Aquatic and Riparian Habitat Assessment for the Eugene-Springfield Area

Final Report
September, 2002

Prepared for:
Eugene-Springfield
Metropolitan Endangered Species Act
Coordinating Team (MECT)

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City of Eugene, City of Springfield, Lane County, Lane Council of Governments, Metropolitan Wastewater Management Commission, Springfield Utility Board, Eugene Water and Electric Board, and Willamalane Park and Recreation District

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This project was funded, in part, by a grant from the Oregon Watershed Enhancement Board.

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Introduction

This document was prepared at the request of the Metropolitan ESA Coordinating Team (MECT) which includes representatives from the City of Eugene, City of Springfield, Lane County, Lane Council of Governments, Metropolitan Wastewater Management Commission, Springfield Utility Board, Eugene Water and Electric Board, and Willamalane Park and Recreation District . This project was funded, in part, by a grant from the Oregon Watershed Enhancement Board.

The purposes of this assessment are to:

- Inform local government staff, elected officials and interested citizens about the current condition of key aquatic and riparian indicators relative to historic conditions.
- Assist MECT agencies with preparation of an action plan for habitat conservation, enhancement, and restoration planning for aquatic and riparian resources, and fishes listed under the federal Endangered Species Act.
- Provide preliminary site-specific recommendations for protection, restoration, and enhancement of habitat.
- Identify key gaps in information and monitoring related to these resources.

This assessment includes the evaluation of the following topics:

Physical and historic setting
Physical condition of waters and their associated vegetation
Water quality
Hydrology
Aquatic organisms, including fish, turtles, and macroinvertebrates.
High priority protection and restoration opportunities

The study area includes portions of five fifth-field watersheds (Map 2). The Long Tom River watershed includes streams that flow west and northwest into Fern Ridge Reservoir or directly into the Long Tom River. The majority of stormwater draining from the City of Eugene is routed through this watershed (Map 14).

The Lower Coast Fork Willamette River watershed within the study area includes only the lower 5 miles of the river and the Russell Creek drainage. The Lower Middle Fork Willamette watershed within the study area includes the lower 7 miles of the river, a few small tributaries, and some drainage from the south part of Springfield.

The Lower McKenzie River within the study area includes the lower 18 miles of the river and Cedar Creek, a major tributary of the study area. Much of the stormwater draining from the east one-half of Springfield flows into Cedar Creek and the McKenzie River. The Mohawk River is not in the study area, but it does flow into that portion of the McKenzie River that is included in the study area.

The Upper Willamette/Muddy Creek watershed within the study area includes 12.5 miles of the most upstream portion of the Willamette River and some small tributaries. In addition, stormwater from the west portion of Springfield and the east portion of Eugene is conveyed into this watershed.

A glossary of technical terms used in this document is provided in Appendix A.

1. Geographic Setting and History

The MECT study area includes the cities of Eugene and Springfield, their respective urban growth boundaries, and a few areas outside the urban growth boundaries (Map 1, Map 2). It is situated at a unique crossroads of ecological and social influences.

The Middle and Coast Forks of the Willamette River flow into the south border of the study area and then join to form the Willamette River. The McKenzie River flows from the Cascade Range and forms the northern boundary of the study area until it joins the Willamette River. Both natural and engineered streams flow northwestward through the study area. The largest of these, including Amazon Creek and Willow Creek, are in the Amazon Creek watershed, which is a subbasin of the Long Tom Watershed. Cedar Creek flows for a short distance alongside the McKenzie River on the eastern side of the study area. It is also a significant ecological system in terms of habitat for juvenile spring Chinook and water quality.

The Willamette Valley is a unique, grassland and savanna ecoregion. Its plant and wildlife communities have been influenced by humans from aboriginal Americans to early trappers and explorers, to pioneers and continuing, increasingly, into the present.

1.1 Geology

The landforms of the study area were created over millions to thousands of years ago by a combination of influences including ice ages, volcanism, and cataclysmic hydrologic events. The area is comprised of three major geologic formations (Map 5). One, the basalt geology, is found below the steeper slopes and their rock outcroppings that form the southern boundary of the study area. Specifically, these hills were formed from andesitic basaltic or pyroclastic bedrock formed 10-25 million years ago (Thieman 2000, 14; U.S. Army Corps of Engineers 1953, 4). The second geologic formation is the Missoula flood deposits which consists of that part of the main valley floor buried with silts deposited primarily during the Bretz Floods that filled the Willamette Valley with sediment 12,000-600,000 years ago (Allen et.al. 1986). The third geologic formation is the river alluvium. This is the area within and near the rivers that has been scoured of silts left over from the Bretz Floods and is characterized by coarse sediments and gravel deposited by rivers originating in the Cascade Mountains.

Prior to the geologically recent series of ice ages, 40-50 million years ago, the Willamette Valley was submerged under the Pacific Ocean. Fossil remains of marine mollusks, crabs, and sharks indicate that the climate was tropical (Thieman 2000). From 25-40 million years ago, the Willamette Valley dried as the Coast Range rose from the ocean floor, blocking marine inundation. Two to three million years ago, a series of ice ages sent glaciers stretching south of Seattle (Kettler 1995, 50). Glacial melt water flooded the Willamette Valley, leaving behind till and debris (Thieman 2000). During the Wisconsin ice age, for which there is the best geologic record, sea levels were significantly lower than they are currently as most water was held on land in the form of ice. As the ice started to melt, however, both coastal and inland areas were inundated (Thieman 2000, Allen et.al. 1986).

The most recent significant geologic events that have shaped the Willamette Valley as we see it today are the Lake Missoula Floods, which occurred from 12,000-15,000 years ago. The most recent of these flood events is the Bretz Flood (Allen et.al. 1986). Prior to the Bretz Flood, the Willamette Valley was likely much as it is now, though the valley was likely deeper and the Willamette and McKenzie Rivers larger, roaring with glacial melt from the ice capped Cascades. Flooding from the Bretz Flood began far up the Columbia River Watershed in Montana and Idaho at Lake Missoula. Lake Missoula was an enormous lake formed behind large ice dams created by a glacial finger of the continental ice sheet that extended into northern Idaho. The ice dams broke suddenly and rapidly, allowing 500 cubic miles of lake water to rush out at 60 miles per hour in volumes greater than ten times the current volume of all the rivers on earth (Parfit 1995). This flooding may have occurred a number of times starting 600,000 years ago. The most recent flood event, the Bretz Floods, occurred 12,000 years ago (Allen et.al. 1986).

