve as an indicator of the potential for wider contamination by diseases causing pathogens. *E. coli* are measured by growing colonies from individual bacteria found in a water sample. Colonies are counted and expressed as the most probable number (mpn) of individual bacteria that were in the sample. Freshwater systems are considered impaired for primary contact and recreation in Oregon if the 30-day mean of samples is greater than 126 mpn/100mL, or any one sample exceeds 406 mpn/100mL. A qualitative interpretive criterion was used to gauge the severity of impaired waters in addition to the DEQ standard; defining “Good” waters as being suitable for recreational contact at <100 mpn/100mL, and “Poor” waters having counts >930 mpn/100mL.

E. coli was measured at 39 sites in the Johnson Creek watershed between 2009 and 2014. The number of samples collected was greatest at sites sampled by the EMSWCD in the upper reaches of Johnson Creek, especially at Stone (n=38) and 354th Ave (n=35). The Sycamore fixed site for the City of Portland had the longest record (n=42 samples). The densest spatial sampling of *E. coli* data was collected on the mainstem reaches of Johnson Creek between SE 82nd and SE 182nd Ave. Agencies contributing data for *E. coli* were the City of Portland, City of Gresham, and the EMSWCD.

Sample collection was uneven. At some sites, samples were collected bimonthly on a regular basis, although the years of coverage for each sample differ by site and jurisdiction. Many sites were sampled infrequently, with only 3-5 samples collected. The City of Gresham and City of Portland sampled during the monitoring period from 2009-2014. The City of Portland PAWMAP measured sites 5 times annually but only for a one year duration at each site. The EMSWCD sampled four sites monthly from 2011-2014.

There were not generally enough samples (at least 5 within a 30 day period) to evaluate compliance with the 126 mpn/100mL standard. Although at sites where there was enough data, the 30-day mean was usually in excess of the 30-day average standard. The 1-time maximum standard of 406 mpn/100mL was exceeded at 26 of the 32 sites. A three-tiered condition range was also used to determine the general water quality of sites in relation to *E. coli* counts. *E.* coli counts were rated as “Good,”,” “Fair,”,” or “Poor” depending on a pre-determined threshold (see Table 3.F.3). Of the 398 samples collected at all sites, 150 samples met or were below the “Good” criterion, 214 samples were “Fair”, and 44 sample sites exceeded the “Poor” criterion during the time window of the assessment.

Conclusions

E. coli contamination of the Johnson Creek mainstem appears to be significant and widespread. Sites that exceed the DEQ water quality standards typically exceed both the 30-day average of 126 MPN/100mL and the single sample maximum of 406 MPN/100mL (Figure 3.F.2). For the 3-tiered interpretive criteria, mean count values are predominantly in the "Fair" range, while the maximum count values at each site sampled were in excess of the "Poor" criterion, and in violation of single-value maximum criterion for Oregon water quality standards by 2-3 orders of magnitude. Only 5 sites of the 39 had mean counts in the "Good" range, although none of the mean counts were in the "Poor" range. Exceedances of the "Fair" and "Poor" thresholds occurred year round, and were not confined to any particular seasons. The source of *E. coli* contamination is not readily determined. The likely sources are leaking or illegal sewage connections, malfunctioning or poorly maintained septic systems, domestic animals, wildlife, and biofilms both in stormwater pipes and naturally occurring in the stream sediment.

Tables

Table 3.F.1 Summary Statistics

E. coli, mpn/100mL	
n	398
Mean	434.9
Standard Error	73.2
Median	174.5
Standard Deviation	1286.3
Minimum	10.0
Maximum	20000

Table 3.F.2 Individual sample events by condition range

Condition, n				
Condition*	Mainstem, n	Mainstem, %	Tributary	Tributary, %
Poor	22	9%	22	6%
Fair	152	63%	64	42%
Good	70	28%	80	52%
Total	244		154	

Samples collected quarterly at each of 32 sites from 2009-2014.
* See ranges defined in table 3.F.3.

Table 3.F.3 Condition ranges

Index	*Quantity, mpn/100 mL*
Good	< 100
Fair	100 – 930
Poor	> 930

Figure 3.F.1 Mean sample concentrations of *E. coli* in mpn/100mL. The horizontal bar at the center of each box represents the sample median. The vertical box ends represent the 25th and 75th quantiles. Whisker bars represent the range of 1st and 4th quartiles. Points represent outlier values. Dashed lines across the figure represent the condition range thresholds (see Table 3.F.3). The number of observations for each site are shown above the bars at top.

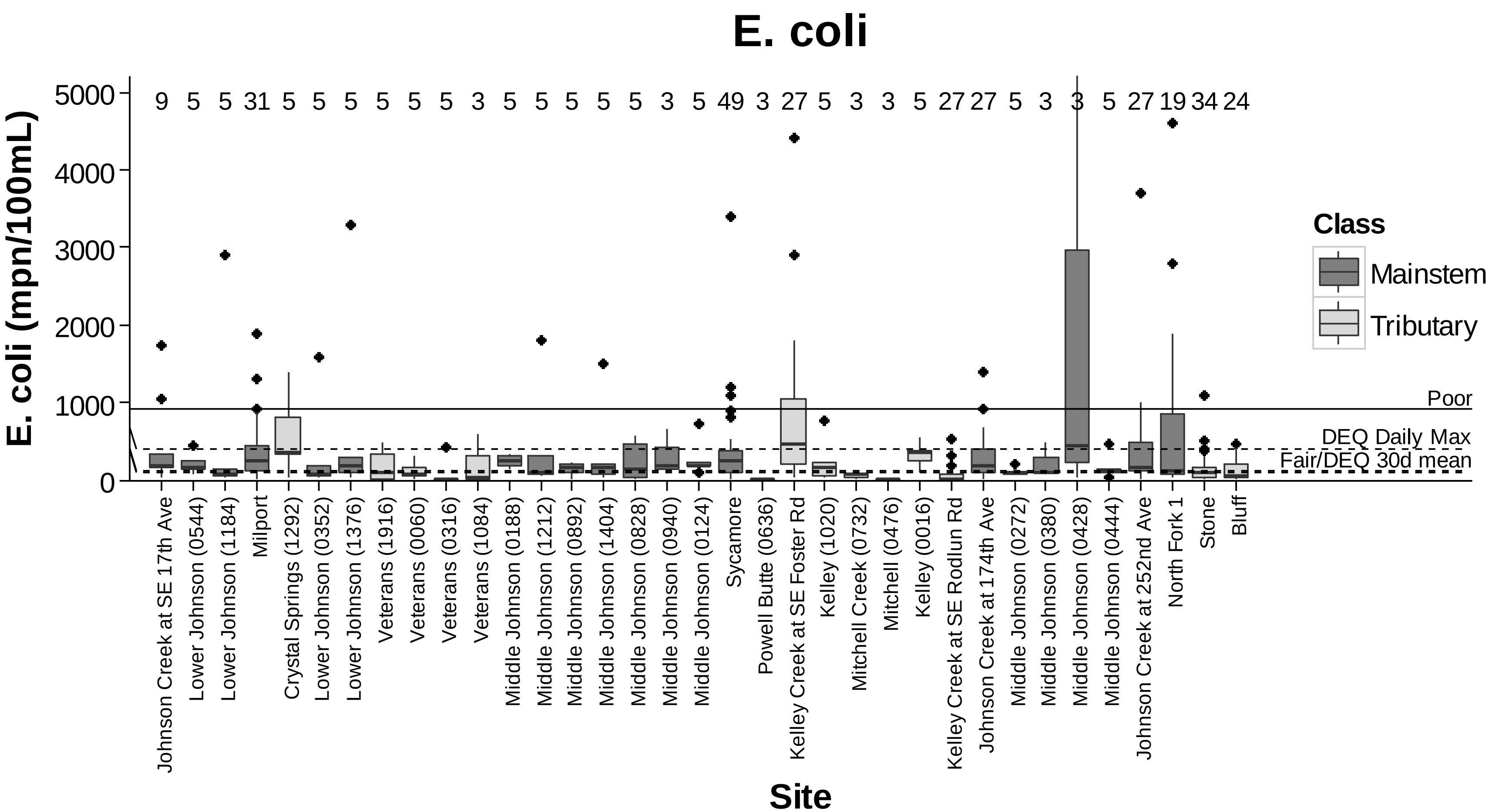


Figure 3.F.2 *E. coli* compliance with DEQ water quality standard. A site is considered to violate the standard if either the 30-day mean exceeds 126 MPN/100mL, -OR- any single sample exceeds 406 MPN/100mL.

