3. Water Quality

Water quality of streams, rivers, channels, and ponds in the study area is the result of both natural and human influences. One influence on surface water is the underlying geology over which it flows. The McKenzie River and Middle Fork Willamette River originate in the Cascade Mountains in porous rock that is young in geological age and favors deep infiltration and delayed transfer of water to channels where there are few opportunities for warming and incorporation of nutrients or other substances. Farther downstream, these two rivers flow through rock of older geologic age in the Cascades consisting of porous, fractured basalt that also promote deep infiltration of runoff and delayed transfer of water to the rivers, although the effect is not as significant as in the new Cascades. Upon reaching the flat valley bottoms, groundwater influx to the rivers is small; warming accelerates, fine-grained substrates that line their banks are readily incorporated, and nutrient-rich lenses of water within the Missoula flood deposits leach into the rivers.

The Coast Fork of the Willamette River flows through a much different terrain consisting of weathered basalt rock and extensive sediment deposits. Unlike the McKenzie and Middle Fork, the Coast Fork does not receive large influxes of cool groundwater in the summer and may transport larger loads of fine sediments and nutrients.

Streams in the study area are primarily influenced by the geology of the flat valley floor, a landscape that does not promote infiltration of water and the delayed release of winter precipitation into the dry season. These water bodies tend to readily warm in the summer and are relatively high in sediment and nutrients at other times of the year. A few streams, such as Amazon Creek and Willow Creek, have their headwaters in fractured basalt hills but, for most of their length, the valley deposits define their water characteristics.

Water characteristics of ponds and sloughs in the study area, many of which are manmade, are highly variable depending on subsurface connectivity with the main river. Those near-river ponds that experience a considerable influx of river water moving subsurface through coarse gravel have water that is the most similar to the river. Ponds without this subsurface connection tend to be warm and nutrient-rich during the summer.

An overlay of human activities also defines the characteristics of water throughout the study area. A significant factor for the rivers is the presence of upstream reservoirs with their influence on flow, nutrients, and temperature. For example, average monthly flows for the McKenzie River (measured at Vida) are now 18% higher in July and 51% higher in August than they were prior to construction of upstream reservoirs (Moffatt et al. 1990). Summer flow released from reservoirs is typically cool water from near the bottom of the reservoir, which helps keep the river cool, as well as maintaining a deeper river. The extra flow also helps dilute pollutants.

Another impact is the reduction of peak river flows. High flows are a primary means by which rivers form and reform side channels, alcoves, and other ‘fish friendly’ riverine features. By virtually eliminating flooding, river hydrology is constrained in ways that adversely affect fish

and wildlife habitat formation and maintenance. Furthermore, the reservoirs have reduced sediment loads in downstream reaches. The dampening of peak flows by upstream flood control reservoirs has resulted in a 59% decrease in annual suspended sediment load between the late 1940s to the early 1990s for the McKenzie River (Alsea Geospatial et al. 2001).

Reservoirs can also influence downstream nutrient levels whereby water released during the summer contains higher bioavailable nitrogen than that flowing into the reservoirs (Alsea Geospatial et al. 2001). Phosphorus in water flowing out of reservoirs in spring and summer is lower than inflow water; phosphorus is usually the limiting nutrient for primary productivity in Pacific Northwest rivers.

Stormwater discharge into streams, rivers, and other waterways throughout the urbanized portions of the study area also introduce significant concentrations of pollutants including bacteria, nutrients, heavy metals, oil and grease, sediment, and temperature change. Municipal stormwater discharges are regulated under the Clean Water Act National Pollutant Discharge Elimination System (NPDES) program.

The City of Eugene operates a stormwater management program, which addresses water quality under an NPDES stormwater permit. In addition, the City of Eugene and the Oregon Department of Environmental Quality (DEQ) have entered into an agreement to transfer coordination and oversight of 1200Z, 1300J, and 1700A NPDES permits to the City. These permits regulate discharges of stormwater, oily wastes, and wastewater from washing activities. This agreement covers all facilities inside the Eugene city limits and those discharging to a city conveyance system. The City of Springfield also operates a stormwater management program that addresses water quality. Under Phase II of the Federal Stormwater NPDES program, Springfield will submit a stormwater permit application in March, 2003. The Oregon Department of Environmental Quality currently administers such permits within the City of Springfield.

One human influence on rivers in the study area includes permitted point source discharges. These include discharge of treated sanitary wastewater into the Coast Fork downstream of Cottage Grove, and into the Willamette River downstream of Eugene. In addition, cooling water is discharged from power generation facilities at the University of Oregon into the Eugene Mill Race (an artificial side channel of the Willamette River), and from both treated and non-contact process water from numerous industries in both Eugene and Springfield, which discharge to both the McKenzie and Willamette Rivers.

Other activities upstream of the study area may result in water quality change. These activities and possible altered parameters include forestry (sediment, herbicides, temperature), agriculture (sediment, herbicides, nutrients, pesticides, bacteria, temperature), rural residences (sediment, bacteria, nutrients, temperature), and old mines (heavy metals).

The influence of these discharges on humans is twofold; it can affect human health, through direct or indirect exposure to pollutants such as heavy metals and bacteria, and it can result in changes in the ecosystem. These changes may present long-term problems such as declines in

plant and animal species viability and variability. These result in reduced quality of life, increased economic burdens, and an overall decline in long-term sustainability of the ecosystem.

Passage of the Clean Water Act in 1972 required states to regulate end-of-pipe or "point source" discharges from cities and industries in order to protect the nation's surface water resources. Since then, focus has included pollution from "non-point" sources such as runoff from urban and rural areas. Federal and state water quality standards and permits address the pollutants of concern that result from the activities described above. These standards are designed to protect water quality at levels that are safe for fish and other aquatic organisms. However, once a water body is measured and found to violate water quality standards, it appears on a state's 303(d) list as water-quality impaired. Few streams have actually been measured so it is only a partial listing. Federal law requires that a waterbody appearing on the state's 303(d) list be managed to meet that state's water quality standards. The Oregon Department of Environmental Quality is then required to initiate a process to bring the water body back into conformance with applicable standards if the waterbody is not meeting state water quality standards because of human activities.

The DEQ is currently required to develop a Total Maximum Daily Load (TMDL) for temperature, and other pollutants in various reaches of the Willamette River basin. During development of a TMDL, data is gathered on the water quality parameter of interest and assessment is made of point, non-point, and natural sources. Allocations are then developed for the identified sources and issued through point source permits (NPDES) or implemented through water quality management plans. The purpose of this process is to eventually improve water quality so that all beneficial uses are protected.

Influences of water temperature on fish

The influence of water temperature on fish relates directly to the fact that fish cannot make their bodies cooler than the surrounding water. There is a range of temperature at which growth and other functions are optimized, and then as temperature rises further, first sublethal effects occur (symptoms usually include slow movement), and finally an upper lethal limit of temperature is reached. The food requirements of a fish increase with increasing water temperature, and, as temperatures increase, eventually can reach a point at which fish starve (Hazel 1993). However, for substantial periods of time, fish can survive within water that is above optimal levels and that is why salmonids can be found in water that peaks at more than 75˚ F. Nevertheless, their presence does not mean that the fish are thriving. Fish have developed adaptive strategies for minimizing energy expenditures, including searching out cool pockets of water, migrating up- or downstream, and congregating in areas with abundant food (Nielson et al. 1994). But these strategies can also expose them more to predators or result in greater competition for food as fish congregate in favorable areas. Dams and impassable culverts can foil strategies by fish to migrate in search of cooler water. On the other hand, water released from dams during the summer is usually from the cool lower depths of the reservoir and this helps cool the river.

The state water quality standard for water temperature (7-day mean of maximum values) is 64˚ F for most streams and rivers in western Oregon. This is an estimate of the upper limit of the optimal temperature for salmonids in general and not an upper threshold. Many streams are

naturally warmer than the standard, so the standard is not an indicator of what the stream temperature should be.

Water temperature can be subtlety related to other processes that limit fish use of waters. For example, Ceratomyxa shasta, a myxosporidian parasite, is a native disease that kills cutthroat trout and steelhead trout in the Willamette River. Because of its presence, few trout are found downstream of Corvallis in the summer, although trout use of the lower Willamette during non-summer months is common. A small aquatic worm is an alternative host of Ceratomyxa shasta and the spatial distribution of the worms in the Willamette River (more downstream where water is warmer) may play a role in how trout are distributed in the summer. Also, the ability of trout to resist this parasite may be greater where the water is cooler.

Water temperature tolerances for fish vary widely among species. Salmonids exhibit the least tolerance for warm water, while other native species such as redside shiner, dace, largescale sucker, northern pikeminnow, and Oregon chub have a greater tolerance. Introduced species, such as largemouth bass and bluegill, are highly tolerant of warm water.

Influences of heavy metals on fish

Fish suffer damage to gills, gonads, and blood when exposed to high concentrations of zinc. Young fish are more vulnerable to zinc exposure than older fish. Gills of larval stages of tilapia (an Asian warmwater fish now grown throughout the world for food) exhibited damage at 2 mg/L when chronically exposed for 21 days; fingerlings suffered fusion of gill plates at 10 mg/L and died at a zinc concentration of 30 mg/L (Carino 1993). At similar concentrations, tilapia suffered undifferentiated gonads and anemia. The state water quality standard for total zinc in water having pH levels typical of the study area waters is 0.11 mg/L. Most zinc in waters of the study area is in the dissolved state and,therefore, is readily available for fish uptake.

Copper affects fish by causing “coughs” which are attempts by the fish to clear foreign matter and mucus. High concentrations of copper in the water induces mucus production on the gills and, therefore, the need to clear this mucus (Drummond et al. 1973). This leads to interruptions in respiration and a need for even more water to be pushed through the gills to get necessary levels of oxygen. Fish accomplish this by swimming faster through the water but at a high energy cost.

Influences of nitrogen and phosphorus on fish

The nutrients nitrogen and phosphorus have no direct influence on fish but can change the properties of water via the by-products of other aquatic organisms. The abundance of algae and bacteria in a stream usually increases with increasing concentration of nutrients, especially of phosphorus, which is typically the limiting nutrient in Pacific Northwest streams. The decay of the organic matter sloughed off by algae and the respiration of bacteria acts to depress oxygen levels in the water while the production of oxygen by algae increases oxygen levels during the day and water turbulence acts to increase levels both day and night. Materials that are added to the river can have a biological oxygen demand (such as cellulose from a pulp mill) or a chemical oxygen demand (such as ammonia from a wastewater treatment plant) that can also depress

oxygen levels as these substances decay or are transformed into other forms. The net effect of demands and additions determines the oxygen concentration at any given time.

Juvenile and adult salmonids typically prefer water with an oxygen concentration of 7 mg/L or more, although they have been found in water as low as 4 mg/L (Andrus and Landers, in process). Other native fishes of the Willamette River have been found in concentrations as low as 1 mg/L. The developing eggs of salmonids require a high concentration of oxygen (greater than 8 mg/L). Except for spring Chinook, salmonid spawning occurs in the spring when oxygen levels are typically high. Spring Chinook do not spawn in waters of the study area.

In the following section we examine selected water characteristics for streams and rivers for sites within and near the study area. The discussion focuses on maximum water temperature, E. coli bacteria, nitrate-nitrite, total phosphorus, and total zinc. Each represents a class of pollutants that have potential to influence fish and other aquatic organisms. In the bacteria, nutrients, and heavy metals sections, data obtained from ambient monitoring programs in rivers and streams has been separated from data obtained by sampling stormwater discharges during wet weather events. Typically, pollutant concentrations of bacteria, nutrients, and heavy metals are higher in wet weather stormwater discharges than in rivers and streams.

The water quality monitoring programs that generate data used for this study do not include analysis for pesticide occurrence in rivers and streams within the study area. This is primarily due to the cost associated with laboratory analysis for these types of contaminants, which can be several orders of magnitude greater than other water quality parameters. In addition, relatively few laboratories are capable of analyzing water samples for pesticides at the trace level concentrations believed to be toxic to fish. Existing pesticide studies of Willamette basin streams (Rinella and Janet 1988, Anderson et al 1997) provide no insight on how to interpret pesticide detections, especially at low concentrations.

Oil and grease in stormwater discharges is dependent on the magnitude of the rainfall event and the intervening period between events. The quantity of oil and grease in stormwater discharge is also dependent on the area of impervious surface exposed to vehicles and machinery, and the amount of biofiltration/remediation that occurs in swales, detention facilities, and open channels in a given drainage basin. The first rainfall following summer usually delivers the most oil and grease to streams and is, therefore, most toxic to fish. As the frequency of rainfall events increases, smaller quantities of oil and grease are transported in stormwater discharges to area streams and rivers. Most of the oil and grease is transported from paved surfaces within the first hour of a rainfall event. Given the limited availability of data on oil and grease and its variability over time, oil and grease data are not discussed here. Even so, oil and grease are considered significant pollutants in stormwater. Springfield presently requires on-site pretreatment of stormwater on newly developed sites, which typically includes mechanical oil/grease removal systems, or biofiltration facilities. Eugene is reviewing similar standards for future adoption.