Flood water roared through Idaho and down the Columbia River, carrying boulders, icebergs, glacial wash, loess, and other materials from as far away as Idaho and eastern Washington down through the Columbia River Valley and into the Willamette Valley. Water was directed through two gaps at Lake Oswego and Oregon City when a hydraulic dam was created between Kalama Gap and Crown Point. Approximately a third of the flow in the Bretz Flood sluiced down the Willamette Valley. In effect, the Willamette Valley was a backwater alcove for the floods. Each flood inundated the Willamette Valley from the Columbia River as far south as Eugene under nearly 400 feet of water. This lake, named Lake Allison, was one of the four temporary major lakes formed by flooding, glacial melt, and impoundment and extended as far south as Eugene. As water flowed farther down the valley, it slowed, leaving larger bedload materials lower in the valley and depositing silts and smaller materials farther south. The Eugene area, at the far end of Lake Allison's reach, experienced the finest deposition of silts and clays. Most of these depositions reach to the west of Eugene. These silts form the lower parts of the *Willamette Silt* soil type (Allen et. al. 1986).

1.2 Vegetation

1.2.1 Prairie / savannas

The Willamette Valley was originally a wide plain of grassland, prairie, and savanna habitats. The prairie landform varied throughout the Willamette Valley in terms of dominant soil character and terrain. The prairie along and around the Willamette near and just south of Eugene was described as "gravelly" by Walling (1884).

Prairie types can be divided into seasonally wet prairie and dry, or upland, prairie. Seasonally wet prairie areas were located in swales, other depressions, and alongside smaller streams. Hydric conditions during most of the year, particularly through the fall, winter and spring months, create wetland plant associations in these environments. Sloughs and marshes cover extensive areas as side and braided channels of the main rivers change courses each winter. Historically, seasonal wet prairies were located predominantly in the western parts of the study area through the Amazon Creek basin as well as in the Springfield area between the McKenzie and Willamette Rivers (Map 3). This plant community type is rare today in the study area and throughout the Willamette Valley.

Upland prairie areas are situated on higher ground. These grasslands contain many grass and wildflower species which are now rare, including golden Indian paintbrush, white-topped aster, white rock larkspur, Willamette Valley larkspur, peacock larkspur, Willamette Valley daisy, shaggy horkelia, Kincaid's lupine (Titus et.al. 1996). Historically, upland prairie was the predominant cover type of most of the flatter portions of the Study area (Map 3).

Oak savanna and upland prairie vegetation conditions were maintained by fire regularly set by aboriginal peoples (Towle 1982, Morris 1934). Regular burning of open areas favored annuals and perennials and reduced the number of woody plant seedlings that could gain a foothold in the lower elevations. Oregon white oak was the most common tree species within the prairie landscape because it tolerates heavy clay soils and frequent fire. Oak groves were scattered throughout the prairie in isolated pockets of three to four trees or in forest stands extending for a number of square miles (Towle 1982) (Map 3). The Wilkes expedition described the southern Willamette Valley as "wild prairie ground, gradually rising in the distance into low undulating hills, which are destitute of trees, except scattered oaks; these look more like orchards of fruit trees, planted by the hand of man, than grove of natural growth" (Towle 1982, 69).

However, by 1852, as "the country was somewhat settled up and the whites prevented [the Native Americans from burning]", "the hills and the prairies had already commenced to grow up with a young growth of firs and oaks" (Morris 1934, 317). Walling, in 1884, remarks in describing the Willamette Valley as it must have appeared to the pioneers first arriving, "The impenetrable jungle of today at this time was not, the smaller growth being kept low by Indian fires, while the timber land presented an expanse of tempting glades open to movement on foot or on horseback" (335). With the cessation of periodic burning and the introduction of herds of domesticated grazers such as sheep, goats, and cattle, oak savanna and upland prairie habitats declined in area and species composition.

1.2.2 Hillslopes

In 1854, woodland patches and hillslope forests consisted of Douglas-fir (*Pseudotsuga menziesii*), Oregon white oak (*Quercus garryana*), black oak (*Q. kelloggii*), and ponderosa pine (*Pinus ponderosa*) (Towle 1982). Douglas-fir was found on hill tops and within the gallery forests bordering streams and rivers (Map 3). Upland habitats surrounding Springfield and Eugene have changed character since 1850. Walling (1884, 302) describes the hills north of Eugene as being "not high or precipitous, but are most covered with timber of one kind or another, pine and fir being the most plentiful. In some localities large pine trees are scattered over the country and the spaces between them densely covered with an undergrowth of young pine so dense as to be almost impassable for man or beast."

In addition to decreases in acreage, species composition has changed from predominantly oak to Douglas-fir and forest densities have increased because of fire suppression (Titus et.al. 1996). In the late 19th and early 20th centuries, farming and grazing attempts were made on the hillslopes. Sheep ranches were common in the hills surrounding Eugene and Springfield (Walling 1884, 306). However, these proved unsuccessful and abandoned fields were quickly taken over by dense brush. In the mid 1930s, the Oregon State Planning Board advised to allow hillslope farmland to revert to forest (Towle 1982, 84). Although abandoned hillside fields continue to suffer from invasion of exotic brush species such as Armenian blackberry (*Rubus armeniacus*, previously misidentified as Himalayan blackberry) and Scotch broom (*Cytisus scoparius*) to this day, forested acreage on the hillslope of the Willamette Valley has increased.

1.2.3 Bottomland / gallery forest

Bottomland forest occurs on the Horseshoe, Ingram, and Winkle soil types which are all formed in the Missoula flood deposit and alluvial silt geologies (Titus et. al. 1996). The Horseshoe and Ingram are the youngest soil types and are well-drained to excessively well-drained. The Winkle type is well- to moderately well-drained because it contains clay-enriched subsoils. Bottomland forest consists of Oregon ash (*Fraxinus oregana*), Douglas-fir (*Pseudotsuga menziesii*), bigleaf maple (*Acer macrophyllum*), black cottonwood (Populus trichocarpa), red and white alder (*Alnus rubra* and *Alnus rhombifolia*), and willow (*Salix* spp.). These gallery forests bordered the larger rivers (Map 3). The lower Middle Fork of the Willamette also had cedar trees (likely incense cedar, *Calocedrus decurrens*) along it that would eventually provide a source of shingle bolts to settlers (Frost 1978, 43). The associated understory included hazelnut, vine maple, ninebark, and red-osier dogwood. The bottomland forests were proximate to streams, rivers, and sloughs. Low areas within these gallery forests contained wetland species.

The bottoms along the Willamette are heavily timbered with [grand] fir, [big leaf] maple, [Oregon] ash, Balm of Gilead [black cottonwood], and a dense undergrowth of vine maple, hazel, and briers ... there are numerous sloughs that would make the township impossible to survey in the winter (General Land Office Survey T13S R4W, 1852 as cited in Benner 1997).

In 1884, Walling writes poetically about viewing “continuous groves of maple and other kinds of timber marking [the Willamette River’s] course as far as the eye can reach” (301) and the “course of the beautiful Willamette may be traced in many a meander…by the dense mass of woods that skirt its banks” (328). Large stands of “cottonwood, alder,…poplar,” and Oregon ash grew along the Willamette around Eugene, necessitating that the residents travel upstream several miles to find “good” logs to float down to the local saw mills (Frost 1978, 33).

Although overstory species have not changed in the Willamette Valley bottomlands to a great extent, the width of the gallery forests has. When the original survey was completed in 1854, gallery forests bordering the Willamette River and its tributaries averaged a mile to two miles in width (Towles 1982, 67).