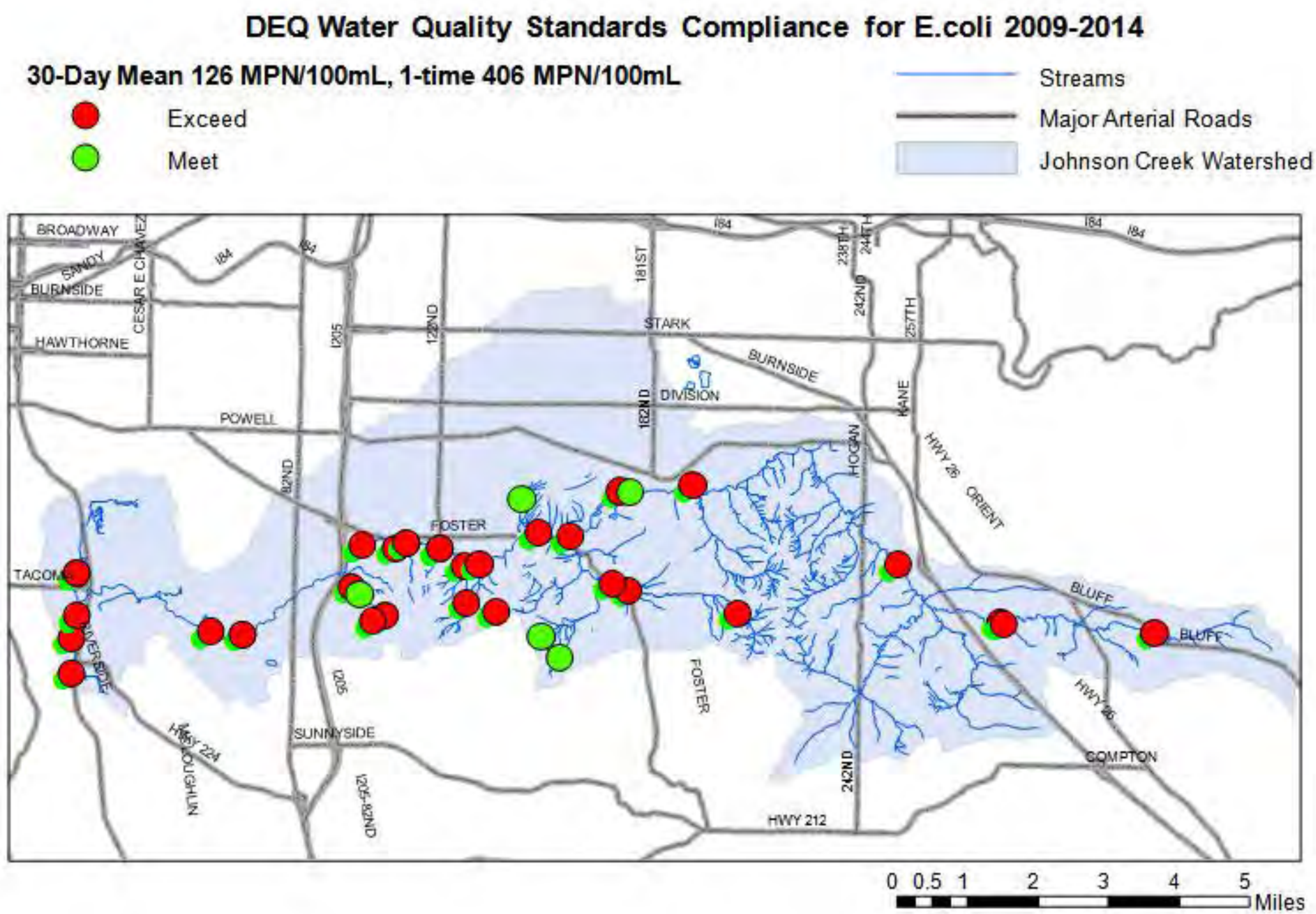


Figure 3.F.3 Mean *E. coli* concentrations for the assessment period 2009-2014

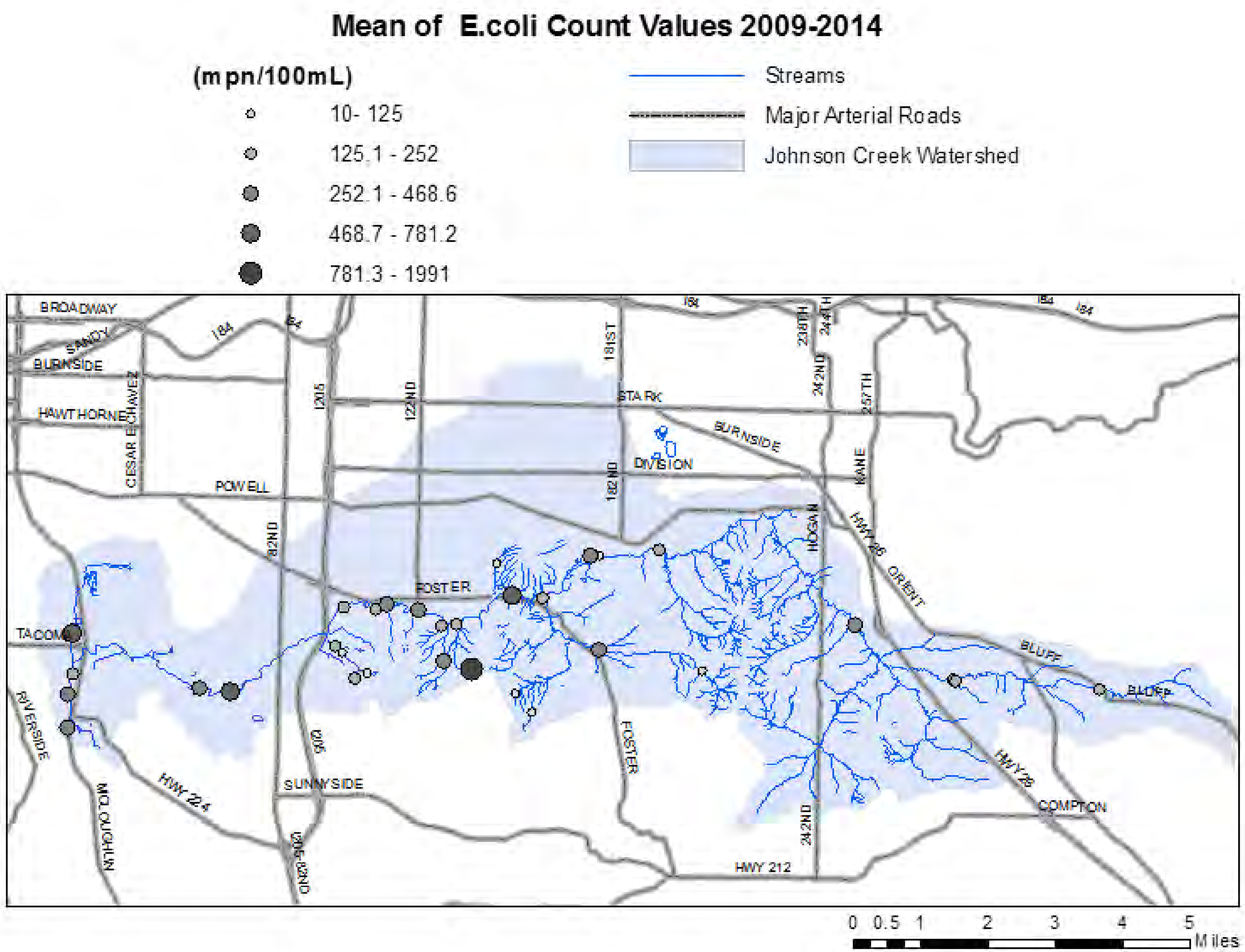


Figure 3.F.4 Stream condition using mean *E. coli* concentrations compared to three-tiered interpretation criteria