3.1 Water temperature

The Oregon water temperature standard in the upper Willamette River basin for waterbodies that directly support salmonids or influence salmonids in downstream reaches is 64º F (OAR 340-041-0445). While the natural temperature regime of many waterbodies will exceed 64˚ F at various times of the year, the aim of the standard is to protect beneficial uses most sensitive to water temperature--in this instance, fish and aquatic life. Specifically, the rule states in part that no measureable increase (0.25˚ F) from human sources is allowed in basins that exceed the numeric criteria. Waterbodies in the study area that exceed the numeric criteria and, therefore, have been identified as water quality-limited for temperature, include the McKenzie River, Middle Fork Willamette River, Coast Fork Willamette River, mainstem Willamette River, Mohawk River, and Amazon Creek.

Monitoring during the summer of 2001, conducted for development of the temperature TMDL, generated data for a number of sites in the study area. Flows were unusually low during this time, thus water temperatures were above normal. Figure 21 provides a summary of the summer's greatest 7-day average of maximum water temperature centered on August 9. Temperature data collected from monitoring stations are expressed as the average of maximum daily values for a seven-day period. The maximum 7-day average is then compared to the water temperature standard.

Maximum 7-day average water temperatures exceeded the water quality standard of 64˚ F for the upper Willamette River basin at all measured sites. The McKenzie River had the coolest water at 64.9˚ F, followed by the Middle Fork Willamette River at 69.6˚ F. The temperatures of both rivers are moderated by releases of cool water at upstream reservoirs and high influxes of cool groundwater. The Coast Fork Willamette River was considerably warmer at 74.9˚ F. Upstream reservoirs on the Coast Fork do not provide much additional flow during the summer and the geology does not yield much groundwater influx. It is also a much shallower river and is, therefore, more influenced by direct solar radiation. The Mohawk River tributary watershed area is similar in temperature to the Coast Fork Willamette River but flows are smaller. This is partially a result of irrigation withdrawals and scarcity of shade along the lower main channel. The Mohawk River and Amazon Creek were among the warmest streams in the study area at 77.2˚ F and 83.3˚ F, respectively.

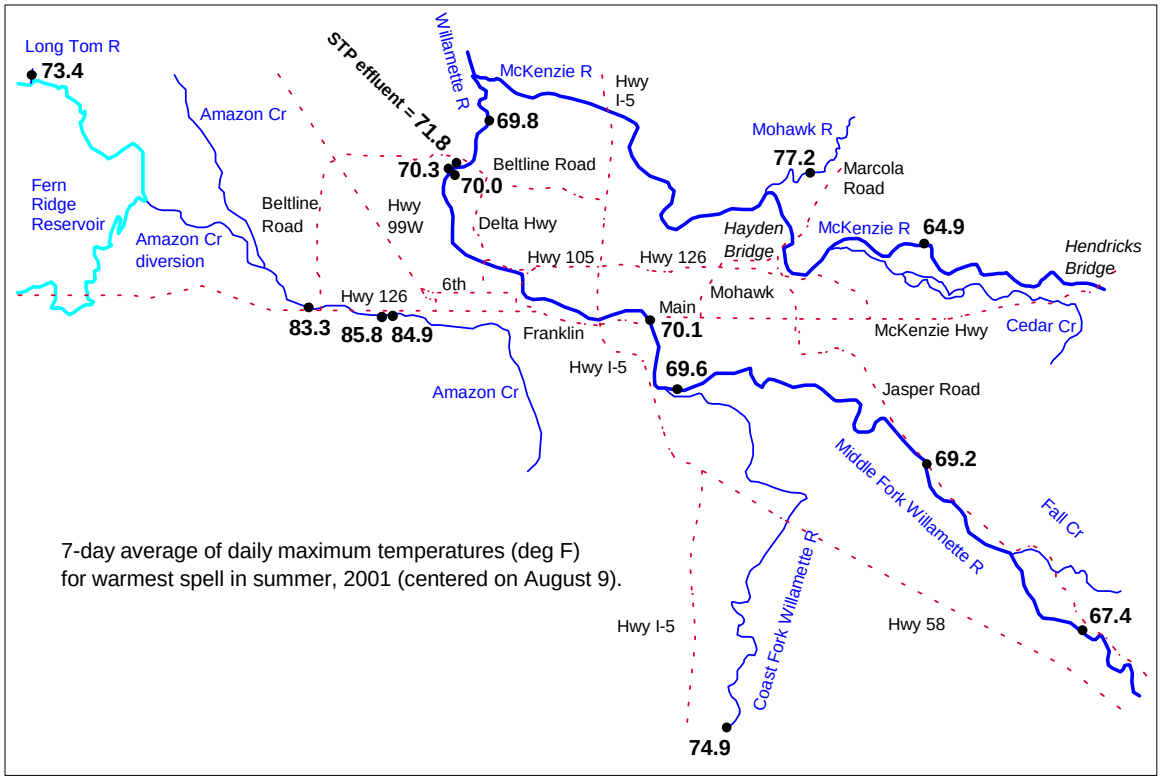


Figure 21. The 7-day average of daily maximum temperatures (˚F) for the warmest spell in summer, 2001 for sites within and around the MECT study area. Sources of data include monitoring conducted by U.S. Geological Service, City of Eugene, and Long Tom Watershed Council. WPCF effluent means wastewater entering the river from the wastewater treatment plant.

The Springfield Mill Race is an appendage of the Middle Fork Willamette River constructed through a system of historic interconnecting channels and sloughs in the 1850s. This waterway routinely exceeds temperatures suitable for anadramous fish (City of Springfield, 2000). Temperature data collected for the study on the evaluation and recommendations for the Springfield Mill Race (OTAK, 1997) show water temperatures increase substantially as the water flows from the inlet on the Middle Fork to the outlet on the mainstem Willamette River. Measurements taken when the inlet flows measured 55˚ F showed an increase to 60˚ F as flows entered the millpond in the lower reaches, and 72˚ F at the downstream end of the pond. Shallow flow and lack of shade between the pond and the outfall to the mainstem Willamette River probably prevent significant cooling in the short distance to the outfall.

The Willamette River maintains a relatively steady temperature as it flows through the study area. Two temperature monitoring stations were located immediately upstream of the Eugene-Springfield wastewater treatment plant outfall, yielding a 7-day maximum temperature of 70.2˚ F. The wastewater effluent temperature was warmer at 71.8˚ F, but accounted for only 2.4% of the river flow at that time. Thus, the calculated temperature increase in the river due to the effluent was 0.04˚ F. A comparison of 7-day minimum temperatures during the same period suggest wastewater effluent caused river temperatures to rise by 0.08˚ F, given the flow conditions. River temperatures at the monitoring station upstream of the outfall were lowest in

the early morning at 66.4˚ F, about 3.8˚ F cooler than the maximum that occurred during the day, while effluent temperatures dropped by 2˚ F.

In general, the coolness of water at night has some bearing on the ability of cool-water fish to withstand maximum water temperatures during the day. Since fish are cold-blooded, their energy needs increase with increasing water temperature. Trout usually leave water that regularly exceeds 70˚ F during the day. Rivers and streams with low water temperature at night enable fish to rejuvenate and be better prepared for the next day's increased water temperatures.

Temperatures in the McKenzie River dropped to about 58˚ F at night during the relatively warm period of August 6-12, 2001 (Figure 22). Temperatures in the Willamette River downstream of Eugene and the Coast Fork Willamette River cooled to about 66˚ F at night, while the Mohawk River and Amazon Creek cooled to only 70˚ F and 69˚ F, respectively.

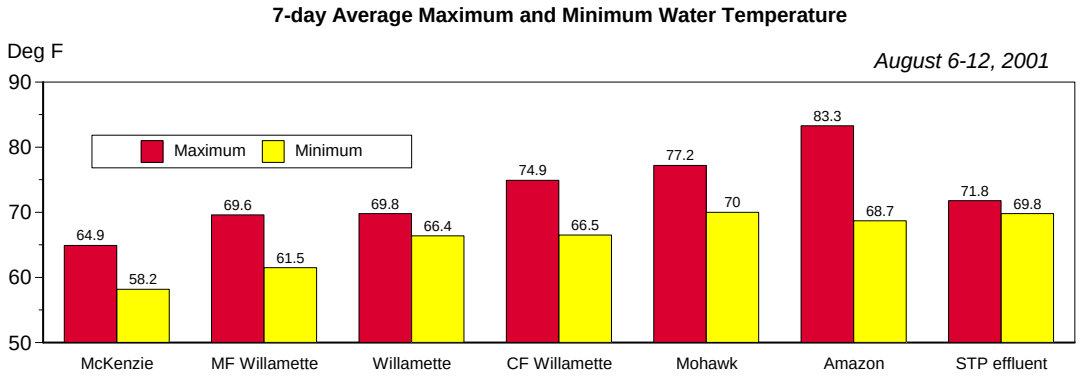


Figure 22. The 7-day average maximum and associated 7-day average minimum water temperature for selected sites within and near the MECT study area. Sources of data include monitoring conducted by U.S. Geological Service, City of Eugene, and Long Tom Watershed Council. STP refers to the wastewater treatment plant near Beltline Road along the Willamette River.

Information on 7-day maximum water temperatures for streams in the study area are limited to a middle section of Amazon Creek. Here, temperatures were in the mid-80s which is much more than most native fish species can tolerate. Interestingly, water exiting from Fern Ridge Reservoir, into which Amazon Creek flows during the summer, was 10˚ F cooler than Amazon Creek.

Monitoring of urban streams in Corvallis that have characteristics similar to MECT study area streams illustrates the influence of shading on small streams during summer hot spells. For the fully urbanized Dixon Creek, maximum daily water temperature increased by about 2˚ F in a short reach exposed to sunlight but then lost that heat in the next mile of shaded reach (Figure 23). Then, it warmed 8˚ F in the downstream reach that was fully exposed to sunlight. Similarly, the semi-urbanized Squaw Creek gained over 4˚ F after flowing through a short reach where no shading occurred. It had lost only a small portion of this gain in the downstream shaded reach before it flowed into the Mary's River. A study of a number of small streams on

forest land in the Coast Range of Oregon showed similar results; water temperature increases incurred in clearcut areas decreased in downstream reaches that were fully shaded (Robison et al. 1995).

These case studies illustrate that small valley streams are thermally sensitive to even short reaches of unshaded channel. Yet, these increases are not necessarily cumulative; streams will cool if allowed to flow through shaded downstream reaches.

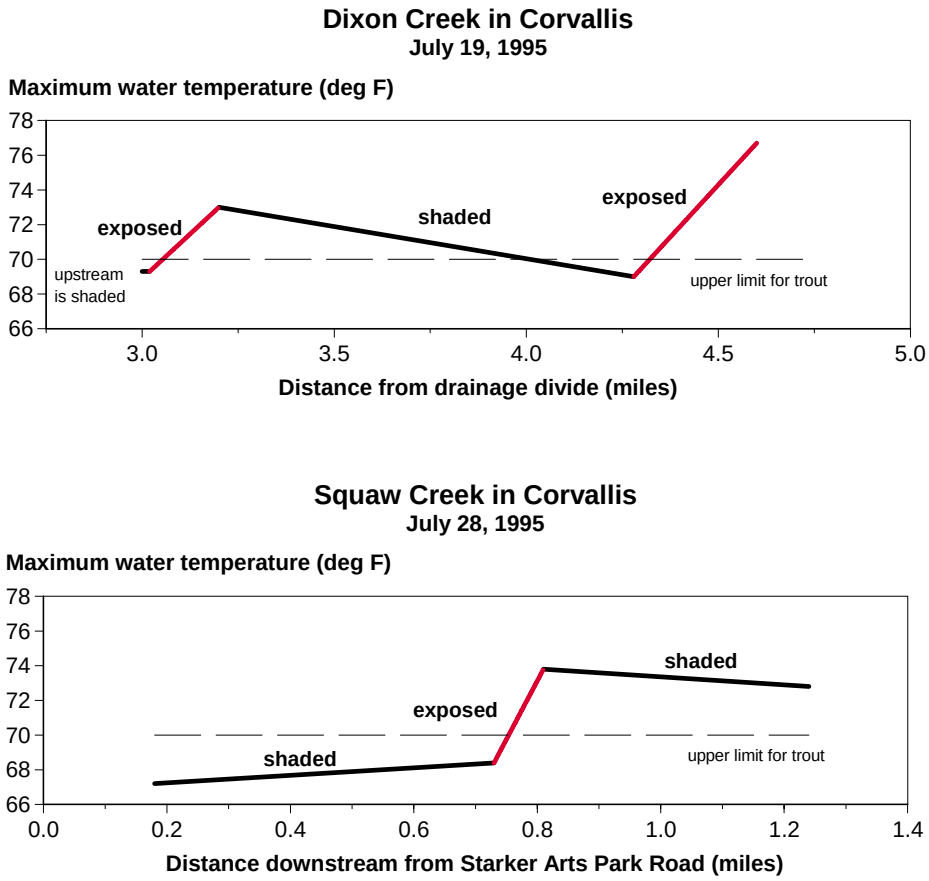


Figure 23. Daily maximum water temperature for two urban streams in Corvallis, Oregon. Data were collected for the Benton County Soil and Water Conservation District in 1995 by C. Andrus. Water warmed in exposed reaches cooled in downstream shaded reaches.