Riparian tree species were harvested continually as settlement expanded along the Willamette River. River reaches in Eugene and Springfield were no exception. Because the rivers offered a way to transport large trees to mills, riparian trees were the first ones logged. Steamboats along the Willamette River consumed large amounts of riparian timber for fuel (Seddell and Froggatt

1984). Western red-cedar was harvested for shingles and fencing, old-growth bigleaf maple was harvested for the furniture trade, cottonwoods were used for barrels and boxes, and white oak and Oregon ash were cut for firewood (Titus et.al. 1996).

Despite periodic harvest, the bottomland forests largely persisted until the early 1900s. Just before the start of the 20th century, the demand for softwood pulp increased dramatically for paper production. The proximity of the gallery forests to the water ways that transported the logs to the mills made them the first to be cut (Towle 1982, 81). In addition, the floodplain soils were better suited than the prairie soils for orchard, vegetable, and fruit crops. Consequently, intensive farming replaced the bottomland forests. As agriculture and transportation spread through the Willamette Valley in earnest, development of streamside reaches, marshes, and wetlands, and installation of drainage tile, irrigation, and flood control measures contributed to the demise of the river bottom gallery forests. Forests were replaced with or divided into smaller stands by agriculture. Remaining hydric bottomland areas were reduced to smaller, drier, disconnected patches. By the 1950s, managed crops or upland and invasive species had replaced most of the study area's riparian forests.

1.3 Streams and Waterways

1.3.1 Streams

Amazon Creek

Amazon Creek begins at its headwaters from springs on the basalt slopes of Spencer Butte, flows through Eugene through Missoula Flood sediments, and drains into the Fern Ridge Reservoir. Before the reservoir was constructed, Amazon Creek drained directly into the Long Tom River. Along the way, its historic channel and hydrology has been dramatically altered by engineered approaches designed to reduce flood effects. As a result of channelization activities, Amazon Creek now splits into the Amazon Creek Diversion Channel north of 11th Street and slightly west of Danebo. Amazon Creek is confined by urban development and heavily affected by urban stormwater inputs from Spencer Butte until it reaches the western edge of Eugene. At this point, though not as affected by stormwater inputs, most of the channel length remains heavily confined and disconnected from the floodplain. Recent restoration activities, however, have attempted to reconnect Lower Amazon Creek with its floodplain. The Lower Amazon Restoration Project that is within the West Eugene Wetlands area is one such example.

Historically, the headwaters of Amazon Creek were small, likely intermittent streams and springs surrounded by pine and Douglas-fir hillslope forests and Oregon ash flats. Once Amazon Creek reached the valley floor, it likely meandered between slough and wetland type systems through bottomland valley forests and seasonal wet prairies (Alverson 1993, Salix Associates 2000). It frequently overflowed its banks during the winter months. James Collins writes "Between Spencer's Butte and [Skinner's] cabin, Coyote Creek [now called Amazon Creek] widened into a shallow lake, more than a half mile across; but it was frozen over, I thought, solid enough for me to cross it" (Collins 1846, as cited in Thieman 2000, 31). Prior to management by the City of Eugene, Amazon Creek was a shallow creek and slough no more than 5 or 6 feet deep upstream of Jefferson [Street]. The banks were moderately sloped, and the peak storm discharges during heavy winter storms resulted in almost annual flooding in what are now South Eugene High School, Amazon Park, Civic Stadium, and the south part of the downtown area (Long 1992, as cited in Thieman 2000, 40).

Because the reaches of Amazon Creek above the County Fairgrounds were not mapped on the original land survey, they were likely intermittent, summer dry channels, much like some of the remaining natural channels in the Willow Creek system are today. During winter months, the Lower Amazon Creek system was frequently connected by flood flows with the Willamette River (Alverson 1993).

Willow Creek

Willow Creek is a summer dry channel system flowing west of and into Amazon Creek just north of West 11th between Beltline and Danebo. Historically, Willow Creek and Amazon Creek joined at what is now the north end of the Spectra-Physics facility (Alverson 1993). In the 1850s, Willow Creek flowed through primarily flat prairie scattered with a few large oaks. Its sloped headwaters were surrounded by oak savanna.

The Willow Creek system, according to General Land Survey Office notes, had very few distinct channels. Low areas, or swales, were dry in the summer and flooded over large areas in the winter (BPA 1995).

Within the area of the lower reaches of Willow Creek north of West 18th, a large log pond was created between 1952 and 1960. The pond was abandoned and filled in the late 1970s. At about the same time, the lower reaches of both branches of Willow Creek, between West 18th and West 11th Avenues, were relocated by the property owner into a single, straight trapezoidal channel (Alverson 1993).

Cedar Creek

Cedar Creek is a tributary of the McKenzie River. Starting at the Cedar Flat area, water is diverted into Cedar Creek from the McKenzie River and it then flows eight miles through the floodplain of the Thurston area, forks into North and South Cedar Creeks, rejoins, and then flows out into the McKenzie through two miles of braided channels. The diversion of a portion of the McKenzie River into Cedar Creek is one of the oldest water rights on the McKenzie River. This diversion provides landowners with irrigation water and helps maintain minimum flows necessary to maintain habitat for fish and aquatic life (Ferschweiler 2002).

Cedar Creek has been utilized as a stormwater runoff channel since flood control became an urban management concern. As early as 1979, residents observed increases in winter flood levels as natural channel flows were augmented by drainage contributions (Brown and Caldwell 1979).

Cedar Creek drains into the McKenzie River just upstream from the City of Eugene's water supply intake (Ferschweiler 2002) so the quality of water coming from Cedar Creek is of considerable interest to the Eugene Water and Electric Board.

1.3.2 Engineered waterways

Springfield Mill Race

The Springfield Mill Race was constructed in 1852 by Elias and Issac Briggs to direct water flow to a log mill that was under construction. They hand deepened and extended an existing backwater slough to bring water from the Middle Fork of the Willamette River in to Springfield's newly developing mills. The Mill Race exits the Middle Fork west of Clearwater Lane and flows northwestward up toward Jasper Road and the Union Pacific railway. It parallels the railroad until it exits into the Willamette River just upstream from the 126 Bridge. The original mill pond near the downstream end of the Mill Race near Island Park was created in the late 1800s (Donald 2000). This area is no longer a pond. The current mill pond is located further upstream of the confluence near the Rosboro Lumber Company yard. Most of the upper portion of the Mill Race retained its natural slough features (Figure 1). The lower half of the Mill Race is the more intensively managed portion.

Figure 1. The upper Springfield Mill Race, 1907 (Courtesy of the Oregon Collection, University of Oregon Library).