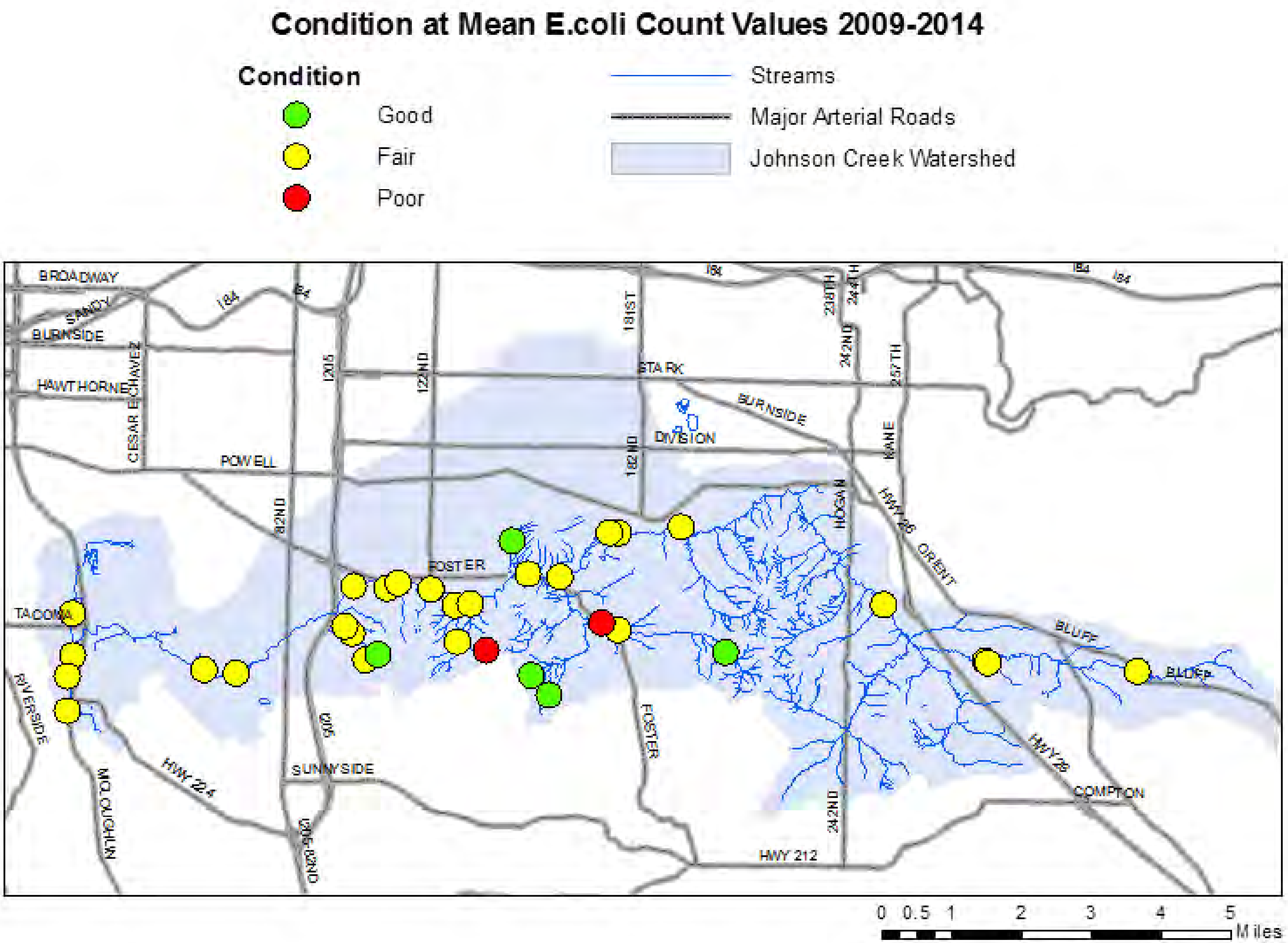
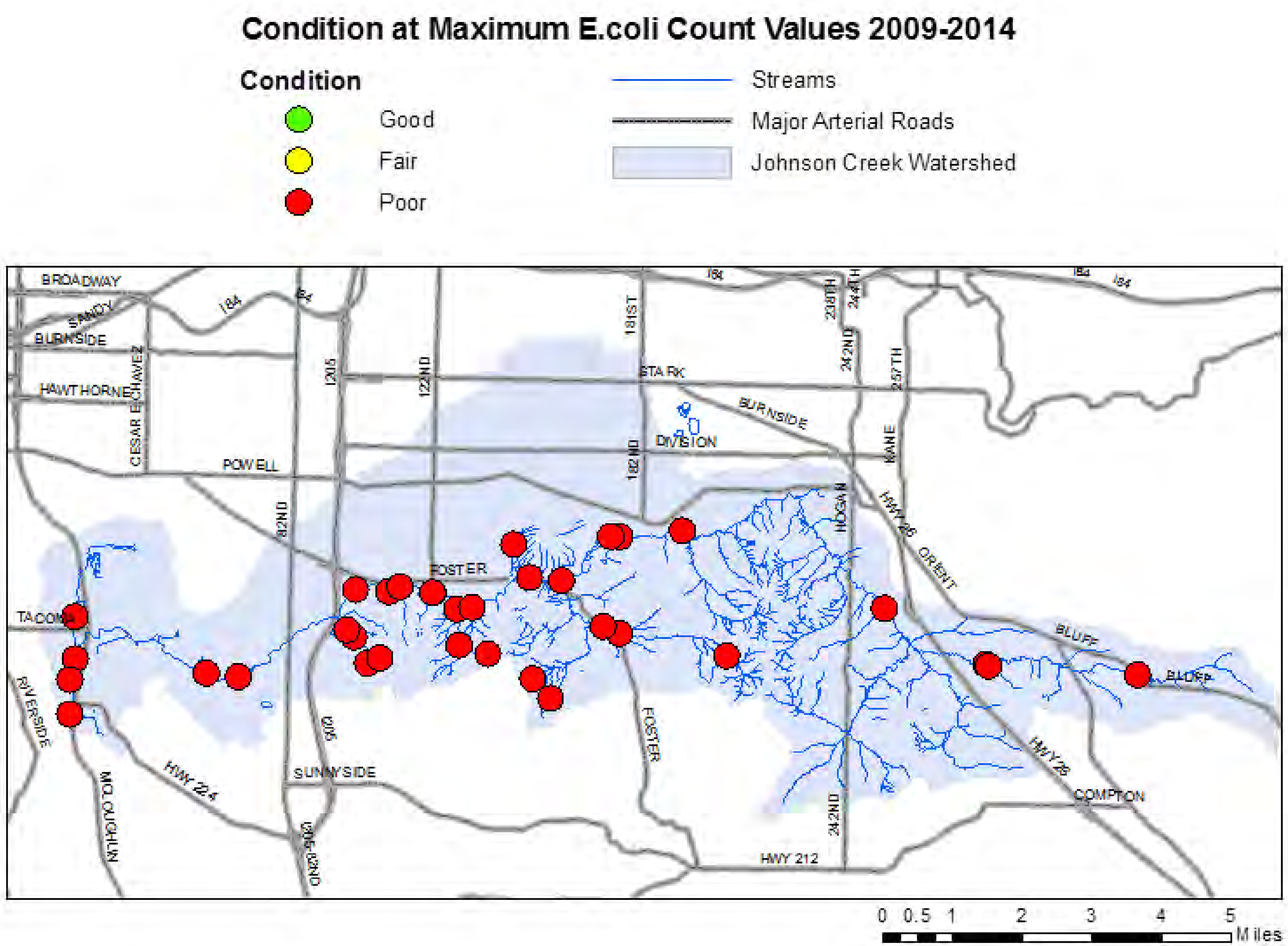


Figure 3.F.5 Stream condition using maximum *E. coli* concentrations compared to three-tiered interpretation criteria



Chapter 4 Macroinvertebrate Community

Biological communities are often used as indicators of the condition of a watershed. Biological communities integrate many aspects of watershed condition such as pollution, temperature, habitat quality, and other aspects. Because biological organisms often live in the stream throughout the year they can show the effects of events that might otherwise be missed by other types of monitoring.

The macroinvertebrate community was sampled at 60 sites from 2009 through 2013. Most of these sites were sampled only once. The plan for future monitoring is to begin to resample these sites. Sites were randomly selected using the Oregon Master Sample system developed by USEPA. At each site, a sample was collected using a 500µm D-frame net to collect organisms from eight one foot square areas of stream bottom following a defined pattern. Samples were preserved and sent to a commercial laboratory for processing and taxonomic identification.

The identification of taxa and counts of individuals by taxa are available for each sample. The data were analyzed by Jeff Meacham, a student at Portland State University. Over twenty interpretive metrics were calculated. For this condition assessment the Benthic Index of Biotic Integrity (B-IBI) was used.

Degree of Impairment	B-IBI Score	Number of sites
None	>40	3
Slight	30-39	3
Moderate	20-29	14
Severe	<20	40

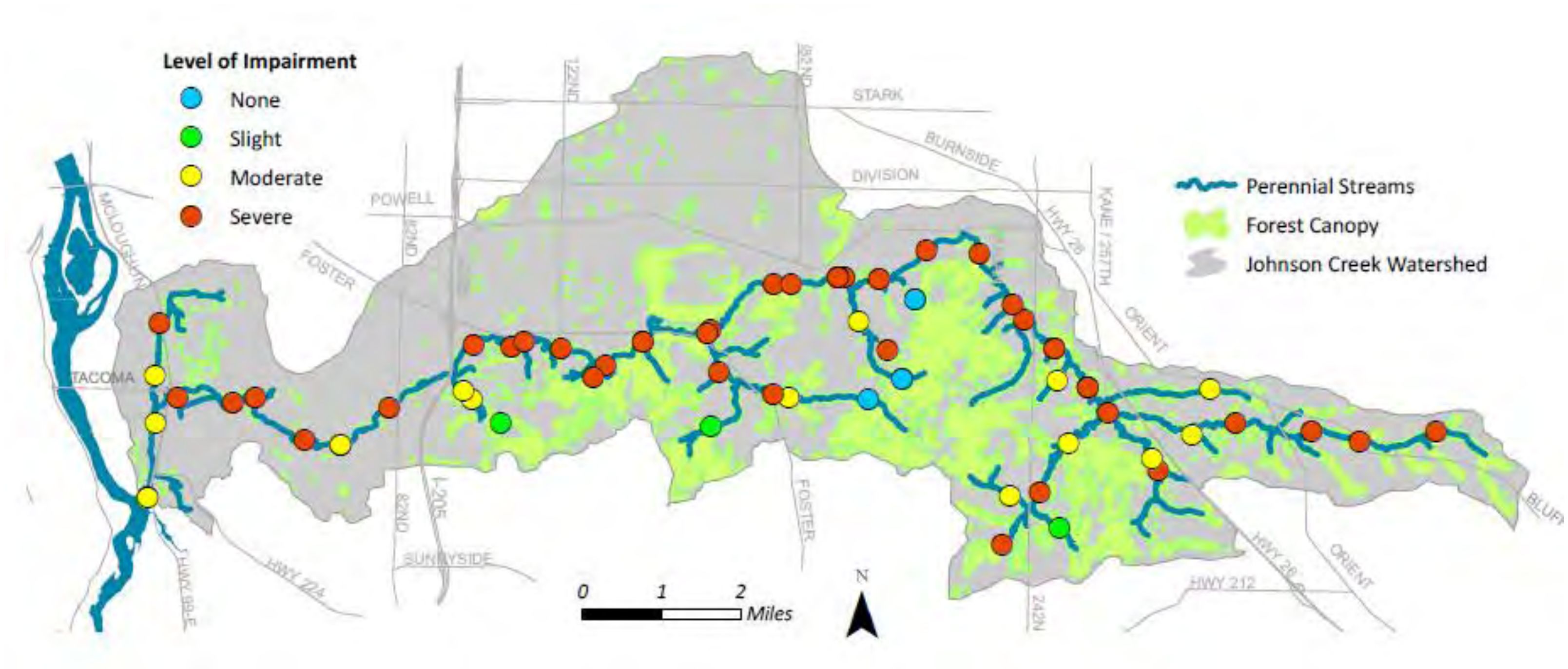
Of the 60 sites sampled, three sites exceeded the threshold for the “None” level of impairment, 3 sites were in the “Slight” range, 14 sites were in the ”Moderate” range, and 40 sites were in the “Severe” range.