Urban streams that are routed underground for a distance can also experience cooling. For example, Clark Creek, a tributary of Pringle Creek in Salem, warmed to 70.7˚ F as it flowed through about 1000 feet of concrete-lined channel that had no shading. It then dropped 3º as it was routed underground through a culvert for 2000 feet (Figure 24). When a stream is piped, its use by fish (other than for passage to upstream surface reaches) is eliminated. Yet, the cooling caused by piped reaches where upstream water is too hot for fish does provide opportunities for thermal refuges at the downstream ends of the piped reaches.

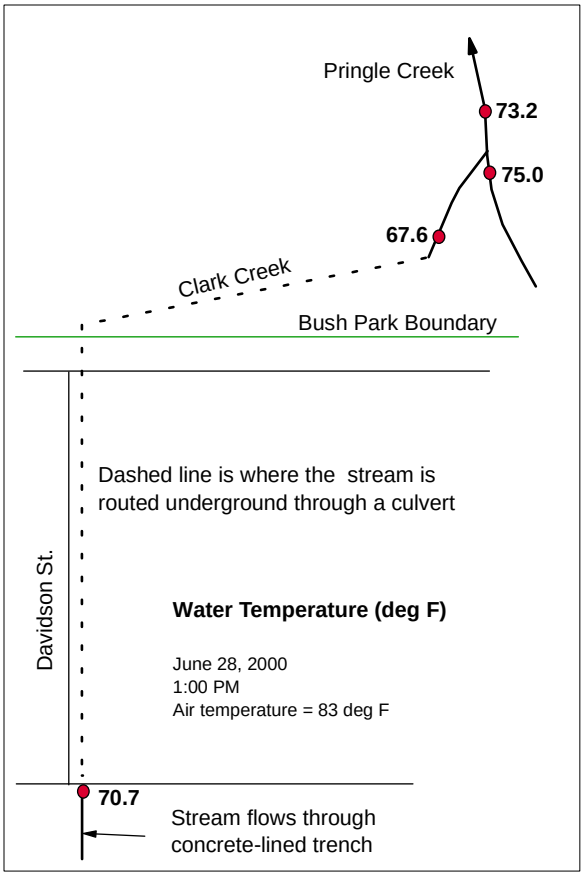


Figure 24. Example for Clark Creek in Salem, an urban stream that cooled when routed underground for a distance. Data were collected for Oregon Watersheds in 2000 by C. Andrus.

Streams in the Willamette River basin exhibit a rapid warming rate in the upper reaches and then drop to a low background warming rate for the remainder of their length. Monitoring of sites by the Mary's River Watershed Council (Andrus et al. 1999) of the Mary's River and its tributaries demonstrates that warming rates can be as high as 2˚ F per mile of stream for distances less than 6 miles downstream from the drainage divide (the ridge that defines the stream's watershed boundary) (Figure 25). At distances from the drainage divide greater than 6 miles, warming rates declined to a background level of 0.3˚ F per mile. Most stream segments monitored in this study had high levels of shading so differences in warming rates among sites at similar distance from drainage divide were probably due to the quantity of groundwater seeping into the streams.

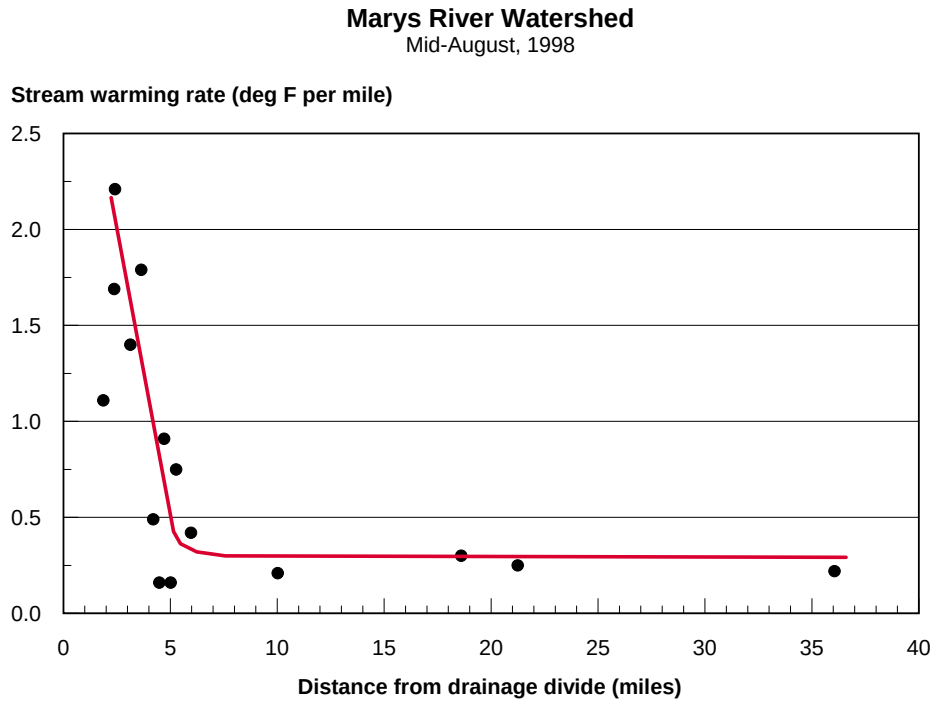


Figure 25. Stream warming rates for streams in the Mary's River Watershed in 1998. Warming rates were highest in reaches closest to the drainage divide and then fell to a low background rate further downstream.

These phenomena suggest that remedies to bring warmed streams back to their natural temperatures are best approached by first re-establishing shade in the most upstream reaches where surface water warming rates are naturally the greatest and then move downstream to the next exposed reaches to establish shade, making sure that even short upstream reaches of stream are not exposed to sunlight. This approach acts to expand the cool-water zone of a watershed into lower portions of the basin.

3.2 Bacteria

Urban stormwater runoff is a conduit for concentrations of microorganisms to reach waterways. While naturally occurring bacteria in streams generally have no effect on fish, other aquatic organisms, or wildlife, certain types of bacteria or high concentrations may pose a health risk to people through recreational contact with the water. In addition to bacteria, other water-borne protozoa and disease-causing microorganisms can adversely affect human and animal health. Because of the number of various organisms with potential to affect health, monitoring commonly focuses on easily-detected but relatively harmless bacterium, which frequently occurs with the other, more harmful varieties. Currently, *Escherichia coli* (abbreviated as *E. coli*) is widely used to evaluate the level of harmful bacterial contamination in water. In Oregon, the water quality standard for *E. coli* is 406 organisms/100 mL (milliliter) to protect swimming and aquatic life; the drinking water standard is <1 organisms/100 mL. These organisms, along with other, more harmful types, have their origin in the intestinal tracts of humans and some animals.

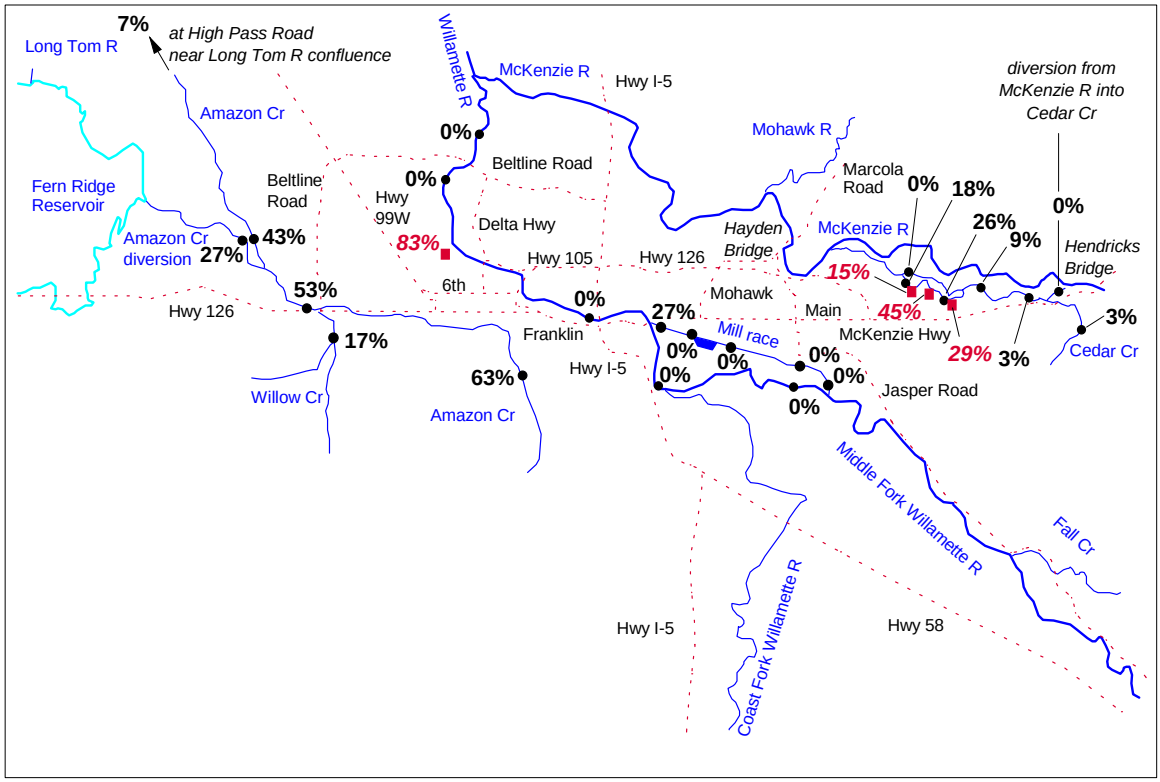
In a study conducted by the University of Washington on a Seattle, Washington, creek in 2000, a wide range of *E. coli* sources were identified. Researches found that about 32% of *E. coli* detected in the creek originated from birds, 20% from dogs, 11% from rodents, and about 3% from human sources (Samadpour, personal communication). It is unknown whether or not *E. coli* in MECT streams are from similar origins.

The following sections describe monitoring results for *E. coli* at stormwater discharge points and at monitoring stations in rivers and streams within the study area. These data were not all gathered during the same days or at the same intervals throughout a year so there is only a loose correlation between concentrations in a stormwater discharge and those in a receiving water. When considering the affects of stormwater on receiving waters, one must keep in mind the volume of water at each outfall. The volume of water at a stormwater outfall is usually much less than the receiving water so dilution of high concentrations of bacteria in stormwater will occur. The equipment used to measure stormwater flow is expensive and resources have not been available to acquire them. While *E. coli* counts alone do not measure contamination risk for humans, they are indicative of stormwater quality entering rivers and streams. Perhaps more importantly, they are indicators of potentially more significant water quality issues that are generally associated with land development.

Monitoring for *E. coli* in the study area has occurred over a number of years and for a large number of sites. The main rivers of the study area that were sampled, including the mainstem Willamette River, Middle Fork Willamette River, and McKenzie River. These had no exceedences of the state water quality standard. In addition, water that is diverted from the McKenzie River to Cedar Creek (near the McKenzie River Highway crossing) had no exceedences. Bacteria counts were also low in the headwater reaches of Cedar Creek. Figure 26 summarizes the percentage of samples that exceeded the state water quality standard at each monitoring site.

The upper Amazon Creek basin sites exceeded the standard for *E. coli* in 63% of samples collected, while exceedences in the lower basin ranged from 27 to 53%. Willow Creek, a relatively undeveloped tributary of Amazon Creek, had a low number of exceedences at 17%. No statistically significant trend over time has been observed for the three monitoring stations downstream of the Railroad Crossing site on Amazon Creek.

Sampling for *E. coli* by the McKenzie Watershed Council and Partner Organizations during high water on February 21, 1998, indicated that the Mohawk River had a count of 380 per 100 mL, while counts were near zero for a sample taken upstream from the McKenzie River (Runyon 2000). Potential sources of bacterial contamination in the Mohawk basin include failing septic tanks and cattle grazing (Huntington 2000). Water quality sampling events conducted on Cedar Creek downstream of a series of stormwater outfalls exceeded the standard 18% of the time, while the northern branch of Cedar Creek (which receives no stormwater) had no exceedences.