Nine out of ten interviewees involved in the Springfield Mill Race Oral History Project identified the Mill Race and the mill pond as important fish waterways (Donald 2000). Quite a few had fished the Mill Race for cutthroat and salmon. One respondent, who at one time worked security at Georgia-Pacific, had to patrol the fish ladder on the Mill Race once an hour at night to keep salmon poachers out. Others reported that the "pond monkeys" working at the mill pond would commonly spear salmon with their pikes to take home for dinner (Donald 2000). Many respondents of the same oral history project also remembered swimming in and picnicking beside the Mill Race in their youth.

Georgia Pacific donated the Mill Race to the city of Springfield in December 1985 (Donald 2000). Recently, the Eugene-Springfield Metropolitan Area Public Facilities and Services Plan determined that it is a functional and usable drainage facility for the city's stormwater (MAPFSP 1999).

Eugene Mill Race

The Eugene Mill Race was constructed in 1851/1852 by Hilyard Shaw and William (or Avery) Smith to power the first Eugene saw mill. They took advantage of two pre-existing sloughs on Mr. Shaw's land claim to facilitate the excavation (Rees 1975). As Bishop (2001) reports, industries, including a distillery, furniture factory, tannery, cider and vinegar factory, woolen, grist, and lumber mills, and a sash and door factory sprung up alongside its ready source of power. In 1887, the Eugene Electric Company built a generator on it. Figure 2 illustrates the flow of the Mill Race near 1910, including the industrial area to the west.

In 1890, a flood destroyed the intake point and changed the course and bed depth of the Willamette which decreased the flow of water through the Mill Race (Rees 1975). After industry stopped depending on the Mill Race for power and subsequent floods continued to damage the intake, it was neglected and even ran dry in 1945.

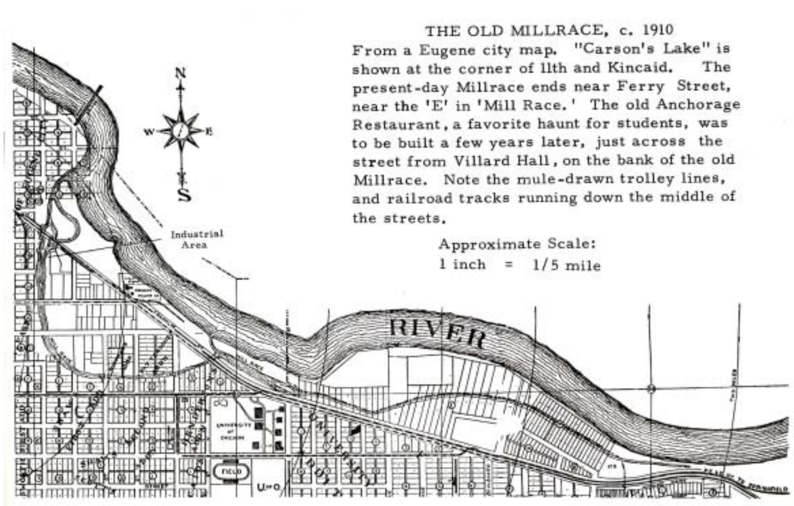


Figure 2. Map of the Eugene Mill Race ca. 1910 (Courtesy Oregon Collection, University of Oregon Library).

The last six blocks of its length were buried under a road improvement project in 1949. In 1952, it was described as a "half-filled muddy slough, clogged with debris." In 1959, pumps were installed to pump Willamette River water into the Mill Race. Despite the pumps, flow remained slow and urban pollutants continued to pour into the water and settle in its sediments. Pollutants at the time included large objects such as furniture and boxes; smaller objects such as cans, bottles, and containers; low dissolved oxygen; stagnant flows; *E. coli;* petroleum; and stormwater runoff and its constituents (Rees 1975). Through the 1960s and into the present, the

Mill Race has remained a controversial feature, with planning decisions that remain torn between historical appreciation, ecological concern, taxpayer expense, and development ease.

1.3.3 River geometry

The combination of a broad floodplain, deep, erodable soils deposited from the Bretz Floods, and large amounts of bedload carried in from the upper watersheds of systems like the McKenzie River and Coast and Middle Forks of the Willamette River, created a historically highly sinuous and braided Willamette River.

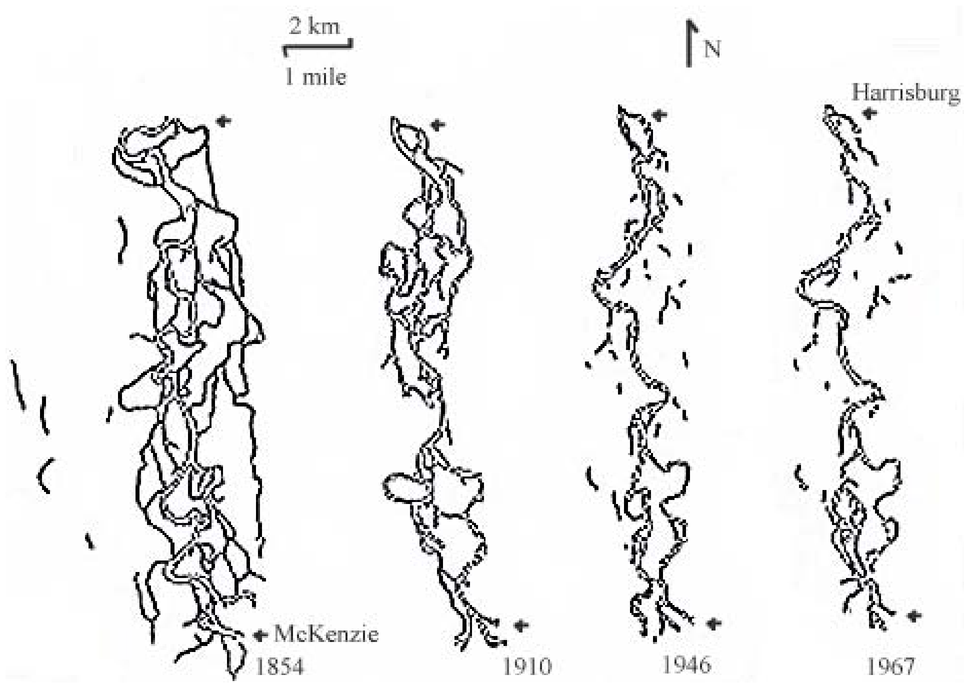
Sinuosity is a reflection of the erosive and dynamic nature of streams and rivers operating in unconstrained valley bottoms. A sinuous river is one that moves laterally by eroding one side of a bank while depositing sediment and building a bank on the other. Sinuous river channels also force the development of side channels and alcoves as the moving river bed separates old channels from newly developing ones or closes off side channel ends through deposition. The complexity of these systems connects the riparian area more closely to the stream by extending the length of riparian edge directly exposed to river processes. The U.S. Army Corps of Engineers wrote in 1875 (as cited in Brenner 1997):

> Each year [upper Willamette] channels are opened, old ones closed, new chutes cut, old ones obstructed by masses of drift; sloughs became the main bed, while the latter assume the characteristics of the former…the formation of islands and bars is in constant progress…only to disappear at the very next high water. Captain Miller, one of the oldest and most experienced pilots in shoal waters of the same nature as the Willamette, has stated that he has never run the same channel for two consecutive years between Harrisburg and Eugene City.