The locations of the sites and their B-IBI condition are plotted on the following map.

Conclusions

The benthic macroinvertebrate community is highly degraded in the mainstem and in many of the tributaries. Figure 4.1 shows areas where the land cover is predominantly forest. The sites where the macroinvertebrate community was not impacted or only slightly impacted are all in the upper reaches of tributaries in forested areas.

Figure 4.1 Benthic Index of Biotic Integrity ratings at macroinvertebrate sampling sites.



5. Fish Community

Biological communities are often used as indicators of the condition of a watershed. Biological communities integrate many aspects of watershed condition such as pollution, temperature, habitat quality, and other aspects of water quality. Because biological organisms often live in the stream throughout the year they can show the effects of events that might otherwise be missed by other types of monitoring. Fish community sampling is more difficult than macroinvertebrate sampling. As a result, there have been a limited number of fish sampling studies in Johnson Creek. The following studies have been conducted:

- In 2011 and 2012 Multnomah County sponsored an electrofishing survey in spring and fall in the upper half of the watershed. Data is available at https://multco.us/file/13322/download.
- The City of Portland includes fish sampling as part of the PAWMAP program. Sites are sampled for fish once per year , and any given site is only sampled every fourth year.
- Oregon Department of Fish and Wildlife (ODFW) and the City of Portland in four City of Portland watersheds (Van Dyke and Storch, 2009) and earlier investigations in urban streams of the lower Willamette River watershed (Ward 1995; Friesen and Zimmerman 1999; Tinus et al. 2003).
- Johnson Creek Watershed Council conducts spawning surveys every fall using volunteers.

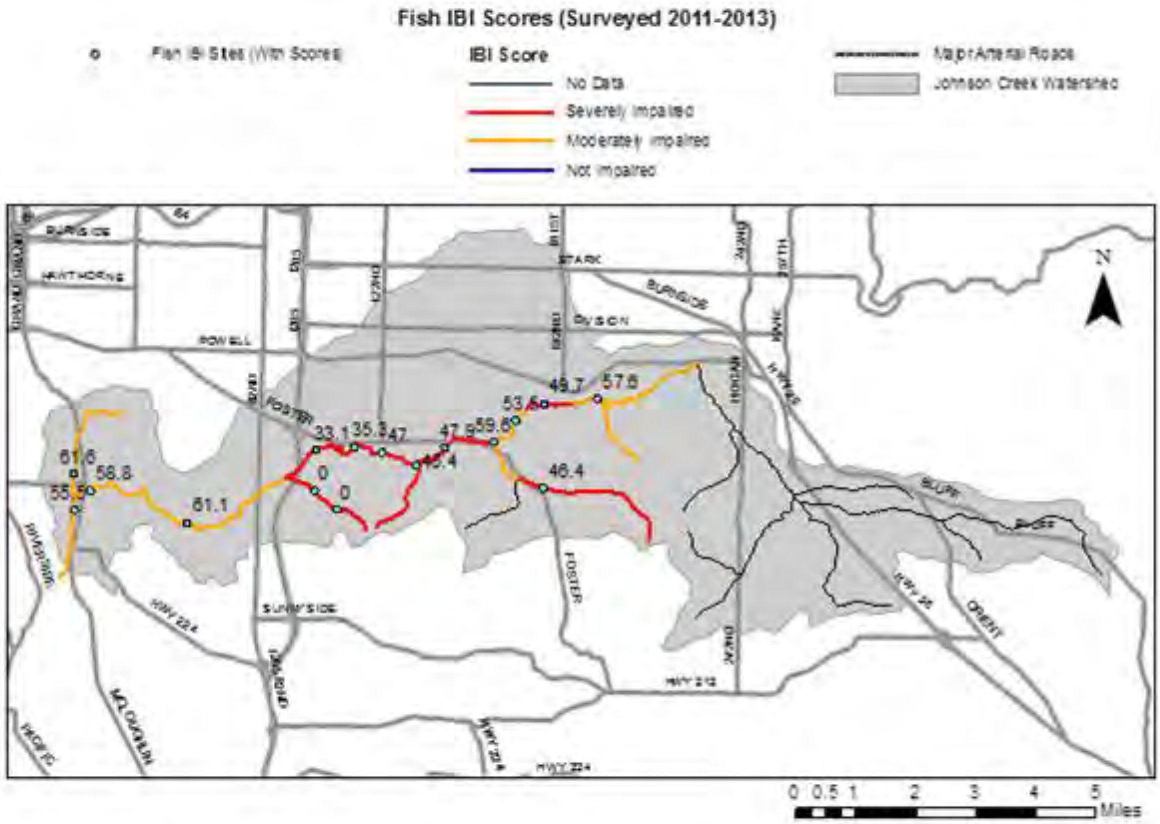
Lower Watershed Fish Community Monitoring

The City of Portland, as part of the PAWMAP program, monitors randomly selected sites within the City boundary. Data from the PAWMAP fish community monitoring are presented in Table 5.1. F-IBI scores from 50 to 75 are classified Marginally Impaired. F-IBI scores from 0 to 50 are classified Severely Impaired. No sites had F-IBI scores in the Not Impaired range (greater than 75). These results are mapped in Figure 5.1. The results indicate that the lower watershed fish communities are moderately to severely impaired. Veteran's Creek, lower Kelley Creek, and middle portions of the Johnson Creek mainstem were Marginally Impaired. Crystal Springs, Upper Kelley Creek, and stretches of Lower and Middle Johnson Creek mainstem were Severely Impaired. The two Veteran's Creek sites with F-IBI scores of zero were sites where there were no fish captured. These sites are upstream of fish passage barriers.

Table 5.1. Lower Johnson Creek F-IBI data

Site (PAWMAP)	Subwatershed	Sample Date	IBI Score
Crystal Springs (1292)	Crystal Springs	7/31/2012	61.6
Veterans (0060)	Veterans	8/5/2010	0.0
Veterans (0316)	Veterans	9/27/2012	0.0
Middle Johnson (0124)	Middle Johnson	8/10/2010	47.9
Middle Johnson (0272)	Middle Johnson	9/14/2010	49.7
Middle Johnson (0444)	Middle Johnson	7/28/2011	57.6
Middle Johnson (0828)	Middle Johnson	8/18/2011	46.4
Middle Johnson (0892)	Middle Johnson	9/23/2011	33.1
Middle Johnson (1212)	Middle Johnson	8/2/2012	35.3
Middle Johnson (1404)	Middle Johnson	8/23/2012	47.0
Middle Johnson (2320)	Middle Johnson	9/17/2013	53.5
Kelley (0016)	Kelley	8/19/2010	46.4
Kelley (1020)	Kelley	8/31/2011	59.6
Lower Johnson (0352)	Lower Johnson	8/24/2010	61.1
Lower Johnson (0544)	Lower Johnson	9/24/2011	55.5
Lower Johnson (1184)	Lower Johnson	9/6/2012	58.8

Figure 5.1 Fish IBI Scores in Lower Johnson Creek (2011-2014)



Upper Watershed Survey

In 2011 Multnomah County hired Wild Fish Conservancy (WFC) to conduct a stratified-random single-pass electrofishing survey in the upper watershed (upstream of Kelley Creek). Sampling occurred within 9 distinct reaches of mainstem Johnson Creek and major tributaries in September 2011. In addition, fish species composition at select locations within headwater reaches was also investigated during higher flows in March and April 2012. During the course of the September 2011 electrofishing surveys a total of 4,643 fish were netted, identified, and released. An additional 127 were handled in the supplemental spring 2012 surveys. WFC documented 10 native fish species and four non-native fish species during fall surveys and one additional non-native fish species during spring surveys.

Fish Index of Biotic Integrity (F-IBI) scores for the nine Upper Johnson Creek reaches are shown in the figure below. Scores below 50 are classified “Severely Impaired” and scores between 50 and 75 are classified “Marginally Impaired.” Three stream reaches (Butler, North Fork, and upper Sunshine) were classified Severely Impaired and seven reaches were classified Marginally Impaired. No reaches were classified “Not Impaired.”