<u>Figure 26</u>. Percentage of *E. coli* samples that exceeded the state water quality standard of 406 organisms/100mL at each within or near the MECT study area. Sources of data include the McKenzie Watershed Council, City of Eugene, Long Tom Watershed Council, Springfield Water Board, and Student Research Project, Springfield. Red squares and red labeling in italics indicate stormwater sites and circles indicate stream sites.

Long-term stormwater monitoring has been conducted by the City of Eugene at a number of sites. Five stormwater sites in Eugene have been monitored for a year or more, some beginning as early as March, 1997, and continuing to the present. All sites had at least one or more sampling events exceeding the standard. *E. coli* counts ranged from 4 to 110,000 per 100 mL, and the percent of samples exceeding the standard ranged from 9% to 79%. Sampling is conducted on a monthly basis. Generally, high *E. coli* counts occurred in drier, warmer months.

In Springfield, Cedar Creek, a tributary of the McKenzie River, receives urban stormwater from six major outfalls and five minor outfalls. Minor outfalls serve just a couple of catch basins or area drains. Data for three of the major outfalls show that 36% of stormwater sampling events conducted on the 72nd Street outfall exceeded the standard, while at the 69th Street outfall 50% exceeded the standard, and at the 64th Street outfall 17% of the sampling events exceeded the standard (Figure 26).

Sites monitored by students from the City of Springfield along the Springfield Mill Race had no samples that exceeded the state water quality standard, except for some very high readings at the most downstream site just before the Mill Race enters the Willamette River. It is likely that a stormwater drain between the dam forming the mill pond and the Willamette River confluence

discharges into the Mill Race and contributes bacteria. Values exceeded the water quality standard 27% of the time at this downstream site. The Mill Race receives most of its water from Middle Fork Willamette River.

Beginning in 2002, the Eugene Water and Electric Board (EWEB), City of Springfield, and schools from the city of Springfield have coordinated a monitoring program of water quality of stormwater and receiving waters within Springfield. Only one sampling period, during a storm in early March, has occurred so far but the results do provide an initial view of *E. coli* counts at four stormwater sites and of Cedar Creek downstream of two of the stormwater sites (Figure 27). Sampling is timed to be concurrent with major runoff events.

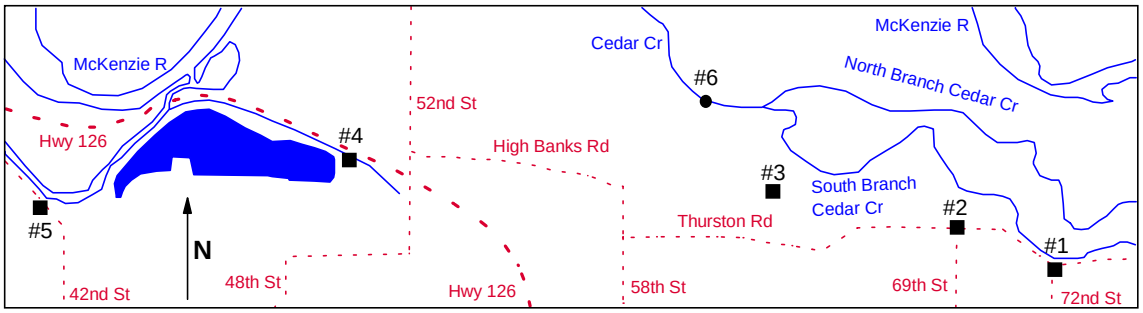


Figure 27. Sites for long-term monitoring in and near the City of Springfield. Squares indicate stormwater sites and circles indicate stream sites. Site #1 is the 72nd Street stormwater site, #2 is the 69th Street stormwater site, #3 is the 64th Street stormwater site, #4 is the 52nd Street stormwater site, #5 is the 42nd Street stormwater site, and #6 is the Cedar Creek site.

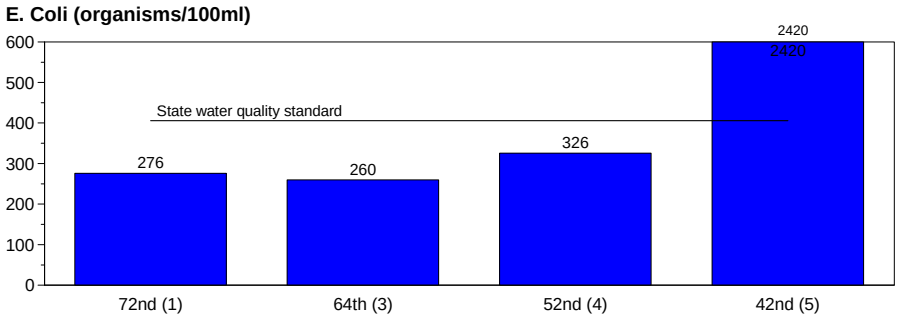


Figure 28. *E. coli* concentrations for 5 stormwater sites in Cedar Creek (downstream of 3 stormwater outfalls) for a storm in early March, 2002. The results are for composite samples taken throughout the storm.

The composite stormwater sample from 42nd Street exceeded the *E. coli* standard with 2400 per 100 /mL and samples from 52nd, 64th, and 72nd Streets were at values below the standard. There was no composite data for sites 2 and 6, however a grab sample at 69th Street site (2) had a value of 770 /mL, while the Cedar Creek site (6) had no detection of *E. coli*. During the storm, Cedar Creek ran high from water that is diverted from the McKenzie River and from its natural drainage south of the McKenzie River Highway, thereby diluting pollution from the stormwater drains. This contrasts with the results of the multi-year monitoring done by the McKenzie

atershed Council for various times of the year and for a range of flows where, on average, *E. coli* concentrations from stormwater did increase concentrations in downstream portions of Cedar Creek (Figure 28).

3.3 Heavy metals

Heavy metal concentrations in Oregon streams and rivers are generally well below water quality standards. Where concentrations above water quality standards are found, it is usually a result of contamination from human sources, such as industrial sites, paved surfaces, mining operations, galvanized metal siding and roofs on buildings, and wastewater treatment plants. Aquatic insects and algae are organisms most affected by high concentrations of heavy metals, many of which readily adhere to sediment particles so they may not appear in the water column except at short distances downstream from their source.

In this study, water quality data are examined for a number of heavy metals that are harmful to aquatic life, such as zinc, cadmium, chromium, copper, lead, mercury, and nickel. Above a certain concentration, these metals have been determined to be toxic to aquatic life, thus the Oregon DEQ has established a set of water quality standards for their protection. These are specified in OAR 340-41. When applicable, the standards consider water hardness (a measure of mineral salts dissolved in the water). A discussion of the heavy metals found in river, stream, and stormwater samples collected within the study area, are presented in the sections below.

Heavy metals in rivers and streams

Ambient water quality monitoring has been conducted by the City of Eugene on surface water bodies within the study area. Table 21a presents summary statistics for bimonthly monitoring beginning in January, 1997, through December, 2001.

With few exceptions, heavy metal concentrations in the Willamette River and Amazon basin streams are, on average, less than the specified water quality criteria specified in Table 21b. In many instances, the concentrations are several orders of magnitude less than the criteria. The exceptions are total lead and total copper at several monitoring stations along Amazon Creek. For example, average total lead values for the A3 Channel at Terry Street is reported at 3.60 µg/L (micrograms per liter) with a hardness of 111 mg/L (milligrams per liter). Lead concentrations at several other monitoring stations in the lower Amazon Creek basin approach the chronic criterion. While total copper values do not exceed the chronic range of 12 µg/L, averages of between 4 and 8 µg/L and corresponding standard deviations suggest there is probability of exceeding the standard for copper.

The lower Amazon Creek basin drains areas with high industrial development, in contrast to the Willow Creek drainage, which is relatively undeveloped. Average concentrations for dissolved and total copper, lead, and zinc at the Willow Creek monitoring station are several times less than averages reported for the Amazon Park/29th Avenue monitoring station where residential development is mixed with some commercial development.

<u>Table 20a</u>. Summary statistics for ambient water quality monitoring of metals and water hardness. From the City of Eugene NPDES Annual Stormwater Report, November 2000-November 2001.

Surface Water Sample Location:		Amazon Creek Site M2 at 29th Avenue	Willow Creek 450 ft north of 18th Avenue	Amazon Creek at Railroad Track Crossing	Amazon Diversion Channel at Royal Avenue	A3 Channel at Terry Street	Amazon Creek at Royal Avenue	Willamette River Upstream of Urban Growth Boundary (RM 186.9)	Willamette River at Knickerbocker Bridge (RM 183.9)	Willamette River at Owosso Bridge (RM 178.6)	Willamette River Downstream of Beltline Bridge (RM 176.8)
Metal (*μg/L*)	**Statistic**										
Cadmium, dissolved	μ^a	0.00055	0.00114	0.00591	0.00352	0.0164	0.0185	0.00345	0.00321	0.00325	0.00318
	σ^b	0.00256	0.00233	0.00692	0.00572	0.0133	0.0272	0.00814	0.01428	0.01334	0.01051
Cadmium, total	μ^a	0.0103	0.0034	0.0305	0.0255	0.0891	0.0294	0.00256	Ins.	0.00420	0.00649
	σ^b	0.0128	0.0034	0.0258	0.0183	0.0606	0.0264	0.00798	Ins.	0.01155	0.01687
Chromium, dissolved	μ^a	0.693	0.525	0.846	0.795	1.23	0.829	0.103	0.123	0.147	0.162
	σ^b	0.461	0.338	0.282	0.424	0.71	0.572	0.089	0.094	0.131	0.110
Chromium, total	μ^a	1.53	1.09	1.88	1.90	2.10	1.56	0.367	0.361	0.408	0.339
	σ^b	0.78	0.48	0.65	0.51	1.00	0.51	0.219	0.208	0.247	0.197
Copper, dissolved	μ^a	1.54	1.15	1.78	1.80	2.28	2.09	0.260	0.290	0.298	0.349
	σ^b	0.54	0.25	0.64	0.49	1.23	0.87	0.100	0.101	0.101	0.110
Copper, total	μ^a	3.23	2.22	4.10	4.21	8.27	6.41	0.569	0.556	0.616	0.689
	σ^b	1.35	0.70	1.49	1.26	6.38	5.55	0.315	0.286	0.302	0.307
Lead, dissolved	μ^a	0.0305	0.0191	0.0981	0.0963	0.162	0.0914	0.00510	0.00829	0.00865	0.0208
	σ^b	0.0211	0.0154	0.0578	0.0486	0.120	0.0504	0.00711	0.01112	0.00870	0.0109
Lead, total	μ^a	0.778	0.331	2.72	2.48	3.60	2.03	0.0859	0.0770	0.103	0.112
	σ^b	0.463	0.153	2.06	1.21	2.34	1.26	0.0527	0.0392	0.048	0.048
Mercury, dissolved	μ^a	0.00119	0.00117	0.00227	0.00186	0.00216	0.00186	0.00096	0.00111	0.00104	0.00101
	σ^b	0.00062	0.00060	0.00087	0.00099	0.00177	0.00113	0.00054	0.00063	0.00056	0.00053
Mercury, total	μ^a	0.00299	0.00298	0.00994	0.00713	0.0145	0.00772	0.00217	0.00187	0.00208	0.00232
	σ^b	0.00160	0.00157	0.00412	0.00268	0.0078	0.00502	0.00136	0.00106	0.00121	0.00134
Nickle, dissolved	μ^a	1.43	1.90	1.85	1.75	2.63	2.40	0.206	0.217	0.202	0.236
	σ^b	0.48	0.99	0.52	0.41	0.74	0.83	0.106	0.105	0.095	0.118
Nickle, total	μ^a	2.10	2.35	2.65	2.67	4.06	3.54	0.339	0.332	0.340	0.373
	σ^b	0.59	0.94	0.78	0.51	1.19	1.06	0.196	0.169	0.180	0.208
Zinc, dissolved	μ^a	6.19	2.63	6.97	5.86	16.2	8.92	0.237	0.340	0.483	0.982
	σ^b	3.56	1.71	6.85	3.82	13.3	5.66	0.181	0.252	0.333	0.670
Zinc, total	μ^a	13.8	4.77	20.3	17.4	41.3	23.0	0.933	1.01	1.48	1.94
	σ^b	6.9	2.11	10.8	9.20	27.1	19.1	0.574	0.66	0.98	1.13
Hardness (mg/L)	μ	93	112	77	78	111	103	19	19	19	20
	σ	27	94	25	33	41	38	3	2	2	2

$\hat{\mu}$: Mean corrected for censored data
$\hat{\sigma}$: Standard deviation corrected for censored data
Ins. = Insufficient data to compute statistic

Table 21b. State of Oregon water quality criteria for heavy metals. From OAR 340-41.