This degree of continual movement and change exemplifies a functioning Willamette River system. Material is removed from one section and deposited elsewhere. Trees and organic material are pulled into the system, incorporated within the river's nutrient cycles, and then deposited elsewhere to provide structure for aquatic and riparian ecosystems. As the Corps noted, sloughs, islands, side channels, and gravel bars are intrinsic parts of what defines the Willamette River. However, these features contributed to the reported difficulty in navigating and managing log drives on these rivers.

From the perspective of a river boat captain or farmers working on land next to rivers, sinuosity meant unpredictable conditions, erosion, fallen trees, and loss of land. Therefore, cities, like Eugene and Springfield, interested in attracting the commerce associated with boat traffic and successful farms, constructed wing dams to focus water flow into a main channel and riprap to harden banks and make them less susceptible to erosion.

Efforts in the late 1800s and early 1900s to remove snags and other obstructions and confine the center channel were considerable. Figure 3, from Sedell and Froggart (1984) and obtained from Brenner (1997), illustrates the loss in sinuosity and channel complexity in the Willamette River from 1854 to 1967 between the McKenzie River confluence and Harrisburg that resulted from this management.



<u>Figure 3</u>. Loss of Willamette River channel complexity from 1854 to 1967 between the McKenzie River and Harrisburg, Oregon. (Sedell and Froggart 1984).

Over the century, total main channel length in the Willamette River (downstream of the McKenzie River) was reduced to 45-50% of what it once was (Brenner and Sedell 1997) and many side channels were eliminated.

The federal government legislated the ongoing channel modifications with the Flood Control Act of 1950. This empowered the U.S. Army Corps of Engineers to authorize "necessary channel clearing and snagging" and construction of bank revetments. From 1948 to 1951, 7419 feet of stone revetments were installed along the Middle Fork of the Willamette (U.S. Army Corps of Engineers 1953, 14).

In 1951, the City of Eugene constructed a rock wing dike to attempt to control bank erosion between River Mile 184.1 and 184.8. It was ineffective. The U.S. Army Corps of Engineers concluded in their analysis that the diversion dam used to maintain a head for the Mill Race has been a contributing factor to the erosion within this reach (1953). Proposals to minimize the effects of flooding by the Army Corps of Engineers included channel closures, bank hardening for over 1300 continuous feet, raising river side roads to serve as a levee, and constructing levees. Bank hardening and other flood modifications for reaches downstream of Eugene were not included in the analysis because the McKenzie River reservoirs were not in place and their effects on flows could not be anticipated (U.S. Army Corps of Engineers 1953, 36).

In 1959, Soil Conservation Service (SCS) construction plan design diagrams for the Q Street Floodway indicate that the High Banks Dike along Maple Island Slough on the McKenzie River was constructed by Lane County.

"Most of the revetment construction has been along the outside banks of river bends, the locations where the channel is most active in lateral cutting and moving. Channel constraint has ecological consequences, because river channel migration within the valley floor creates off-channel aquatic zones and gravel bars for cottonwood stands, and delivers large wood to the channel from the banks" (Benner 1997).

1.3.4 Gravel mining

Sometime after 1936, gravel operations began on the Middle Fork of the Willamette River just upstream of the confluence with the Coast Fork and in the Willamette River near downtown Springfield. Gravel companies began mining gravel in the Willamette River / McKenzie River confluence area in the late 1960s. Initially, mining was of the bars and beds of the river. Currently, mining is mostly of the land adjacent to the river. Dikes are maintained between the pits and the river to avoid adding turbid water to the river. Some pits are mined deeply (up to 130 feet deep) and, therefore, kept free of water by continuous pumping. Sites with a shallow gravel deposit (up to 25 feet deep) are mined with the water in the pit. Most areas that have been or are currently being mined were occupied by the main channel of the river within the last 70 years (Andrus et al. 2000).

Delta Ponds is an abandoned gravel extraction site with numerous shallow gravel pit ponds that were constructed from the 1940s through the 1960s. The area is now owned by the City of Eugene. The Corps of Engineers will soon release a plan for providing water connection among ponds and the Willamette River, reducing areas of exotic aquatic plants, and improving fish habitat.

1.3.5 Navigation

Even in the mid-1800s, when navigation on the Willamette River was difficult during all but high flows, the river had clearly become the vital link in the valley's transportation system. During fall, winter and early spring, it was the only continuous highway between the upper valley and Portland because the valley floor would become impassable with mud (Foster 1978, 24). However, even at high flows, logs, drift, and heavy sedimentation made river travel hazardous.

> The Willamette River had risen…so high as to render it unsafe and risky to venture with boat into the channel, owing to the number of floating logs and large trees displaced from the banks. The water was so thick with mud as to render it impossible to discern the positions of snags below its surface (U.S. Army Corps of Engineers, 1875 as cited in Benner 1997).

Though most experienced river boat captains believed that the Willamette was too shallow for travel south of Corvallis, in 1854 one adventurous steamboat captain piloted the "Fennix" to Harrisburg "to prove that it could be done." River depth south of Corvallis was unpredictable depending upon winter and spring freshets from rain and melting Cascade snows (Frost 1978, 25). The very first boat to reach Eugene on the Willamette arrived in March, 1857, after a three-day trip from Corvallis dodging mudflats and sunken logs (Foster 1978, 26). By the late 1800s, Eugene and Springfield were regularly accessible by boat at high water stages. The Ferry Street Bridge at Eugene was considered the head of navigation.

In recognition of the need to improve and streamline the Willamette's use as a transportation conduit, the first federal project to improve navigability on the stretch of Willamette between Oregon City and Eugene was initiated in 1870 (Brenner and Sedell 1997). Techniques applied to improve navigation on the river include:

- Depositing dredge spoils at the heads of side channels
- Filling in side channel mouths and "useless sloughs" with trees and drift
- Constructing "closing dams" or "cut-off dams"
- Scraping "shoal bars"
- Installing "water-contracting low dams" to sluice the river bed and deepen flow
- Removing of snags and other channel wood
- Installing of stabilizing revetments to prevent lateral channel migration (Brenner and Sedell 1997)

It became critical to remove the large trees blocking passage and close side channels and sloughs to simplify navigation. Between about 1880 and 1950, the agency removed over 69,000 snags from the channel and overhanging trees from the river banks (Benner 1997). Army Corps of Engineers also built "wing dams" to direct flow into the center of the Willamette main channel or to close off a side channel (Figure 4).

Figure 4. Skinners Bar dam, built in 1898-99 down river of Eugene. The dam served to cut off the head of a side channel and to direct water into the main channel of the Willamette (U.S. Army Corps of Engineers, 1899, as cited in Brenner 1997).