Figure 5.2 Fish IBI Scores in Upper Johnson Creek (2011)

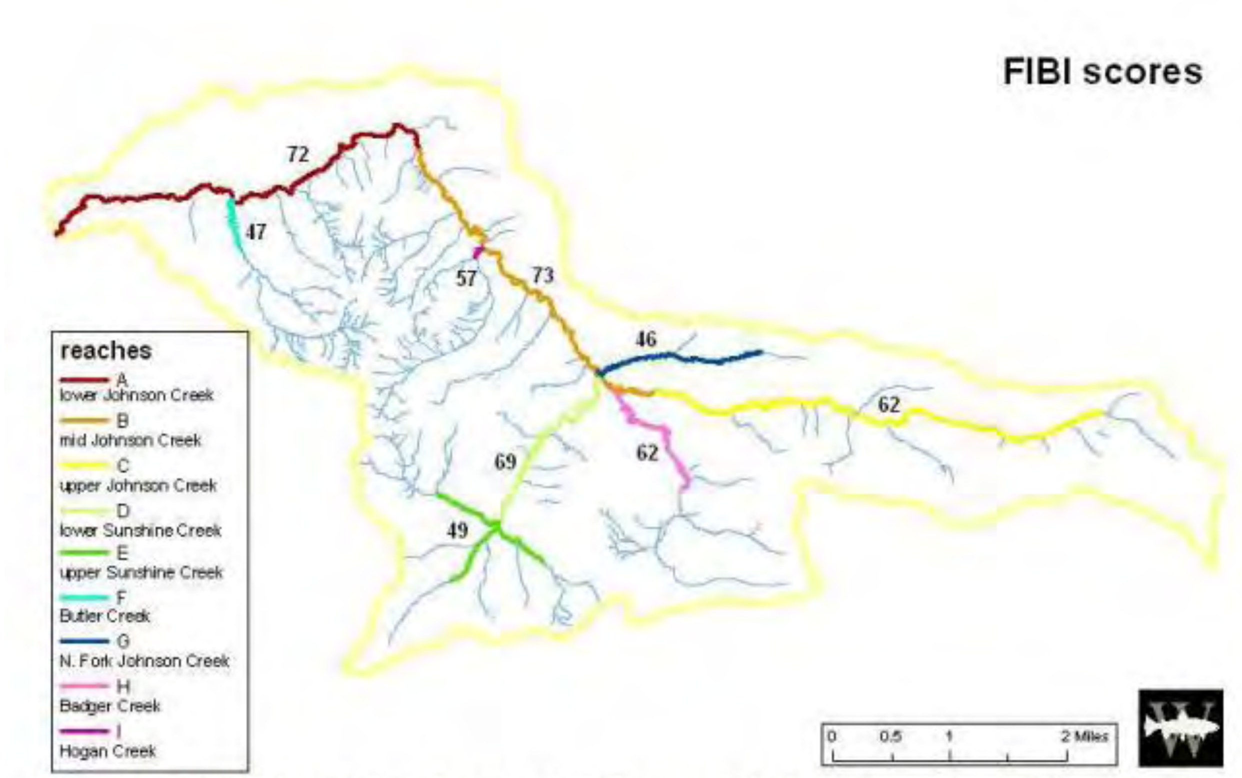
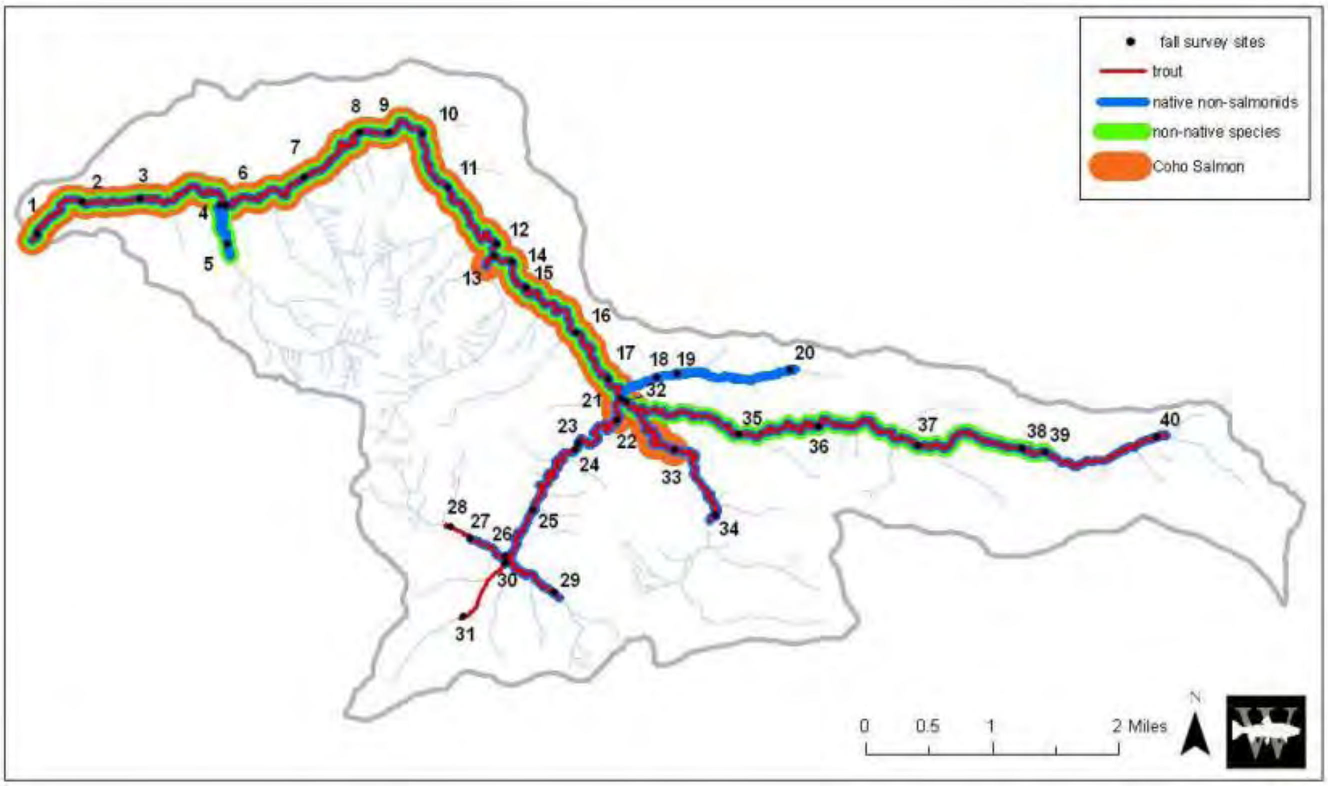


Figure 11. Fish Index of Biotic Integrity (F-IBI) scores calculated for reaches in Johnson Creek, OR, based on fish community data collected in fall 2011.

Occurrence information from the 2011 surveys of the upper watershed is presented in Figure 5.3. Native species or trout were present in every sampling location in the fall.

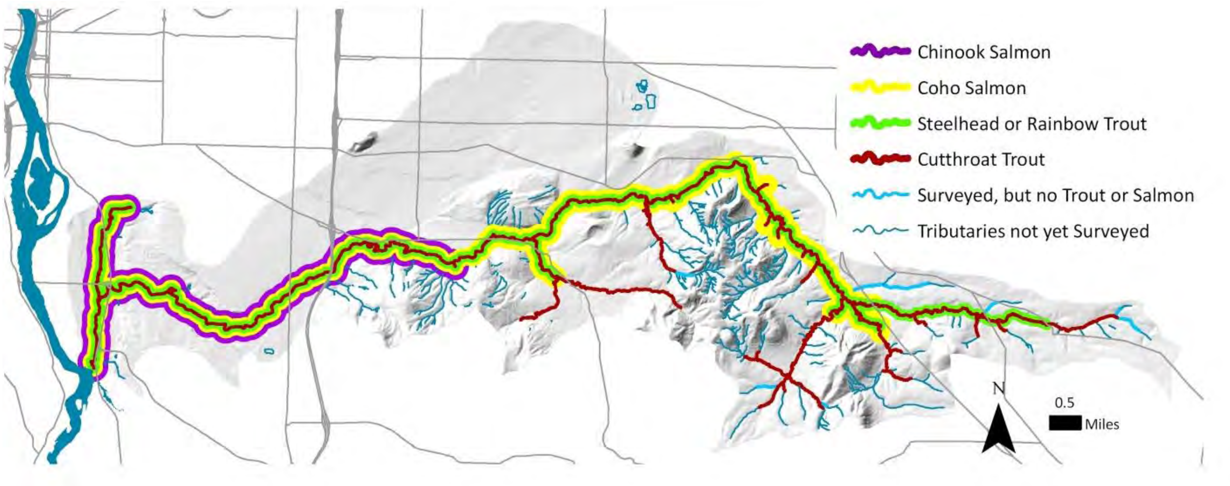
Figure 5.3 Species Occurrence in Upper Johnson Creek



Overall Watershed

Combining the upper watershed survey findings with other studies and the annual spawning survey results shows that the Johnson Creek watershed is able to sustain various salmonid species during certain times of the year.