Metal	Acute Criteria (µg/L)	Chronic Criteria (µg/L)
Cadmium*	3.9	1.1
Chromium (hexavalent)	16	11
Chromium (trivalent)*	1700	210
Copper*	18	12
Lead*	82	3.2
Mercury	2.4	0.012
Nickel*	1400	160
Zinc*	120	110
* Water hardness dependent criteria (values for hardness of 100 mg/L used)		

Mercury has been found in some species of fish caught in the Willamette River and its major tributaries. The mercury in the fish is believed to come from natural volcanic and mineral sources and mining wastes in the headwaters of the Willamette River, and from human sources along the river. Fish with high levels of mercury are resident fish that eat other fish, such as largemouth bass and northern pike minnow. Anadromous fish that spend most of their adult life in the ocean do not have high mercury levels in their bodies.

Potential sources of human-derived mercury include household products, food products, dental waste, wrecking yards (mercury-based automobile switches), fluorescent and compact lamps, and deposition of air-born particles. In Lane County, perhaps one of the largest single sources of mercury in the Coast Fork Willamette River is runoff from the Black Butte mine, which was once the second largest mercury mine in Oregon until operations ceased in 1968. It is estimated that mine tailings on the site contain about 90,000 pounds of mercury, and that between 180 and 1800 pounds of mercury is potentially mobilized into the environment each year (Weiss & Wright, 2001). The Oregon Department of Environmental Quality is currently conducting a TDML (Total Daily Maximum Load) study of mercury in the Willamette basin.

The Oregon Health Division has issued a health advisory for mercury in fish for the Willamette River, recommending that people restrict their diets to the values shown in Table 21c.

Table 21c. Mercury advisory for consumption of resident fish in the Willamette River. Fillets only with skin removed.

Children 6 years or less	No more than one 4-ounce fish meal every 7 weeks
Women of child-bearing age	No more than one 8-ounce fish meal every month
All others	No more than one 8-ounce fish meal every week

Ambient water quality monitoring of the Willamette River at four stations above, within, and below the Eugene-Springfield urban growth boundary, suggests minimal mercury discharges from urban stormwater runoff and permitted point-source discharges. The average total mercury

concentration upstream of the urban growth boundary is 0.00217 µg/L, while the average downstream of the urban growth boundary is 0.00232 µg/L. Effluent from the Eugene/Springfield wastewater treatment plant averages 0.00553 µg/L of mercury. These values are lower than the state chronic criteria standard of 0.012 µg/L. Flow-weighted averages for those days on which samples were collected are 60 g/day (grams per day) of mercury in the Willamette River, and 0.71 g/day of mercury in effluent from the treatment plant. The City of Eugene reported no statistically significant difference between mercury concentrations detected upgradient and downgradient of the urban growth boundary.

An evaluation of the long-term concentration trends for metals by the City of Eugene found that arsenic was decreasing over time. This was the only analyte demonstrating a statistically significant trend. Figure 29 shows the historical data for arsenic at the Willamette River monitoring station upstream of the urban growth boundary.

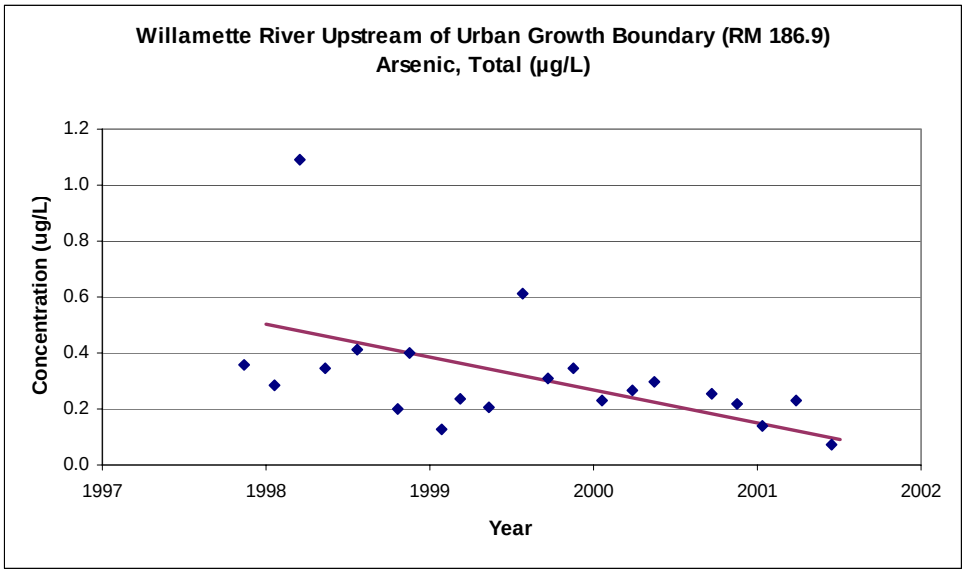


Figure 29. Long-term trend of total arsenic in the Willamette River upstream of the urban growth boundary. From the City of Eugene NPDES Annual Stormwater Report, November 2000-November 2001.

Arsenic, a metalloid, is included in this discussion here because it is toxic to aquatic organisms. Its chronic criterion is 48 µg/L and it is hardness dependent. The decreasing trend is significant at 1%, that is, there is a 1% probability that the observed trend is due to random sample variability. The cause for the decreasing trend is unknown, though changes in land use or practice within the drainage basin could lead to this phenomenon.

Heavy metal data are sparse for river monitoring locations in Springfield within the MECT study area. A search of the DEQ water quality database produced a few results, however, few of the data are recent. Sampling of the McKenzie River conducted by the McKenzie Watershed Council at the Coburg Road monitoring station was done on three separate occasions in

February, November, and December, 1998, during high flow storm events. The data for the three sampling events is shown in Table 21d. Metal values are below the state chronic criteria shown in Table 21b.

The few values for arsenic in the McKenzie River are within range of that observed for the Willamette River upstream of the urban growth boundary. The median hardness of the McKenzie River at Coburg Road is 17 mg/L and ranges from 11 to 24 mg/L. Overall, data vary by an order of magnitude for many of the metals with values highest during the February sampling event.

Table 21d. Total metal concentration (µg/L) data for McKenzie River at Coburg Road. From the City of Eugene database.

1998 Sampling	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Zinc
Feb. 21	1.54	<0.025	1.48	3.33	0.691	0.00530	6.16
Nov. 5	0.307	<0.008		0.272	0.0505	0.00135	0.654
Dec. 2	0.242	<0.016	<0.187	0.783	0.226	0.00213	0.866

Figure 30 shows the distribution of zinc data within the study area. Zinc values in the Springfield Mill Race and Amazon Creek basin monitoring stations are an order of magnitude higher than zinc concentrations found in the McKenzie and Willamette Rivers, indicating zinc concentrations in runoff from developed areas into the small streams. Common sources of zinc include galvanizing facilities, runoff from streets (the wear of tires and brake pads result in readily-moved zinc particles), galvanized metal siding and roofs on buildings, or from wastewater treatment plants.

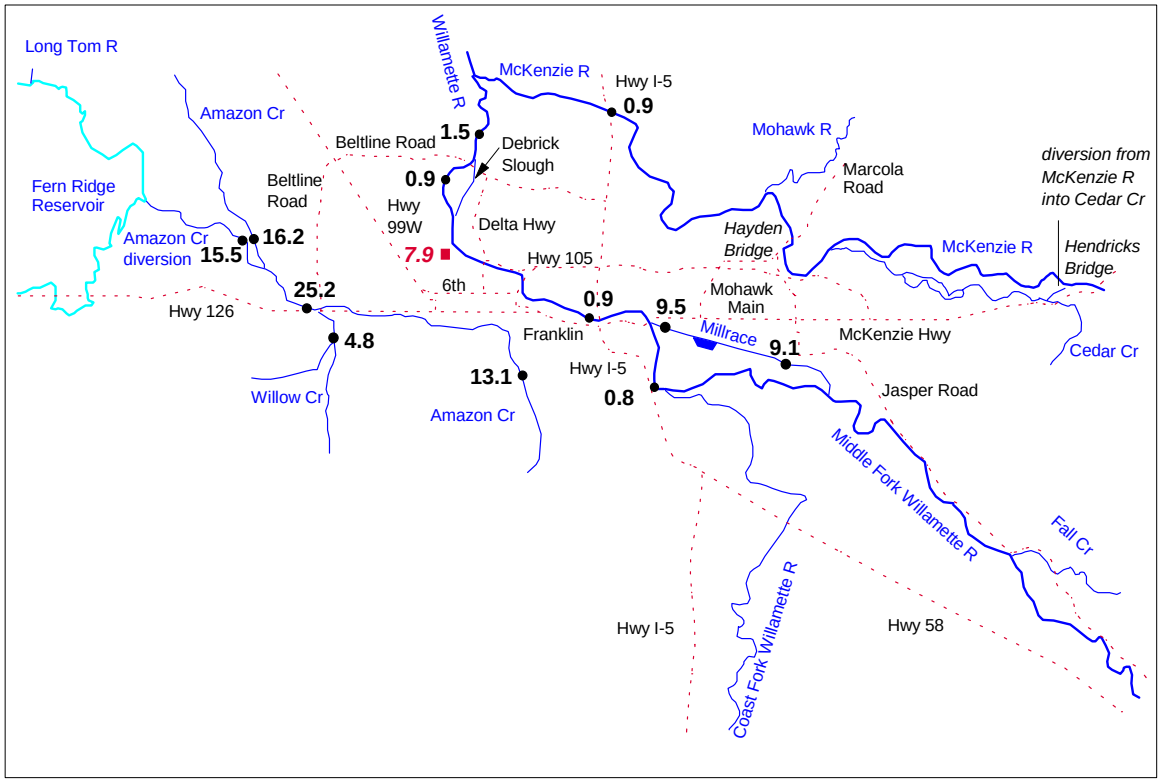


Figure 30. Median values for total zinc concentration (µg/L). Streams or rivers are shown as circles and stormwater drains are shown as red squares and red labeling. Sources of data include the City of Eugene and Student Research Project, Springfield.

Heavy metals in stormwater

Heavy metals were detected in stormwater runoff from Springfield during one storm event in March, 2002, including chromium, copper, lead, and zinc. Data are for stormwater composite samples and are summarized in Table 21e. Total copper values ranged from 5.5 to 22 µg/L, while total lead values ranged from not detected to 9.1 µg/L. Stormwater zinc values ranged from 17 to 940 µg/L. Historical concentrations of metals in Cedar Creek are also presented in Table 21e. Metal values are below the state chronic criteria (Table 21b; the criterion for arsenic is 48 µg/L and is hardness dependent).

Data from City of Eugene monitoring programs are primarily collected under the City's NPDES Stormwater Permit. The City of Eugene deploys automated samplers to collect stormwater samples at 15-minute intervals over a 24-hour period. All of the stormwater collected over the 24-hour period is combined into one sample before analysis. Sampling does not necessarily coincide with storm events or with the water quality-monitoring program for streams and rivers. Data reviewed for this report come from five stormwater sampling locations. Additional source identification investigations are routinely conducted but are not discussed at depth in this study. The focus here is on long-term stormwater site monitoring, a small fraction of which is summarized in Table 21f for comparison with similar studies.

Table 21e. Stormwater runoff quality for the City of Springfield – March 5, 2002 storm event. ND = Not Detected.

Metal (µg/L)	Springfield stormwater sampling location				Cedar Creek (receiving water)
	72nd Street	64th Street	52nd Street	42nd Street	
Total Arsenic	ND	1.36	ND	1.51	1.63
Total Chromium	1.11	1.91	ND	4.13	1.58
Total Copper	5.5	22.3	4.06	19.5	4.17
Total Lead	ND	4.61	1.57	9.14	ND
Total Zinc	17.2	940	180	153	15.2

Table 21f. Summary of stormwater water quality for metals. From City of Eugene monitoring programs.

Metal	Range (µg/L)	Median values (µg/L)
Total Cadmium	ND – 5.7	ND – 0.3
Total Copper	ND – 190	9 – 18
Total Lead	ND – 200	3 – 17
Total Zinc	ND – 2400	30 – 210

In 1997, the Oregon Association of Clean Water Agencies (ACWA) conducted a survey of urban stormwater runoff water-quality data from seven municipalities and agencies. The primary focus of the study was to assess stormwater runoff water quality in terms of land use type. Data were collected between 1991 and 1996, and are summarized in Table 21g. A comparison of Eugene and Springfield stormwater monitoring data for heavy metals with the ACWA data indicates that median concentrations of total copper, lead, and zinc are within the range of values reported in the ACWA study. However, a few values from the Eugene data set are above the upper concentration range reported in the ACWA study, specifically one total zinc value at 2400 µg/L, and one total copper value at 190 µg/L. The ACWA study reports the 90th percentile values for these metals at 1848 and 104 µg/L, respectively. The stormwater data from the Springfield and Eugene sites can be classified as either industrial, commercial, or mixed commercial and residential.

Table 21g. Stormwater runoff quality based on land use – median concentrations. From Oregon Association of Clean Water Agencies, 1997.