1.3.6 Log transport

Some of the earliest alterations to the natural river systems in the MECT study area were related to supplying mills with water for power and log transport. The log drives that supplied the mills with timber also affected channel shape and flow. By the 1870s, log driving "was common practice" on the McKenzie and Willamette Rivers, including the Middle and Coast Forks. One of the biggest log drive fiascoes occurred in 1871, when the Laird brothers contracted to drive five million board feet of sugar pine logs down the Middle Fork of the Willamette from Fall Creek at Pine Openings to the Eugene City Mill. The Laird brothers did not realize that sugar pine floated poorly and all five million board feet sank up in the higher reaches of the Middle Fork (Frost 1978, 38).

In the early 1900s, several large log drives were moved down the Middle Fork Willamette River. Millions of board feet of timber would be driven down in separate log drives that had to be coordinated. When they were not or when flows fell before the drive was done, logs were left stranded or drivers resorted to using powder kegs to blow jams out (Frost 1978, 46). In 1903, there were “no less than 35,000,000 board feet of logs” in the Middle Fork to supply the various mills in Eugene and Springfield (Frost 1978, 49). Farmers and river-side residents complained about the force of the logs slamming into the river banks and accelerating erosion. In 1912, the construction of a railway up the Middle Fork brought an end to the log drives (Frost 1978, 67).

1.3.7 Land drainage

Land drainage did not become an issue of concern until the cities of Eugene and Springfield had grown enough where annual flooding of urban streams became a nuisance.

Situated between the McKenzie River and the Middle Fork Willamette River, and built around a natural spring area, Springfield required urban drainage as it grew. The city took advantage of its available natural drainage features and constructed others to correct flooding problems. The four major drainage water courses in West Springfield are the McKenzie River, the Willamette River, the Mill Race, and the Q Street Ditch (Floodway) (Kramer, Chin and Mayo, Inc. 1983). In a 1979 analysis, hydrologists reported that East Springfield utilized open ditches to direct water into the McKenzie River and Cedar Creek. Most major storm sewers and drainage channels were constructed in the 1960s (Brown and Caldwell 1979).

The existing Q Street Floodway was completed in 1962 by the SCS to handle drainage for most of central western Springfield (SCS 1962). At the time of construction, an open ditch called the McKenzie ditch ran through the center of Springfield from east of 25th Street up to Mill Street where it joined with the initial Q Street Floodway (SCS 1962). It was abandoned with the construction of the Q Street Floodway. The far western portion of the Q Street Floodway that runs underneath I-5 and into the Patterson Slough area already existed prior to 1962.

After construction, small ditches and drain pipes drained into the channel from surrounding areas. Larger open channels including the I-5 Floodway, the SCS Channel No. 6 and an irrigation canal near Marcola Road continue to drain directly into it. The I-5 Channel drains approximately 325 acres. The SCS Channel 6 was constructed by the SCS in the 1960s and drains 540 acres. The Marcola Road irrigation channel drains 450 acres. In addition to this combined 1315 drainage acres, the Q Street Floodway also has its own drainage area. The Lower Q Street Floodway area drains 970 acres and the Upper Q Street Floodway drains 750 acres. A 1200-acre drainage area (formerly called the Willamalane drainage area) empties into the Q Street Floodway through a pipe just west of 5th Street. The total drainage area affecting the Q Street Floodway is approximately 4235 acres (Kramer, Chin and Mayo, Inc. 1983).

The 1983 West Springfield Drainage Master Plan recommended that, though most small cross country and road side ditches be phased out and piped, the larger open ditch systems including the Q Street Floodway, the 1-5 Floodway, the Mill Race and the SCS Channel No. 6 be left open.

In 1912, the City of Eugene authorized ditching on Amazon Creek. In 1925, it was widened between 15th and Jefferson Street to 17th and Pearl Street (Thieman 2000, 40). Major stormwater and flood management occurred on Amazon between 1951-58, when the U.S. Army Corps of Engineers constructed the A-3 diversion channel to Fern Ridge reservoir, widened the channel from 17th and Pearl Street up to 33rd and Hilyard Street, and constructed the concrete channel between Jefferson Street and 24th Street (Thieman 2000). These flood mitigation efforts were successful in reducing the frequency of floods and has allowed development to increase in this area of Eugene.

1.3.8 Reservoirs

Though outside the study area, 8 major reservoirs on the McKenzie, Middle Fork, and Coast Fork of the Willamette Rivers have a large influence on the rivers and their aquatic organisms that flow through Springfield and Eugene. The dams were constructed over a 25 year period, beginning in 1942 and ending in 1966. The reservoir projects were built, in part, to protect downstream areas from flooding and to generate electricity for the region. They were also built to supplement flow in downstream waters for purposes of summer irrigation and pollution dilution. Though not originally designated for this purpose, the reservoirs are also managed for boaters, fishers, and other summer recreationists. Power producing capacity of each of the 8 reservoirs upstream of the MECT study area is provided in Table 1a.

Table 1a. Power producing capacity of reservoirs upstream of the MECT study area

Reservoir	Basin	Power-producing capacity (kW)
Cougar	McKenzie	25,000
Blue River	McKenzie	None
Fall Creek	Middle Fork Willamette	None
Hills Creek	Middle Fork Willamette	30,000
Lookout Point	Middle Fork Willamette	120,000
Dexter	Middle Fork Willamette	15,000
Dorena	Coast Fork Willamette	None
Cottage Grove	Coast Fork Willamette	None

McKenzie River reservoirs

Cougar dam is on the South Fork of the McKenzie River approximately 42 miles east of Eugene. It was completed in 1964. It is the highest embankment dam ever built by the Army Corps of Engineers and sits 452 feet above stream bed. Blue River dam is on the Blue River tributary, 38 miles east of Eugene. It was completed in 1969, partially in response to the devastating floods of 1964. Blue River reservoir is usually drawn down in the summer sooner than Cougar reservoir so recreation use is greater at Cougar reservoir.

Middle Fork of the Willamette River reservoirs

Fall Creek dam is located on the Fall Creek tributary, 22 miles southeast of Eugene. It was completed in 1966. Hills Creek dam is located on the Middle Fork Willamette River, about 45 miles southeast of Eugene and was completed in 1961. Lookout Point dam, also located on the Middle Fork, is approximately 22 miles southeast of Eugene. It is 26 miles downstream of Hills Creek dam. It was completed in 1954 and creates the second largest reservoir in the Willamette basin. Dexter dam is on the Middle Fork and is 2.8 miles downstream of Lookout Point. It serves as a re-regulating reservoir for Lookout Point. It was completed in 1954.

Coast Fork of the Willamette River reservoirs

Dorena dam is on the Row River tributary and is 6 miles east of Cottage Grove. It was completed in 1949. Because of its small size, it is not usually drawn on during the summer months to augment Willamette River flow.

Cottage Grove dam is on the Coast Fork Willamette River about 6 miles south of Cottage Grove. It was completed in 1942. Like Dorena dam, Cottage Grove dam is also small so is not often drafted for flow to the Willamette River.

The physical and ecological consequences of these dams on downstream areas are discussed in later sections.