Figure 5.2 Overall Watershed Salmonid Occurrence



Conclusions

All of the sites or reaches surveyed had F-IBI scores that fell in the Marginally Impaired (50 to 75) or Severely Impaired (0 to 50) ranges. This reflects low fish diversity. No sites had F-IBI scores in the Not Impaired range (greater than 75). Although the fish community throughout the watershed is impaired, it is not dominated by invasive species. Non-native fish species such as Bluegill, Pumpkinseed, and Largemouth Bass are present in the watershed but they do not dominate the fish community and constitute less than 1% of the community by number of individuals. Native species such as Redside Shiner, Reticulate Sculpin, Speckled Dace, and Cutthroat Trout dominate the fish communities and are found in the smallest tributaries. In addition, Coho Salmon, Steelhead, and Pacific Lamprey can be found in many reaches.

Chapter 6 Conclusions

The Johnson Creek watershed exhibits great spatial variability in water quality. There are tributaries in the watershed with few water quality limitations and good water quality. This is seen in the chemical/physical monitoring as well as in the biological (macroinvertebrate and fish) monitoring. However, the mainstem and the majority of tributaries exhibit degraded water quality.

Three water quality parameters had violations of State Water Quality Standards -- **water temperature**, ***E. coli***, and **total mercury**. However, there were only five sites with exceedances of the mercury standard.

There were no exceedances of State Water Quality Standards for **zinc**, **copper**, and **lead**. There are no State Water Quality Standards for **total suspended solids**.

In addition to comparing the monitoring data to State Water Quality Standards, we compared the data to a generally more stringent three-tiered classification of Good, Fair, or Poor. This analysis allowed assessment of conditions in ranges of pollution below State Water Quality Standards. The criteria for the three-tiered classification system were set by the authors.

High **water temperature** is a widespread problem within the watershed and may be the most significant limitation on aquatic communities. Even the upper reaches of many tributaries are in “poor” or “fair” condition for water temperature primarily due to loss of riparian shading. The headwaters of Botefuhr, Butler, Chastain, and Kelley Creeks were the only significant areas of the Johnson Creek stream network meeting the “good” criterion. All of the Johnson Creek mainstem and nearly all of the tributaries exceed 64.4°F/18°C at some point during the year, and much of the watershed exceeds the State Water Quality Standard for the majority of the summer. There are, however, some areas of cool water refuge in a few small tributaries in the mid-watershed.

Dissolved zinc concentrations are well below State Water Quality Standards. Zinc concentrations in the Johnson Creek watershed appear slightly elevated, with multiple exceedance of the “Good” criterion even at average concentrations. Sampling locations were limited to the lower reaches of the watershed, and focused on the mainstem and the Veteran’s Creek, Powell Butte, and Kelley Creek tributaries. Further analysis is required to definitively determine the risk to aquatic life from these zinc levels (particularly to adjust criteria for hardness). The headwaters of Veteran’s Creek (PAWMAP site 1084) and a site on Middle Johnson Creek (PAWMAP site 0428) appear to have zinc concentrations significantly higher than the rest of the watershed, and may warrant further investigation.

Total mercury concentrations in the Johnson Creek watershed tend to average between “Fair” and “Poor.” Most of the “Poor” samples occurred during storm events. Violations of State Water Quality Standards were infrequent (7 samples out of 257) and five sites exceeded the Standards in at least one sample. These exceedances occurred during storm events. Mercury contamination of Johnson Creek is relatively widespread, with hotspots that may indicate accumulation of mercury from upstream sources near the lower mainstem sites. These sites may reflect cumulative impacts of the drainage area as particulate mercury is flushed through the stream network. Mercury appears to be a pollutant of concern for Johnson Creek, although data on concentrations in fish and invertebrates would be more indicative of potential impacts to wildlife and human health than the values for concentrations within the water itself. No point sources are suggested by the data. Atmospheric deposition of particulate mercury onto urban landscapes, followed by transport to streams during storm events is a common route of contamination in urban areas.

Dissolved copper concentrations in the Johnson Creek watershed are generally within an acceptable range and rank in the "Good" or "Fair" categories for all sites. Of 298 samples only one sample exceeded the threshold for the "Poor" category and that sample was taken during an extreme storm event. There were no observed violations of State Water Quality Standards.

Dissolved lead concentrations in the Johnson Creek watershed are generally within an acceptable range and rank in the "Good" category for all but one site. Of the 297 samples collected at all sites, only one sample was in the "Fair" category and one sample was the "Poor" category. These fair and poor samples both occurred at one site. There were no observed violations of State Water Quality Standards.

Total suspended solids in the Johnson Creek watershed show a mixture of "Fair" and "Good" conditions on average. However, the maximum concentrations are usually many times the median value at each site, and are typically in the "Poor" range. This pattern of low concentrations most of the time with episodic high concentrations is typical of storm-driven runoff pollution or re-suspension of sediments. High concentrations of suspended solids could were found throughout the watershed, including mainstem and tributaries. Suspended solids are often increased in agricultural and urban areas due to increased surface runoff, erosion, and channel incision caused by storm flows interacting with impervious surfaces and drainage networks. This mechanism could explain the disparity between low mean total suspended solids concentrations and high peak concentrations.

E. coli is an indicator bacteria widely used in water quality assessment to provide an estimate of the level of general sanitation and water pollution due to bacterial contamination of waters related to warm-blooded organisms. While most forms of *E. coli* do not directly cause disease, they can be found in association with more virulent species of bacteria, and serve as an indicator of the potential for wider contamination by disease-causing bacteria. *E. coli* contamination of the Johnson Creek mainstem appears to be significant and widespread. Average values are predominantly in the "Fair" range, while the maximum values at each site sampled were in excess of the "Poor" criterion, and in violation of single-value maximum criterion for Oregon water quality standards by 2-3 orders of magnitude. Only five sites of the 39 had average values in the "Good" range, although none of the average values were in the "Poor" range. Exceedances of the "Fair" and "Poor" thresholds occurred year round, and were not confined to any particular seasons. The source of *E. coli* contamination is not readily determined. The primary sources are probably wildlife and/or domestic animals and biofilms, although it is possible that malfunctioning or poorly maintained septic or sewer systems could be a source.

Macroinvertebrate community sampling shows that conditions are moderately to severely degraded throughout most of the watershed. However, there are areas within the watershed with healthy macroinvertebrate communities. Of the 60 sites sampled, three sites rated "no impairment" and 3 sites rated "slight impairment." These sites are all in forested headwaters. Fourteen sites were rated "moderately impaired." The remaining 40 sites were "severely impaired."

Fish community sampling shows that conditions are marginally to severely impaired throughout the watershed. All of the sites or reaches surveyed had F-IBI scores that fell in the Marginally Impaired or Severely Impaired ranges. This reflects low fish diversity. No sites had F-IBI scores in the Not Impaired range. Although the fish community throughout the watershed is impaired, it is not dominated by invasive species. Non-native fish species such as Bluegill, Pumpkinseed, and Largemouth Bass are present in the watershed but they do not dominate the fish community and constitute less than 1% of the community by number of individuals. Native species such as Redside Shiner, Reticulate Sculpin, Speckled Dace, and Cutthroat Trout dominate the fish communities and are found in the smallest tributaries. In addition, Coho Salmon, Steelhead, and Pacific Lamprey can be found in many reaches.

The monitoring data indicate that the mainstem and the major tributaries exhibit degraded water quality. The most significant water quality problems are temperature, *E. coli*, and total suspended solids. In addition, there may be potential pollution problems with mercury. The macroinvertebrate community sampling also shows impacts to the biological community in the mainstem and major tributaries. However, the macroinvertebrate sampling indicates healthy conditions in several of the less developed upper tributaries. The fish community sampling shows marginally impaired to severely impaired communities throughout the watershed. However, non-native fish species are not a significant problem and native salmonids are present in many reaches.

Chapter 7. Data Archive

This section provides a description of how the data assembled for this assessment are organized and how to access them for future use.

Data used in this report were compiled from multiple organizations and assembled into three Excel spreadsheets: (1) Water Quality Parameters; (2) Hourly Summertime Stream Temperatures; and (3) Macroinvertebrates.

The Water Quality Parameters excel spreadsheet contains grab sample results for metals (copper, zinc, lead, and mercury), *E. coli*, and total suspended solids. Data was included for years 2009 to 2014. It was compiled by James McConaghie (JCWC contractor).

The hourly summertime stream temperature database includes records from 179 temperature probes from 85 sites monitored between 2009 and 2014. It was compiled in an excel workbook by Robin Jenkinson (JCWC), Nicole Czarnomski (ESA-Vigil Agrimis), and Brian Pyper (Fish Metrics). Hourly air temperature from the Portland Airport was added for future comparison.

The macroinvertebrate database includes records from the City of Portland's PAWMAP sampling as well as from the Johnson Creek Inter-Jurisdictional Committee's monitoring from 2009-2013 and was compiled by Jeff Meacham (PSU graduate student), Torrey Lindbo (City of Gresham), and Roy Iwai (Multnomah County).