Land use type	Total copper (µg/L)	Total lead (µg/L)	Total zinc (µg/L)	Total phosphorus (µg/L)
Industrial	32	21	251	380
Transportation	28	43	197	330
Commercial	22	26	115	210
Residential	10	10	69	150
Open	4	2	12	160

The City of Eugene has conducted several source identification surveys, including one in a series of shallow ponds and drainages along Delta Highway. The ponds, which were created as gravel pits, were mined for construction of the highway, receive stormwater runoff and permitted

discharge that eventually drains into the Willamette River. Samples collected from surface waters and stormwater outfall discharges from one industrial facility indicated concentrations of total zinc in surface waters were as high as 1400 µg/L, and 5600 µg/L from the facility stormwater outfall. Following an abatement order from the City of Eugene, this facility has implemented measures to prevent stormwater runoff from the site.

Plans are currently underway to restructure flow through Delta Ponds, as well as reshape banks and excavate certain areas in order to improve conditions for fish and wildlife. The Corps of Engineers is working with the City of Eugene to minimize suspension of zinc in pond sediments into the water column, thereby reducing potential risk to aquatic life.

3.4 Nutrients

The productivity of fish and their food base hinges on the amount of bioavailable nitrogen and phosphorus in the water. In natural waters of the Pacific Northwest, phosphorus is usually the nutrient that limits primary productivity, which includes algae and zooplankton. This means that, unless extra phosphorus becomes available, there will still be spare bioavailable nitrogen in the water column.

The bioavailable form of phosphorus is referred to as soluble reactive phosphorus. There is another portion that is attached to sediment particles, which is not immediately available for uptake by aquatic organisms, but has the potential to be released into the water column if dissolved oxygen levels become low. Shallow reservoirs, such as Fern Ridge Reservoir, can have low dissolved oxygen levels and release phosphorus from sediments, especially at night and during early fall when plant material begins dying off.

Nitrogen has three bioavailable forms that include nitrate (NO_3^-), nitrite (NO_2^-), and ammonia. The term ammonia refers to two chemical species that are in equilibrium in water, un-ionized (NH_3), and ionized (NH_4^+). Tests for ammonia usually measure total ammonia, that is, NH_3 plus NH_4^+. The toxicity of ammonia is primarily attributable to the un-ionized NH_3, as opposed to the ionized form NH_4^+. In general, the toxicity of NH_3 to fish is a function of pH and water temperature. In the presence of NH_3, an increase in either pH or temperature can be harmful to aquatic organisms.

Nitrite (NO_3^-) and ammonium (NH_4^+) are rarely found in Pacific Northwest streams and rivers except immediately downstream of point sources of pollution since chemical and biochemical processes in a river quickly transform them into nitrate. Consequently, most bioavailable nitrogen in the Pacific Northwest is in the form of nitrate for streams, rivers, and groundwater. Nitrate and nitrite data evaluated for this study are reported as nitrate plus nitrite as nitrogen. We have abbreviated the form to NO_3+NO_2 (as N) in this report.

Nutrients in rivers and streams

Blue River and Cougar reservoirs, located on two major tributaries of the McKenzie River, release water during the summer that is higher in bioavailable nitrogen (nitrate, nitrite, and

ammonium) than that flowing into the reservoirs (Table 21h). Conversely, soluble reactive phosphorus concentration in water flowing out of these reservoirs in the spring and summer is lower than that of inflowing water. The entrapment of phosphorus in these reservoirs probably decreases primary productivity in the phosphorus-poor McKenzie River and, consequently, limits the entire food web downstream.

Median values for total phosphorus are shown in Figure 31 for river water quality monitoring stations in the MECT study area. Concentrations are relatively low in the Willamette River upstream of the urban growth boundary at 0.03 mg/L, and rise slightly to 0.06 mg/L downstream of the urban growth boundary near the Beltline Road Bridge. Upstream monitoring locations on Amazon Creek and Willow Creek have median phosphorus concentrations of 0.09 and 0.06, respectively.

Median values for combined nitrate+nitrite as nitrogen (NO_3+NO_2 as N) are 0.03 mg/L in the Willamette River upstream of the urban growth boundary, and rise slightly to 0.10 mg/L downstream of the Beltline Road Bridge (Figure 32). A review of the long-term trend of NO_3+NO_2 data downstream of the urban growth boundary shows that concentrations are increasing with time (Figure 33). This is likely due to continued development of land immediately upstream of the monitoring location. This trend is statistically significant at 1%, that is, there is a 1% probability that the trend is due to random sample variability. Median concentrations of NO_3+NO_2 (as N) in the Amazon Creek basin range from 0.16 to 0.33 mg/L. At the Willow Creek site, which has limited development, the median concentration is 0.04 mg/L.

Table 21h. Influence of two major reservoirs in the upper McKenzie River basin on bioavailable nitrogen and soluble reactive phosphorus concentration in year 1996 (USCE 2000).

	McKenzie River upstream of reservoirs	Blue River Reservoir		Cougar Reservoir	
		inflow	outflow	inflow	outflow
Bioavailable nitrogen (mg/L)					
May 28	0.001	0.004	0.002	0.001	0.006
August 28	0.020	0.014	0.065	0.009	0.057
September 25	0.007	0.005	0.026	0.002	0.014
Soluble reactive phosphorus (mg/L)					
May 28	0.021	0.017	0.012	0.017	0.013
August 28	0.033	0.019	0.008	0.038	0.012
September 25	0.028	0.038	0.017	0.010	0.004

Given the median concentrations for nitrogen and phosphorus in Amazon Creek, a prevalence of suspended and attached algae in the water column would be expected. High algae concentrations combined with high water temperature leads to wide diurnal swings in dissolved oxygen whereby the water column becomes supersaturated during the day as algae give off oxygen, and very low at night as organic material decays, thereby creating unfavorable habitat for native fish. Once these nutrients reach Fern Ridge Reservoir, they continue to play a role in fueling algae growth and disrupting dissolved oxygen levels. Dissolved oxygen concentrations in Amazon Creek follow this phenomenon in that values are generally between 4 and 9 mg/L during early morning hours from May through September.

Long-term concentration trends for dissolved oxygen are presented in Figure 34 for the monitoring station downstream of the enhanced wetland area (Amazon Diversion Channel at Royal Avenue). The trend of increasing dissolved oxygen over time is statistically significant at 1%. That is, there is a 1% probability that the observed trend is due to random sample variability. Increasing productivity of wetland flora is likely responsible for the dissolved oxygen trend.

The City of Eugene evaluated historical data for the Amazon basin sites utilizing the Mann-Whitney statistic to determine whether analyte concentration differences exist between upstream and downstream locations from an enhanced wetland area.

Specifically, comparisons were made of Amazon Creek at the Railroad Crossing (upstream) and the Diversion Channel at Royal Avenue (downstream), and the A3 Channel at Terry Street (upstream) and the Amazon Creek at Royal Avenue (downstream). The wetland area is bounded by Green Hill Road on the west, Royal Avenue to the north, and the railroad tracks to the south as shown in Figure 34.

Results of the statistical analysis for the railroad crossing and diversion channel sites suggest total Kjeldahl nitrogen (TKN; inorganic and organic nitrogen) and total phosphorus are significantly different (at $\alpha = 0.05$). On average, the downstream TKN concentration is slightly higher than the upstream location, which are 0.5 and 0.3 mg/L, respectively. Results for total phosphorus indicate the average downstream concentration is slightly higher at 0.14 mg/L compared to 0.12 mg/L at the upstream site. Comparing the A3 Channel site and its downstream counterpart Amazon Creek at Royal Avenue, on average, the upstream total phosphorus concentration is slightly higher than the downstream location, which are 0.24 and 0.19 mg/L, respectively.

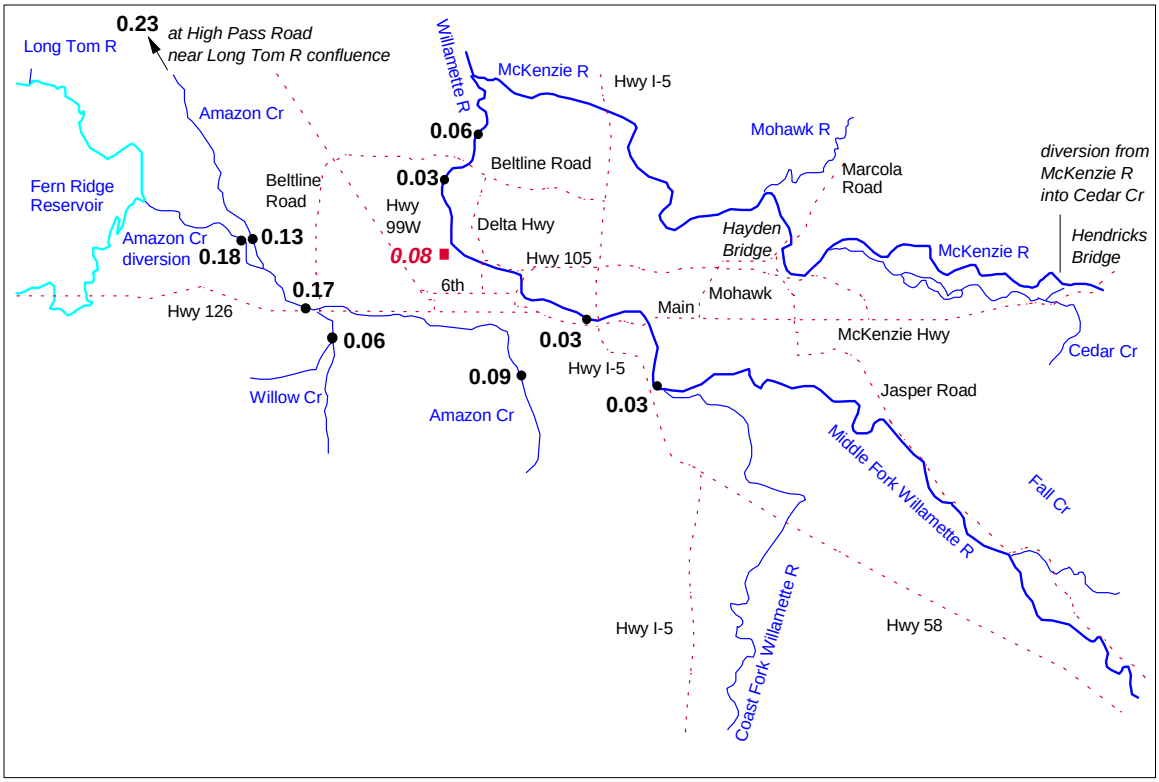


Figure 31. Median values for total phosphorus (mg/L). Sampling sites for streams or rivers are shown as circles and stormwater drains are shown as red squares and red italic text. Data provided by the City of Eugene and Long Tom Watershed Council.

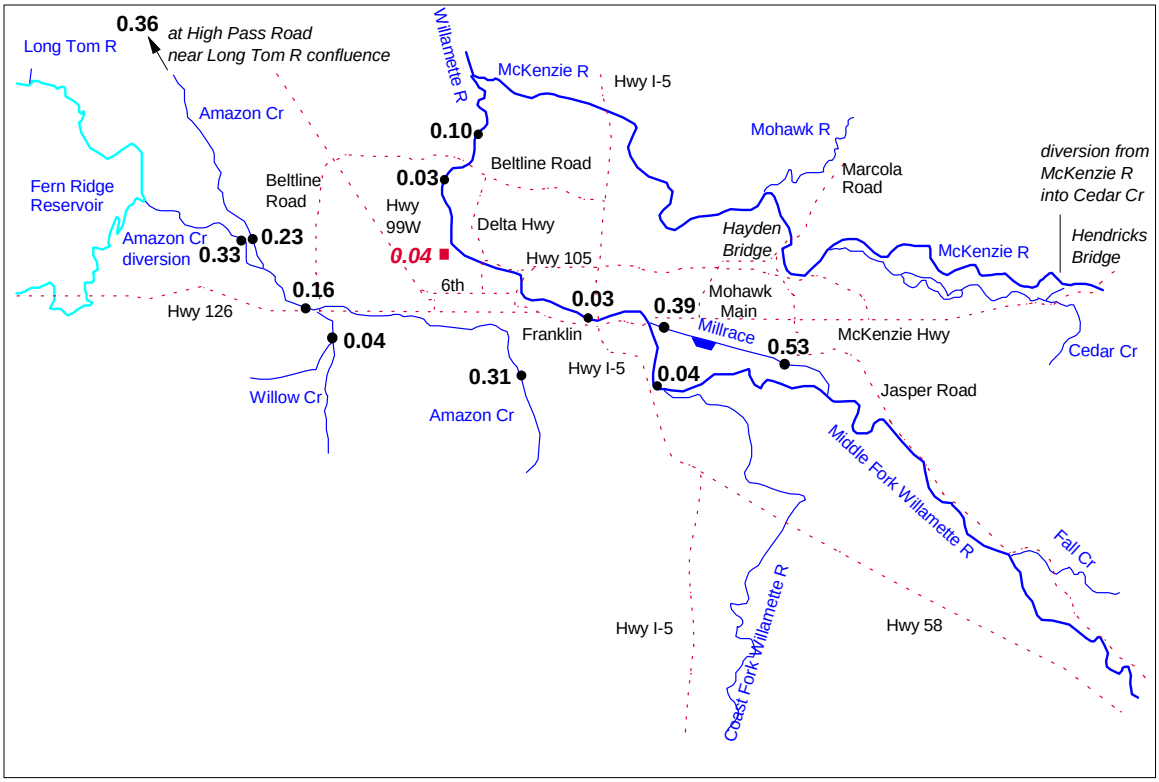


Figure 32. Median values for Nitrate+Nitrite (as N). Sampling sites for streams or rivers are shown as circles and stormwater drains are shown as red squares and red italic text. Data provided by City of Eugene, and Long Tom Watershed Council.