1.4 Disturbance Patterns

1.4.1 Fire

Fire was a common occurrence in the Willamette Valley and surrounding mountain ranges and surely affected the prairie areas within and around the study area. Early settlers and explorers report that Willamette Valley fires were annually set by native Americans. Jesse Applegate, who lived near Dallas, Oregon, reported that "We did not know that the Indians were wont to baptize the whole country with fire at the close of every summer; but very soon we learned our first lesson" (Morris 1934). During his travels through the west side of the Willamette Valley in September and October 1826, which were ill-timed, for immediately after the late summer burns, David Douglas made frequent reference to "charred stubs of brush" throughout the valley that left his feet sore and little food for his horses or game (Morris 1934). Douglas described the valley north of Eugene as comprised of "solitary oaks and pines interspersed through it…having all burned and not a single blade of grass except on the margins of rivulets to be seen" (Morris 1934). Morris (1934) quotes Douglas as stating

> Some of the natives tell me [fire] is [set] for the purpose of urging the deer to frequent certain parts to feed, which they leave unburned, and of course they are easily killed. Others say that it is

> done in order that they might the better find wild honey and grasshoppers, which both serve as articles of winter food.

The fire regime of the Willamette Valley ecosystem was reflected in its plant and wildlife communities. Native Americans used fire to increase deer and other wildlife, promote food plants and their harvest, and to increase the ease of traveling (Thieman 2000, Morris 1934).

Other than annual burning by native Americans, historic records do not mention the occurrence of catastrophic fires in the Eugene-Springfield area as frequently as they do in the north end of the Willamette Valley or in the Coast Range Mountains. This could partially be a factor of population differences between the two areas, both in terms of frequency of accidents that ignite fires and number of observers to report them. However, on September 7, 1902, a fire started in the Tillamook area and strong winds swept it toward Portland and by the 11th most areas around Portland were burning. By September 12th, the fire had reached the Corvallis area, and on September 13th, it was reported that Skinners Butte was invisible from Eighth Street because of the density of smoke. Clearly, large areas in the surrounding vicinity of Eugene-Springfield burned during this time (Morris 1934, 335).

1.4.2 Flooding

The Willamette River experienced at least five major floods in the 1800s prior to the 1861 flood (Brenner 1997). The 1861 flood was the largest event since Euro-American settlement for which the flow has been calculated. The 1861 peak flow was estimated at 340,000 cubic feet/second (cfs) at the Albany gage (Brenner 1997). At the mouth of the Middle Fork Willamette River, the discharge 112,000 cfs and, at Eugene, the Willamette River was 170,000 cfs (U.S. Army Corps of Engineers 1953, 9). The 1861 flood was the most severe of the 1851, 1861, and 1881 floods (Walling 1884, 337). "There were at least four feet of water over the entire valley, which carried away fences, houses and stock, and caused a general havoc" and "the streets of Eugene City could be navigated with boats and rafts." During the 1881 flood, "a huge raft of trees and logs [struck] the supports of the northern approach [of the bridge at the town], the piling gave way and the means of access to the bridge was carried down the stream" (Walling 1884, 337). The streets in Eugene were "impassible" and "half the sidewalks afloat." In Springfield, the west side approach to the Springfield bridge was carried away and the mill dam was broken (Walling 1884, 338).

A flood peak in 1881 was 266,000 cfs at the Albany gage. Records from that year by the Army Corps of Engineers recorded "*The river experienced during the winter and spring [1881] two very prominent freshets, and three moderate ones. The one which caused the greatest damage... [was] the result of heavy snows in the Willamette Valley, followed by long continued warm rains, and reached its maximum on the 16th of January…* (U.S. Army Corps of Engineer 1881, as cited in Brenner 1997).

A sudden freshet rushed down the Coast and Middle Forks and flooded the Willamette on May 29, 1912. New fish racks had just been installed above the McKenzie River and these were carried away, allowing thousands of fish to "escape" up into the upper Willamette system. R.E. Clanton, Master Fish Warden, writes in his report that "the flood came so suddenly and so mightily, having reached a stage of nine feet within 24 hours, that it carried huge trees and other large drift down the river, sweeping everything before it". Subsequent heavy freshets occurred on June 15 and in early September. Mr. Clanton remarked that records indicated that flows during these freshets were higher than in previous years (Biennial Report of the Department of Fisheries 1913).

In 1953, the U.S. Army Corps of Engineers published a plan for work within what is now the study area to mitigate flow effects from reservoir releases on the reaches of the Middle Fork and Willamette within the city. At the time of the report, no reservoirs had been installed on the McKenzie River and within the Willamette system, only the reservoirs at Cottage Grove and Dorena on the Coast Fork had been completed. Lookout reservoir was under construction, Hills Creek reservoir was in the advanced planning stages and Fall Creek reservoir had been authorized, but not planned (U.S. Army Corps of Engineers 1953, 31).

A flood in December 1964 was the first major flood to affect the Eugene-Springfield area after most of the reservoirs had been built; 10.30 inches of rain fell in four days. This rainfall level continues to be the local record. The warm rain fell on an extensive low-elevation snow pack throughout western Oregon and produced the second highest peak flow on record for the McKenzie River (57,400 cfs measured at Vida and 72,000 cfs [presumably at Springfield as reported in Brown and Caldwell (1979)]; records began in 1924). The upstream Cougar Reservoir had been completed the year before, but was only minimally effective at moderating a flood of this size. The resulting flood was severe but, because flood control dams were relatively new in the Willamette basin, not much development had yet occurred in the river's flood plains.

When the highest peak flow since construction of all flood control reservoirs occurred in 1996 (30,900 cfs at Vida), much of the new development built in low-lying areas along the rivers was flooded. The 30-year period of reservoir-muted floods had created a false sense of security about building within flood plains. Eugene received 9.14 inches of warm rain during the 1996 flood, and again, a low-elevation snow pack existed throughout the basin and melted rapidly.

1.5 Wildlife

Prior to and during the early European settlement period, gray wolf and grizzly bear inhabited Willamette Valley bottomland habits. Other animals that are gone or declining, but used to thrive in Willamette Valley habitats around the Eugene-Springfield, area are listed in Table 1b.

<u>Table1b</u>. Mammals, birds, amphibians, and insects that are now extirpated or uncommon, but were once common to the Willamette Valley. Habitats include bottomland forests, prairie, wetlands, savannas, and Douglas-fir forests (taken from Titus et.al. 1996). B = bottomland forest, P = prairie, D = Douglas-fir forest, W = emergent wetland, S = savanna.