These spreadsheet files are stored on the Johnson Creek Watershed Council server under Monitoring in a folder titled "2009-2014 Monitoring Database." Contact the Johnson Creek Watershed Council to obtain a copy of these databases.

Station names and locations are provided in Appendix 1.1

Appendix 1. Station names and locations

Field descriptions for the Table of Monitoring Sites on the following pages.

Field	Description
Site	Site name (these have been standardized and often do not reflect a site name or code used by a given agency)
Trib	Name of the tributary to Johnson Creek (can be a first-order or second-order tributary)
Agency	Agency that collected the data. There may be more than agency per site across years (agency by year should be noted in "Notes" field)
JC_RM	Johnson Creek mainstem river mile
Trib_RM	First-order tributary river mile (from confluence with Johnson Creek)
Sub_RM	Second-order tributary river mile (from confluence with first-order tributary)
Latitude	Latitude of site location
Longitude	Longitude of site location
Notes	Comments detailing agency site names, specific data sources, issues, etc.

Site	Trib	Agency	JC_RM	Trib_RM	Sub_RM	Latitude	Longitude	Notes
287th Trib @ 287th	287th Tributary	JCWC	18.9	0.3	NA	45.458947	-122.3677	
287th Trib @ mouth	287th Tributary	JCWC	18.9	0.1	NA	45.461802	-122.3725	
Air temp @ PDX	NA	NA	NA	NA	NA	NA	NA	
Badger @ 9770 Telford	Badger Creek	JCWC	17.8	1.7	NA	45.45214	-122.3804	
Badger @ Coachman	Badger Creek	JCWC	17.8	2.3	NA	45.444292	-122.3854	
Badger @ Rugg	Badger Creek	Gresham	17.8	0.6	NA	45.460186	-122.3879	
Bear @ mouth	Butler Creek	Gresham	12.7	0.9	0.1	45.478299	-122.4581	
Botefuhr @ mouth	Botefuhr Creek	Gresham	16.8	0.0	NA	45.475876	-122.4088	
Butler @ 14th	Butler Creek	Gresham	12.7	0.1	NA	45.486625	-122.4619	
Butler @ Butler/Towle	Butler Creek	Gresham/JCWC	12.7	2.1	NA	45.470233	-122.4482	2011 JCWC; 2013 Gresham
Butler @ Willow	Butler Creek	Gresham	12.7	1.3	NA	45.474281	-122.4566	
Butler d/s of Binford	Butler Creek	Gresham	12.7	0.4	NA	45.483942	-122.4612	
Butler u/s of Bear	Butler Creek	Gresham	12.7	0.9	NA	45.478185	-122.4574	
Butler u/s of Binford	Butler Creek	Gresham	12.7	0.5	NA	45.482472	-122.4607	
Chastain @ mouth	Chastain Creek	Gresham	13.4	0.0	NA	45.488338	-122.451	
Clatsop @ mouth	Kelley Creek	JCWC	10.5	0.5	0.1	45.470072	-122.4957	2012 September data gets weird!
Crystal Springs @ Bybee	Crystal Springs	USGS	1.4	1.0	NA	45.474117	-122.6418	
Crystal Springs @ Lexington	Crystal Springs	Portland	1.4	0.5	NA	45.466996	-122.6425	PAWMAP 1292
Crystal Springs @ mouth	Crystal Springs	USGS	1.4	0.1	NA	45.461418	-122.6423	
Crystal Springs @ SE 28th	Crystal Springs	JCWC	1.4	1.7	NA	45.482029	-122.6374	
Deardorff @ mouth	Deardorff Creek	Portland/JCWC	8.9	0.1	NA	45.471258	-122.5253	2011 PAWMAP 0828; 2012 JCWC
Deardorff @ mouth (duplicate)	Deardorff Creek	JCWC	8.9	0.1	NA	45.471258	-122.5253	
E Fk Butler @ 27th	Butler Creek	Gresham	12.7	1.0	0.1	45.476739	-122.4547	
E Fk Sunshine @ Sunshine Valley	Sunshine Creek	JCWC	17.6	1.8	0.6	45.443159	-122.4063	

Site	Trib	Agency	JC_RM	Trib_RM	Sub_RM	Latitude	Longitude	Notes
Rd/250th								
E Fk Wahoo d/s of Flavel	Wahoo Creek	JCWC	8.6	0.3	NA	45.468519	-122.5288	
Errol Springs @ mouth	Errol Springs	JCWC	2.9	0.0	NA	45.463509	-122.6175	
Errol Springs @ SE 45th	Errol Springs	JCWC	2.9	0.1	NA	45.463403	-122.6158	
Heiney Creek @ mouth	Heiney Creek	Gresham	13.1	0.0	NA	45.487808	-122.454	
Hogan @ Butler Rd	Hogan Creek	Gresham	16.1	1.2	NA	45.468519	-122.4224	
Hogan @ mouth	Hogan Creek	Gresham	16.1	0.1	NA	45.481364	-122.4176	
Jenne @ mouth	Kelley Creek	Gresham	10.5	0.3	0.0	45.473663	-122.4968	
Johnson @ 110th	Johnson Creek	Portland	7.8	NA	NA	45.473859	-122.55	PAWMAP 0188
Johnson @ 122nd	Johnson Creek	Portland	8.8	NA	NA	45.473958	-122.537	PAWMAP 1404
Johnson @ 17th	Johnson Creek	JCWC	0.2	NA	NA	45.446643	-122.6433	
Johnson @ 26th	Johnson Creek	Portland	2.0	NA	NA	45.46302	-122.6365	PAWMAP1184
Johnson @ 282nd	Johnson Creek	EMSWCD	18.9	NA	NA	45.461922	-122.3728	
Johnson @ 307th	Johnson Creek	JCWC	20.2	NA	NA	45.460794	-122.3472	
Johnson @ 49th	Johnson Creek	Portland	3.4	NA	NA	45.45894	-122.6126	PAWMAP 2208
Johnson @ 67th	Johnson Creek	Portland	4.5	NA	NA	45.455323	-122.5938	PAWMAP 1376
Johnson @ Ambleside	Johnson Creek	Gresham	16.3	NA	NA	45.478107	-122.412	
Johnson @ Barbara Welch	Johnson Creek	Portland	9.8	NA	NA	45.475622	-122.5155	PAWMAP 0124
Johnson @ Bluff Road, west of Altman	Johnson Creek	JCWC	21.2	NA	NA	45.460297	-122.3282	
Johnson @ Brookside Wetlands	Johnson Creek	Portland	8.0	NA	NA	45.475033	-122.5466	PAWMAP 1212
Johnson @ Circle Ave	Johnson Creek	Portland	11.4	NA	NA	45.482519	-122.4916	PAWMAP 2320
Johnson @ Confluence near Spring Outlet	Johnson Creek	JCWC	0.1	NA	NA	45.444902	-122.6432	
Johnson @ Gresham Woods	Johnson Creek	Gresham	12.8	NA	NA	45.486532	-122.4611	
Johnson @ Hwy 224	Johnson Creek	JCWC	0.5	NA	NA	45.448877	-122.6428	
Johnson @ Jenne Rd	Johnson Creek	Gresham/Portland	11.4	NA	NA	45.486598	-122.482	PAWMAP 0272; Gresham other years.

Site	Trib	Agency	JC_RM	Trib_RM	Sub_RM	Latitude	Longitude	Notes
Johnson @ Main City	Johnson Creek	Gresham	14.6	NA	NA	45.495869	-122.4304	
Johnson @ Milport/Milwaukie	Johnson Creek	USGS	0.8	NA	NA	45.453153	-122.6433	
Johnson @ Ochoco	Johnson Creek	Portland	0.4	NA	NA	45.45825	-122.642	PAWMAP 0544
Johnson @ Palmblad/252nd	Johnson Creek	Gresham	17.0	NA	NA	45.472871	-122.4034	
Johnson @ Pleasant Home/Revenue	Johnson Creek	EMSWCD	20.7	NA	NA	45.461753	-122.3369	
Johnson @ Pleasant Home/Revenue (duplicate)	Johnson Creek	JCWC	20.7	NA	NA	45.461753	-122.3369	
Johnson @ Regner	Johnson Creek	USGS	15.6	NA	NA	45.486488	-122.4218	
Johnson @ Stanley	Johnson Creek	Portland	3.9	NA	NA	45.455805	-122.6032	PAWMAP 0352
Johnson @ Sycamore	Johnson Creek	USGS	10.0	NA	NA	45.477497	-122.5077	
Johnson @ Telford	Johnson Creek	Gresham	17.8	NA	NA	45.464446	-122.3927	
Johnson d/s of Butler Ck	Johnson Creek	Portland	12.6	NA	NA	45.488222	-122.4638	PAWMAP 0444
Johnson u/s of Errol Springs	Johnson Creek	Portland	3.0	NA	NA	45.463446	-122.6179	PAWMAP 1612
Kelley @ 176th	Kelley Creek	Portland	10.5	1.5	NA	45.466344	-122.4815	PAWMAP 0016
Kelley @ 190th	Kelley Creek	Gresham/JCWC	10.5	2.1	NA	45.46589	-122.4666	2013 JCWC (beaver dam!); 2014 Gresham
Kelley @ Bradshaw	Kelley Creek	JCWC	10.5	1.8	NA	45.465381	-122.4736	
Kelley @ mouth/159th	Kelley Creek	USGS	10.5	0.1	NA	45.476952	-122.4982	
Kelley @ mouth/159th (duplicate)	Kelley Creek	Portland	10.5	0.1	NA	45.476952	-122.4982	2009 Portland KC2; 2011 PAWMAP 1020
Kelley @ PV Grange	Kelley Creek	Gresham	10.5	1.0	NA	45.467845	-122.4873	
Kelley @ Rodlun/Aldercrest	Kelley Creek	Gresham	10.5	3.2	NA	45.462262	-122.4496	
Kelley @ Rodlun/Aldercrest (duplicate)	Kelley Creek	Portland	10.5	3.2	NA	45.462262	-122.4496	KC1
Kelley u/s of Clatsop	Kelley Creek	JCWC	10.5	0.6	NA	45.470262	-122.4951	