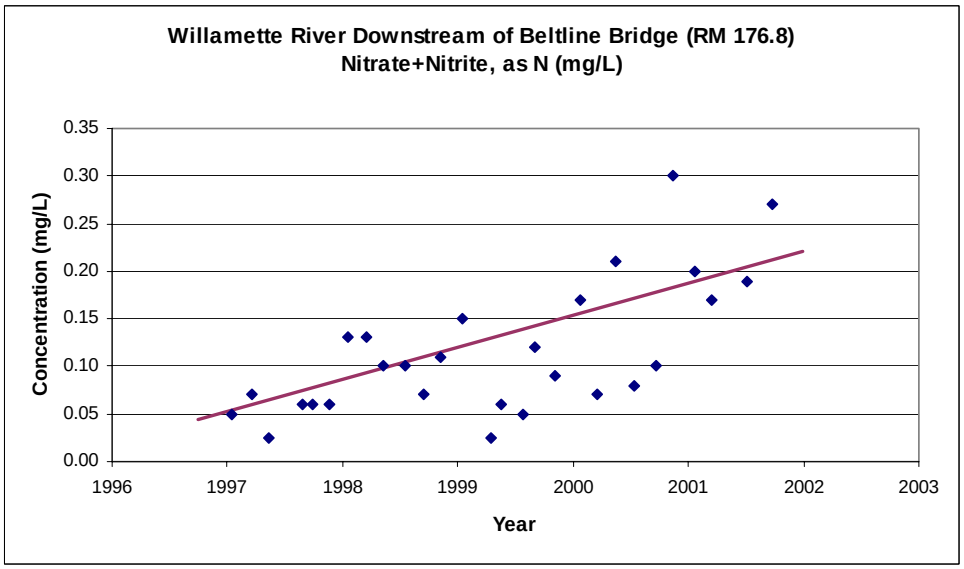


Figure 33. Long-term trend of nitrate+nitrite (as N) in the Willamette River downstream of the urban growth boundary. From the City of Eugene NPDES Annual Stormwater Report, November 2000-November 2001.

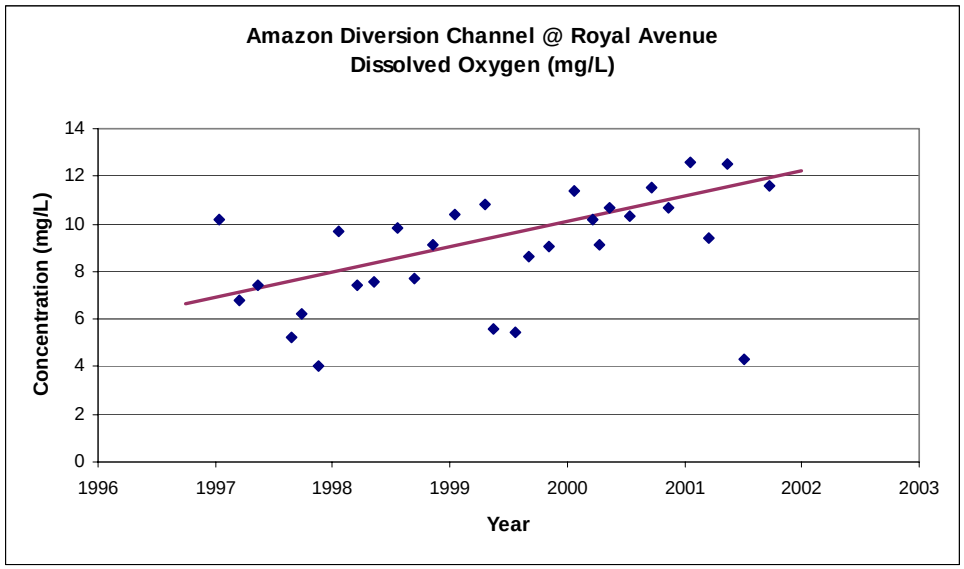
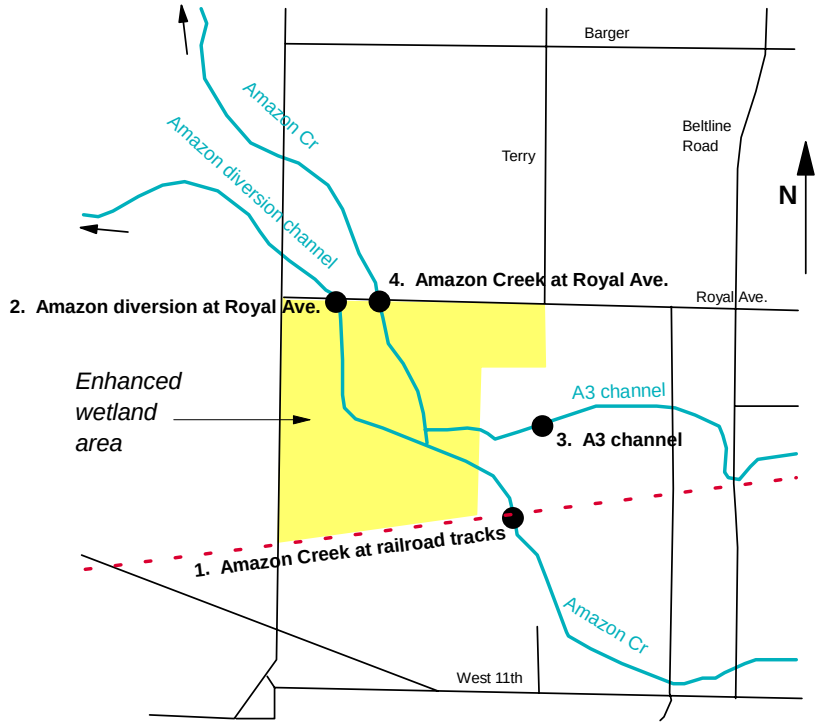


Figure 34. Long-term trend of dissolved oxygen in Amazon Diversion Channel at Royal Avenue downstream of the enhanced wetland area. From the City of Eugene NPDES Annual Stormwater Report, November 2000-November 2001.

Phosphorus data are insufficient on the McKenzie River to determine whether a significant increase occurs between downstream and upstream monitoring locations (Table 21i); recent data are not available from an upstream location. However, data for the Coburg site suggests phosphorus loading within the Springfield urban growth area is relatively low or not significant. The median value for the downstream monitoring location at Coburg Road is 0.04 mg/L and ranges from 0.02 to 0.14 mg/L, though the high value appears to be spurious. No significant phosphorus contributions are observed from the Mohawk River. Total phosphorus measured at one station on Cedar Creek for one sampling event in March, 2002, is within the median range observed for the Coburg site at 0.02 mg/L.

The median value for ammonia in the McKenzie River at Hendricks Bridge is 0.02 mg/L and ranges from 0.02 to 0.08 mg/L. No significant increase is observed downstream at the Coburg Road site, where the median value for ammonia is 0.03 mg/L and ranges from 0.02 to 0.09 mg/L. The median value for NO_3+NO_2 (as N) at Hendricks Bridge is 0.02 mg/L and ranges from 0.006 to 0.16 mg/L; no significant increase is observed at the Coburg site where the median is 0.03 and ranges from 0.006 to 0.19 mg/L

Ammonia contributions from the Mohawk River are not significant; the median is 0.03 mg/L and ranges from 0.02 to 0.15 mg/L. Contributions of NO_3+NO_2 (as N), however, are significant – the median concentration is 0.08 mg/L and ranges from 0.008 to 0.46 mg/L. Nitrate+nitrite (as N) for the same sampling event is reported as not detected (<0.03 mg/L).



Median values for 6 samples in 2001.

	E. coli. bacteria (#/100mL)	Nitrate/ nitrite (mg/L as N)	Total phosphorus (mg/L as N)	Total zinc (ug/L)	Total suspended solids (mg/L)
1. Amazon Cr. at railroad tracks	530	0.30	0.17	25.2	21.5
2. Amazon diversion at Royal Ave.	72	0.02	0.14	9.6	18.0
3. A3 channel	255	0.26	0.28	53.1	30.5
4. Amazon Cr at Royal Ave.	710	0.25	0.13	15.5	17.5

Figure 35. Water characteristics upstream and downstream of the enhanced wetland area on lower Amazon Creek near the Amazon Creek diversion. Data provided by City of Eugene.

Table 21i. Comparison of historical nutrient median concentrations in the Mohawk River and McKenzie River. From DEQ water quality database, for period 1992 to 2001. Median values are shown on the upper row for each site; minimum/maximum values are on the lower row.

Monitoring Location	Ammonia (as N) mg/L	Nitrate+Nitrite (as N) mg/L	Total Phosphorus mg/L
Mohawk River at Hill Road	0.03 0.02 / 0.15	0.08 0.008 / 0.46	0.02 0.01 / 0.11
McKenzie River at Hendricks Bridge	0.02 0.02 / 0.08	0.02 0.006 / 0.16	No Data
McKenzie River at Coburg Road	0.03 0.02 / 0.09	0.03 0.006 / 0.19	0.04 0.02 / 0.14

Nutrients in stormwater

Stormwater monitoring for nutrient loading is summarized here for the same monitoring stations discussed in the previous section. The median value for total phosphorus at all composite stormwater-monitoring sites in Eugene is 0.25 mg/L, with values ranging from 0.09 to 11 mg/L. Data from the five Eugene stations were compared to those reported in the ACWA stormwater study; out of 79 total phosphorus measurements, two values, 9.9 and 11 mg/L, were above the 90th percentile value of 3.0 mg/L for predominantly commercial land use. These were both measured in stormwater runoff from commercial and industrial land use areas. The source of phosphorus in stormwater drains is likely a combination of runoff containing fertilizers, soaps, animal feces, soil erosion, atmospheric deposition, and potential leakage or hookups from adjacent sewage pipes, or industrial sources.

Concentrations of NO_3+NO_2 (as N) in Eugene stormwater samples ranged from not detected to 3.7 mg/L, the median was 0.06 mg/L. Sources for NO_3+NO_2 (as N) are similar to those for phosphorus.

In Springfield, the single stormwater sampling event conducted in March, 2002, produced phosphorus values ranging from 0.08 to 0.31 mg/L, and NO_3+NO_2 (as N) concentrations ranging from 0.42 to 1.61 mg/L. These are similar to historical data reported for Eugene stormwater stations.

Other water quality parameters

Additional water quality data have been generated, compiled, and analyzed by the City of Eugene from 1997 to 2001, as part of the City's NPDES stormwater permit requirements. Data comparisons in Table 21j expand the discussion above with additional water quality analytes whose sources may be attributed to human activity in the Eugene-Springfield urban area.

Water quality analytes whose upstream and downstream difference is statistically significant using the Mann-Whitney statistic, are summarized in Table 21j. The Mann-Whitney statistic is a technique used to determine whether two data sets are from the same location. The data sets are considered significantly different if the probability that the data sets come from the same location is less than 5%. In addition to the analytes considered above, silver, fecal coliform, specific conductance, and total solids are, on average, lower in the Willamette River upstream of the Eugene/Springfield urban growth area than at the downstream site near Beltline Bridge.

Table 21k summarizes average historical analyte concentrations in the Amazon Creek basin whose upstream and downstream difference is statistically significant using the Mann-Whitney statistic. In general, downstream sampling sites in the Amazon basin contain higher analyte concentrations than in upstream sites. Notable exceptions are fecal coliform and ortho phosphorus at the Amazon Park/29th Avenue monitoring site, which were higher than values reported at the Amazon Creek Railroad Track Crossing site, the latter located about a mile downstream of the Willow Creek confluence and some seven miles downstream of the Amazon Park/29th Avenue site.

<u>Table 21j.</u> Comparison of average historical concentrations in the Willamette River upstream and downstream of the urban growth boundary for only those analytes that are statistically different from each other*. From the City of Eugene NPDES Annual Stormwater Report, November 2000-November 2001, for period from 1997 to 2001.