Site	Trib	Agency	JC_RM	Trib_RM	Sub_RM	Latitude	Longitude	Notes
Meadow @ mouth	Meadow Creek	Gresham	15.7	0.1	NA	45.485937	-122.4217	
Miller @ mouth	Miller Creek	Gresham	14.8	0.0	NA	45.493552	-122.4289	
Mitchell @ 162nd	Kelley Creek	Portland/JCWC	10.5	0.8	1.0	45.460208	-122.497	2009 Portland MC1; 2013/14 JCWC
Mitchell @ Baxter Rd	Kelley Creek	JCWC	10.5	0.8	0.6	45.462104	-122.491	
Mitchell @ mouth	Kelley Creek	Portland	10.5	0.8	0.1	45.468613	-122.4909	MC2
Mitchell d/s of Centennial Pond	Kelley Creek	JCWC	10.5	0.8	0.2	45.466896	-122.4915	
Mitchell u/s of Centennial Pond	Kelley Creek	JCWC	10.5	0.8	0.3	45.465321	-122.4911	
N Fk Johnson @ Headwaters Farm	North Fork Johnson Creek	EMSWCD	17.6	1.5	NA	45.469268	-122.3685	
N Fk Johnson @ Telford	North Fork Johnson Creek	Gresham	17.6	0.1	NA	45.466373	-122.3952	
Nechacokee @ mouth	Nechacokee Creek	Gresham	15.8	0.1	NA	45.484358	-122.4204	
Revenue Trib @ mouth	Revenue Tributary	JCWC	20.3	0.0	NA	45.460686	-122.345	
Spring Creek @ Harrison	Spring Creek	JCWC	0.5	0.3	NA	45.446432	-122.6372	
Spring Creek u/s of Waldorf School	Spring Creek	JCWC	0.5	0.4	NA	45.445007	-122.6355	
Sunshine @ Rugg	Sunshine Creek	Gresham/JCWC	17.6	1.0	NA	45.459955	-122.4027	
Sunshine @ Sunshine Valley Rd	Sunshine Creek	JCWC	17.6	2.5	NA	45.447067	-122.4133	
Thom @ mouth	Thom Creek	Gresham	15.2	0.1	NA	45.489821	-122.4253	
Thompson @ mouth	Thompson Creek	Gresham	14.7	0.0	NA	45.49596	-122.4307	
Veterans @ 102nd	Veterans Creek	Portland	6.4	0.4	NA	45.464335	-122.5599	PAWMAP 0060
Veterans @ 98th	Veterans Creek	JCWC	6.4	0.2	NA	45.465782	-122.5621	
Veterans @ mouth	Veterans Creek	JCWC	6.4	0.0	NA	45.468236	-122.565	
W Fk Sunshine @ 242nd	West Fork Sunshine Creek	JCWC	17.6	1.7	0.1	45.447283	-122.414	
W Fk Sunshine @ Borges	West Fork Sunshine Creek	JCWC	17.6	1.7	0.4	45.449544	-122.4208	

Appendix 2. Number of temperature monitoring records by site and by year.

Site	2009	2010	2011	2012	2013	2014	Total
287th Trib @ 287th				3373			3373
287th Trib @ mouth					3050		3050
Air temp @ PDX	3671	3672	3672	3672	3672	3672	22031
Badger @ 9770 Telford						3409	3409
Badger @ Coachman		1629	1429			3408	6466
Badger @ Rugg	3672		3504	3576	3517	3552	17821
Bear @ mouth					3517		3517
Botefuhr @ mouth				3576			3576
Butler @ 14th	3672				3517	3552	10741
Butler @ Butler/Towle			1436		3517		4953
Butler @ Willow					3517		3517
Butler d/s of Binford			3504		3517		7021
Butler u/s of Bear					3517		3517
Butler u/s of Binford					3517		3517
Chastain @ mouth				3576			3576
Clatsop @ mouth				3372	3339		6711
Crystal Springs @ Bybee	3672	3670	3671	3671	3348	3420	21452
Crystal Springs @ Lexington				3285			3285
Crystal Springs @ mouth	3672	3670	2667	3672	3672	1139	18492
Crystal Springs @ SE 28th					3405		3405
Deardorff @ mouth			1651	3157			4808
Deardorff @ mouth (duplicate)			381				381
E Fk Butler @ 27th					3517		3517

Site	2009	2010	2011	2012	2013	2014	Total
E Fk Sunshine @ Sunshine Valley Rd/250th						3611	3611
E Fk Wahoo d/s of Flavel					2231		2231
Errol Springs @ mouth				3370			3370
Errol Springs @ SE 45th					2233		2233
Heiney Creek @ mouth				3576			3576
Hogan @ Butler Rd					3517		3517
Hogan @ mouth	3672			3576	3517	3552	14317
Jenne @ mouth				3528	3517		7045
Johnson @ 110th		2285					2285
Johnson @ 122nd				2663			2663
Johnson @ 17th		1957	1508				3465
Johnson @ 26th				3283			3283
Johnson @ 282nd		2200	3480			3252	8932
Johnson @ 307th		2200		3190		3361	8751
Johnson @ 49th					3238		3238
Johnson @ 67th				1867			1867
Johnson @ Ambleside				3576			3576
Johnson @ Barbara Welch		2288				2563	4851
Johnson @ Bluff Road, west of Altman						3358	3358
Johnson @ Brookside Wetlands				3447			3447
Johnson @ Circle Ave					2876		2876
Johnson @ Confluence near Spring Outlet			1508				1508
Johnson @ Gresham Woods				3576			3576
Johnson @ Hwy 224			1439				1439
Johnson @ Jenne Rd	3672	1135	3504		3517	3552	15380
Johnson @ Main City				3576			3576
Johnson @ Milport/Milwaukie	3672	3648	3672	3672	3671	2372	20707
Johnson @ Ochoco			3276				3276
Johnson @ Palmblad/252nd	3672		3504			3552	10728

Site	2009	2010	2011	2012	2013	2014	Total
Johnson @ Pleasant Home/Revenue			3480				3480
Johnson @ Pleasant Home/Revenue (duplicate)			1436				1436
Johnson @ Regner	3574	3646	3672	3623	3671	3503	21689
Johnson @ Stanley		1640				2088	3728
Johnson @ Sycamore	3672	3668	3672	3672	3672	3645	22001
Johnson @ Telford	3672		3504	3576		3552	14304
Johnson d/s of Butler Ck			3282				3282
Johnson u/s of Errol Springs					3493		3493
Kelley @ 176th		1760				2899	4659
Kelley @ 190th					3372	3552	6924
Kelley @ Bradshaw					3172		3172
Kelley @ mouth/159th	3672	3657	3456	3672	1608	3670	19735
Kelley @ mouth/159th (duplicate)	3000		1196				4196
Kelley @ PV Grange	3672		3504			3552	10728
Kelley @ Rodlun/Aldercrest	3672		3504			3552	10728
Kelley @ Rodlun/Aldercrest (duplicate)	2365						2365
Kelley u/s of Clatsop					3336		3336
Meadow @ mouth				2040			2040
Miller @ mouth				3576			3576
Mitchell @ 162nd	2996				3073	3418	9487
Mitchell @ Baxter Rd					2234		2234
Mitchell @ mouth	2446						2446
Mitchell d/s of Centennial Pond				3157	2233	3339	8729
Mitchell u/s of Centennial Pond						3418	3418
N Fk Johnson @ Headwaters Farm						3252	3252
N Fk Johnson @ Telford	3672		3504	2376	3517	3552	16621
Nechacokee @ mouth				3576			3576
Revenue Trib @ mouth				3169			3169
Spring Creek @ Harrison				3565			3565

Site	2009	2010	2011	2012	2013	2014	Total
Spring Creek u/s of Waldorf School				3565			3565
Sunshine @ Rugg	3672		3504	3576	3517	3217	17486
Sunshine @ Sunshine Valley Rd		1629	1437	3374			6440
Thom @ mouth				3576			3576
Thompson @ mouth				3576			3576
Veterans @ 102nd		2287				2565	4852
Veterans @ 98th				2135	2713		4848
Veterans @ mouth			1103	3370			4473
W Fk Sunshine @ 242nd			1437	3374	2832		7643
W Fk Sunshine @ Borges					2831	3421	6252
Years	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**Total**
Total # of Records	73132	46641	85497	140378	125730	107520	578,898