Analyte	Units	Willamette River upstream of urban growth boundary (RM 186.9)	Willamette River downstream of Beltline Bridge (RM 176.8)
Arsenic, dissolved	(*µg/L*)	0.199	0.226
Arsenic, total		0.307	0.313
Copper, dissolved		0.260	0.349
Copper, total		0.569	0.689
Lead, dissolved		0.00510	0.0208
Lead, total		0.0859	0.112
Silver, dissolved		0.00370	0.00453
Silver, total		0.00569	0.0134
Zinc, dissolved		0.237	0.982
Zinc, total		0.933	1.94
Escherichia coli	(*Col./100 mL*)	23	46
Fecal coliform	(*Col./100 mL*)	17	36
Nitrate/nitrite as N	(*mg/L*)	0.03	0.11
Total Kjeldahl nitrogen as N		<0.1	0.3
Orthophosphorus		0.03	0.05
Total phosphorus		0.04	0.08
Specific conductance	(*µmhos/cm*)	47	53
Total solids	(*mg/L*)	52	60

* Determined using the Mann-Whitney statistic with significance determined at the $\alpha = 0.05$ level.

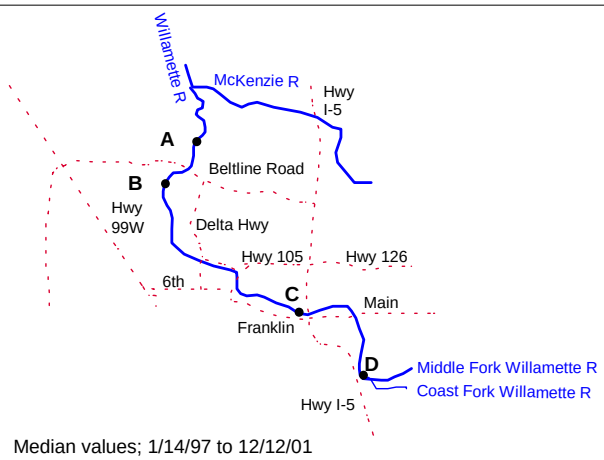
<u>Table 21k.</u> Comparison of average historical concentrations for Amazon Creek basin sites for only those analytes that are statistically different from each other*. From the City of Eugene NPDES Annual Stormwater Report, November 2000-November 2001, for period from 1997 to 2001.

Parameters:	Units	Amazon Creek Site M2 at 29th Avenue	Willow Creek	Amazon Creek at railroad track crossing	Amazon Diversion Channel at Royal Avenue	A3 Channel at Terry Street	Amazon Creek at Royal Avenue
Arsenic, dissolved	(*µg/L*)	0.800	1.02	2.42			
Arsenic, total		1.02	1.62	3.95			
Cadmium, total		0.0103	0.0034	0.0305		0.0891	0.0294
Chromium, dissolved		0.525		0.846			
Chromium, total		1.09		1.88			
Copper, dissolved		1.54	1.15	1.78			
Copper, total		3.23	2.22	4.10			
Lead, dissolved		0.0305	0.0191	0.0981			
Lead, total		0.778	0.331	2.72			
Mercury, dissolved		0.00119	0.00117	0.00227			
Mercury, total		0.00299	0.00298	0.00994		0.0145	0.00772
Nickel, dissolved		1.43		1.85	1.75	2.63	2.40
Nickle, total					2.67	4.06	3.54
Silver, total		0.0127	0.00478	0.0289	0.0411	0.0213	0.0178
Zinc, dissolved		6.19	2.63	6.97		16.2	8.92
Zinc, total		13.8	4.77	20.3		41.3	23.0
Nitrate/nitrite as N	(*mg/L*)	0.36	0.01	0.21			
Total Kjeldahl nitrogen as N				0.3	0.5		
Orthophosphorus		0.06	0.02	0.02	0.03		
Total phosphorus		0.10	0.06	0.12	0.14	0.24	0.19
Biochemical oxygen demand				1.2	1.3	3.5	2.7
Chemical oxygen demand		3	7	9	12		
Magnesium, total				6.8	7.0	12.5	11.1
Hardness						111	103
Turbidity	(*NTU*)	17	23				
Total suspended solids	(*mg/L*)	10	14	21			
Total dissolved solids				129	133	167	163
Total solids						212	204
Specific conductance	(*µmhos/cm*)				202	275	
Escherichia coli	(*Col./100 mL*)	1543	183	1674			
Fecal coliform	(*Col./100 mL*)	160	149	57	102	42	103
pH	(*Units*)	7.2	7.0				

* Determined using the Mann-Whitney statistic with significance determined at the $\alpha = 0.05$ level.

3.5 Conclusions on Water Quality

As the Willamette River flows through the study area, it experiences increases in pollutants that can be tied to human activities but concentrations are far below state water quality standards (E. coli and total zinc) or levels of concern (nitrogen and phosphorus) (Figure 36). Nevertheless, nitrogen concentrations have been increasing in recent years. Arsenic, copper, lead, zinc, *E. coli*, nitrogen, and phosphorus are, on average, statistically lower in the Willamette River upstream of the Eugene-Springfield urban growth area than at the downstream site.



Median values; 1/14/97 to 12/12/01

	E. coli (#/100mL)	Nitrate /nitrite (mg/L as N)	Total phosphorus (mg/L)	Total zinc (ug/L)
A	40	.10	.06	1.5
B	37	.02	.03	0.9
C	23	.02	.03	0.9
D	13	.04	.03	0.8

Figure 36. Summary of water characteristics of that portion of the Willamette River flowing through the study area. Data provided by the City of Eugene.

Amazon Creek is plagued by a number of water quality issues. These include,

- heavy metals zinc, lead, and copper exceed or approach the state chronic criteria for aquatic life protection;
- bacteria counts commonly exceed 406 *E. coli per* 100 mL;
- the stream experiences relatively high nutrient loads; and
- the stream has relatively warm water temperatures in its middle reaches, although the very low flows in 2001 probably overstated the water temperature status of this stream in summer, 2001.

The enhanced wetland area in the lower Amazon Creek basin may have an important role in ameliorating water quality problems in the Amazon Creek basin before flows reach the Fern Ridge reservoir. However, the data are ambiguous without flow information. Flow measurements should be collected at the monitoring locations at the time samples are collected so that mass loadings can be calculated. In addition, the fate of these contaminants over the long term can be understood only if monitoring continues and includes a strategy of detecting contaminant movement during high flows. If contaminants are retained by the wetlands during the summer but are subsequently flushed out during winter flows, or if nutrients are released once vegetation dies in the late fall, then the effectiveness of wetland treatment would be less than if contaminants are immobilized and nutrients utilized in the wetlands. Measuring sedimentation rates would also be important since wetlands will invariably fill in over time.

Without changes in the routing and processing of stormwater, Willow Creek is likely to develop water quality problems similar to Amazon Creek once it becomes developed. Fortunately, opportunities to set aside areas for stormwater retention and treatment still exist in the Willow Creek basin.

The large concentrations of ducks and geese in lower Patterson Slough ponds and within the Eugene Mill Race coincide with areas that are heavily used by children to play and fish. Investigating the role of bread-fed waterfowl on bacteria contamination of these waters should be a high-priority monitoring topic.

The Springfield Mill Race receives high quality water from the Middle Fork Willamette River (when connected) and does not appear to suffer much contamination, even though industrial development along the mill pond has been intense during the last century. Zinc concentrations in the Mill Race are an order of magnitude higher than concentrations found in the Willamette River, though they were still an order of magnitude lower than the chronic criteria for aquatic life. Limitations to native fish use seem to be mainly related to temperature and gravel plugging of the inlet at the Middle Fork Willamette River each year. Previous temperature modeling of the Mill Race used data that was for an unusually cool summer and the typical maximum temperature of inlet water to the Mill Race was assumed to be 55 ˚F (Otak 1997). However, monitoring in 2001 indicated that the maximum 7-day average temperature was 69 ˚F for the Middle Fork Willamette River. Establishing summer-long temperature monitoring sites with recording gauges would provide data to develop more realistic modeling to support temperature management for native fish species in the Mill Race.

Additional data should be collected at other receiving waters in the study area, including the McKenzie River, Mohawk River, and Cedar Creek, to assess water quality in these streams and potential effects of human activities. The three sampling events at the Coburg Road station are insufficient to characterize McKenzie River water quality and variability observed in the data set and warrants additional study. Most other urban streams, sloughs, ponds, and drainage channels in the study area have not been sampled and, therefore, their water quality status is unknown. High priority sites for future monitoring should include waters that receive stormwater and potentially support salmonids. These include Patterson Slough (including the Alton Baker Canoe Canal) and the lower portions of the East Santa Clara Waterway and Spring Creek.

The limited availability of water quality data for stormwater and streams from Springfield sites precludes meaningful analysis or conclusions pertaining to human-related pollutants, particularly with respect to heavy metals and nutrients. The DEQ database contains some nutrient information for area rivers and streams, however, most of these data are pre-1992. Analytical methodologies have changed significantly over the last ten years, hence, the older data are not very useful for assessing recent human activities. In addition, it is unknown whether the DEQ will continue their existing river and stream water-quality monitoring programs given the budget limitations confronting the agency. A long-term monitoring program should be established by the City of Springfield to include heavy metals, nutrients, and other potential contaminants of concern. This, and stormwater quality data deficiency, should largely be addressed with implementation of a stormwater NPDES permit, which the City anticipates submitting to the DEQ in March, 2003.

Assessment of stormwater impacts on rivers and streams cannot be done without flow data. Gauge stations are established on several rivers in the study area, though a few streams remain ungauged. Stormwater flows also are generally unknown because instrumentation required to collect these data are currently unavailable to the groups and agencies conducting stormwater monitoring. However, with increased interest in stormwater and its effects on endangered species, resources are being allocated to collect this data. Qualitative assessment of stormwater data is likewise difficult because sampling events do not necessarily coincide with storm events, thus comparing one stormwater sampling event with another may not prove meaningful. However, stormwater monitoring is still an invaluable tool for source identification and for evaluating the types of contaminants entering rivers and streams.

Recommendations:

1. Water temperature data on small streams is lacking in the study area. TMDL processes for temperature are often abbreviated in detail and it is often erroneously assumed that all streams, with enough restoration, can be cooled to 64˚ F. The MECT can prepare for the upcoming TMDL process by monitoring the temperature of Pudding Creek, the only undeveloped stream with flow during the summer. Such monitoring can help counter proposals by others for unrealistic temperature goals that would apply to Willamette Valley streams.

2. Small streams warm quickly even when flowing through short reaches of channel that have full exposure to sunlight. Expanding the cool-water zone within a small watershed is best achieved by establishing shade in the upper portions of the summer stream network and working downstream, making sure that all reaches are shaded.

3. Bacteria contamination within stormwater and smaller receiving waterways is high for both Eugene and Springfield. Reducing bacteria concentrations in waterways can be best achieved by aggressively looking for sources of contamination, including places where sanitary sewers are hooked up to the stormwater system.

4. Streams flowing through yet-to-be-developed portions of the study area will likely take on the characteristics of Amazon Creek if development is not also accompanied by aggressive efforts to treat stormwater before it enters the streams. Constructed wetlands offer a promising treatment

option that seems to be at least partially effective in this climate.

5. Sources of high heavy metal concentrations (especially zinc) in some stormwater systems should be investigated with rigor in order to avoid violations of the state water quality standard and harm to aquatic life. The 64th Street stormwater drain in Springfield seems to have the highest heavy metal concentrations and, therefore, should be investigated first.

Information gaps:

1. Information on downstream warming trends within undisturbed streams is lacking for the study area.

2. Information is lacking on the sources of bacteria within stormwater. Techniques now exist for discerning whether bacteria is of human or animal origin. Information on the source of contamination can help focus on effective methods to reduce contamination.

3. Ponds that attract high densities of ducks and people are prime areas for bacteria development and transmission to humans, especially to children who play in the water. Information is lacking on bacterial contamination of these waters, which include the Eugene Mill Race and the lower Patterson Slough pond.

4. Constructed wetlands are promising for treating stormwater, but the monitoring at existing wetland treatment sites is not sufficient to determine whether they are effective over the long-term. For effective monitoring, information is needed on flow in and out of wetlands, as well as monitoring of sediment deposition and constituents within sediments.

5. The concentration of nitrate/nitrite in the Willamette River downstream of Eugene is low but has increased 4-fold in the last 5 years. This may be due to more nitrogen entering the river from human sources or it could be a result of unusually low flows in recent summers. This question could be resolved by constructing a nitrogen load (by season) for each year using existing concentration and flow data and determining whether or not the upward trend still exists.

6. Information on flow at monitored stormwater sites is missing due to the lack of equipment to measure flows. Proper analysis of stormwater effects on receiving waters requires that flow be known.