Species	Common Name	Habitat type
Canis lupis	Gray wolf	S
Ursus arctos	Grizzly bear	S
Odocoileus virginianus leucurus	Columbian white-tailed deer	B, P
Plecotus townsendii townsendii	Pacific western big-eared bat	D
Haliaeetus leucocephalus	Bald eagle	D
Strix occidentalis caurina	Northern spotted owl	D
Pooecetes gramineus affinis	Oregon Vesper sparrow	S
Coccyzus americanus	Yellow-billed cuckoo	B
Empidomax traillii brewsteri	Willow flycatcher	B
Branta canadensis leucopareia	Aleutian Canada goose	P
Grus Canadensis tabida	Greater sandhill crane	P
Agelaius tricolor	Tricolored blackbird	W
Batrachoceps wrighti	Oregon slender salamander	D
Chrysemys picta	Painted turtle	W
Clemmys marmorata marmorata	Western pond turtle	W
Megomphix hemphilli	Oregon megomphix	W
Rana aurora aurora	Northern red-legged frog	W,B
Rana boylii	Foothill yellow-legged frog	W
Rana pretiosa	Spotted frog	W
Megascolides macelfreshi	Oregon giant earthworm	D
Pterostichus rothi	Roth’s blind ground beetle	D
Euphudruas editha taylori	Taylor’s checkerspot butterfly	S
Icaricia icarioides fenderi	Fender’s blue butterfly	S
Speyeria callipe ssp.	Willamette callippe fritillary butterfly	S
Speyeria zerene bremnerii	Valley silverspot butterfly	S

Around the early 1800s, beaver (*Castor canadensis*) were abundant in almost every lake and stream in Oregon (Bailey 1936). In 1811, beaver were reported as “plentiful” around the Willamette River and the Willamette River Valley was considered the “finest hunting ground for beaver west of the Rocky Mountains” (Bailey 1936). This abundance attracted fur trappers and in a comparatively few years of vigorous trapping, beaver became scarce (Bailey 1936). By 1824, they were reported as “now scarce” (Bailey 1936).

Restrictions on trapping began in 1893 when the Legislature, alarmed by the reductions in populations, closed certain counties to trapping. In 1930, an Oregon district forester wrote that “the number of beaver in the state has been reduced almost to the vanishing point and this has affected stream flow, fish, grazing, and erosion to a serious degree. The beaver dams originally held back the run-off on the heads of streams…The dams are now gone. These dams originally formed rearing ponds for the small fish and helped to restock the streams” (Bailey 1936). State-wide closure to beaver trapping occurred in 1937 and beaver conservation and management was handed over to the Game Commission. The Commission’s management objectives were to 1) protect property from beaver damage, 2) conserve the “fur resource” and, 3) “to utilize this mammal in water and soil conservation wherever possible" (Biennial Report of the Oregon State Game Commission, 1945-46). Beaver were dead-trapped in the winter to use their fur to help offset the costs of the management plan and to reimburse landowners for property loss. In the summer, beaver were live trapped and transported to "the high reaches of the watersheds throughout the mountainous sections of the state" (Biennial Report of the Oregon State Game Commission, 1945-46). Game wardens observed that, because landowners were compensated for beaver in the winter, many were willing to tolerate beaver damage throughout the summer before reporting the situation to the Game Commission.

Through their dramatic effects on local hydrology and vegetation, beaver can have a significant impact on riparian and aquatic vegetation community structure and succession (Ray et. al. 2001). Beaver require a ready source of woody shrubs and trees for food and to construct their dams and lodges. They also require an area that is hydrologically suited to impounding water behind their dams. Their dams serve the habitat needs of many other plants, animals, invertebrates and fish.

Bailey (1936) reports that, if beaver are desired in particular localities, they can be "baited with favorite food plants, such as the aspen and cottonwood branches". In summer, they feed primarily on green vegetation of aquatic plants or riparian herbs and take down small trees only for the purpose of building. Barnes and Mallik (1996) determined that beaver select woody stems primarily based upon the size of the stem rather than the species of the plant. In their study in northern Ontario, beaver used alder solely for construction and not for food. The authors hypothesized that the alder provided the most suitable diameter material for rapid dam construction. Material selectivity may have an affect on riparian restoration efforts that want to favor certain species for overstory dominance.

Nutria (*Myocaster coypus*) is an introduced species to western Oregon and originated in South America. They were brought to the United States to attempt to revitalize the fur trade by substituting for the dwindling populations of beaver.

Nutria thrive in highly enriched, slow moving water bodies such as runoff canals and polluted holding ponds (Brown 1975). They are highly adaptable and tolerate poor water quality. Nutria can reproduce any time of the year even when food supplies are limited. Nutria consume their body weight in plant material each day. This voracious appetite can have a significant and dramatic effect on the species composition and vegetation cover and biomass of riparian ecosystems (Ford and Grace 1998). Nutria also adversely affect bank stability by burrowing. When population densities are high, this can cause bank failure.

1.6 Pre-Settlement and Settlement Conditions (up to 1900)

The first inhabitants of the Willamette Valley were probably ancestors of those humans that crossed the Bering Strait land bridge from Asia during the Wisconsin ice age, sometime between 70,000 and 25,000 years ago (Allen et. al 1986). When European settlers and explorers reached the southern Willamette Valley, the Kalapuya tribe occupied the area (Thieman 2000).

1.6.1 Timeline since European settlement to 1900

- In 1846, Eugene Skinner settled at the base of a small rounded peak. The small settlement that grew around his claim was called "Skinner's Mudhole" because it was so low (Frost 1978, 3). J.M Ridson erected the first dwelling in the area that seven years later would become Eugene City.

- In 1848, Jacob C. Spores began running a ferry across the McKenzie with a canoe. He obtained a ferry license in 1850 and operated it until 1878 when the bridge was built by A.S. Mille & Son (Walling 1884, 337). Elijah Bristow remarked upon arriving that the "panorama of mountain and vale stretching out" before him from his perch on a "low, rolling ridge, sparsely covered with oak, fir and pine timber, ever since known as Pleasant Hill", reminded him of a "scene in far-off Virginia" (Frost 1978, 3).

- In 1849, Elias Briggs chose his claim because of a "convenient spring of cool mountain water." Locals knew the fenced portion of his claim as "spring-field." When a settlement grew up around this claim, it was given that name (Foster 1978, 4).

- In 1851, Hilyard Shaw and William Smith constructed the first Eugene saw mill and powered it by water from the Mill Race.

- In 1852, Elias and Issac Briggs constructed the first Springfield saw and grist mill. It was powered by a mill race canal that was dug to extend a natural slough from the Middle Fork closer to Springfield.

- In 1852, Eugene, then called Eugene City, was platted and recorded, and in 1853, was established as the county seat (Walling 1884, 336). A large influx of settlers arrived that year from Eastern Oregon by following the Middle Fork of the Willamette down through the Willamette Pass (Foster 1978, 6).

- The University of Oregon, then just a college, was opened in November 1856. Unfortunately, on the fourth night of that first term, the building was burnt "to ashes" (Walling 1884, 338). It was reconstructed, housed the college for another two terms and then, burnt to the ground again at the close of the third term.

- By 1884, Springfield, situated three miles to the east of Eugene, contained "one of the best water-powers in the country", the Springfield wheat mill, and saw mills.

- In 1886, the first water-supply franchise was granted to T.W. Shelton, Charles Lauer and Associates. The first water supply source for Eugene was located at the northeast end of Skinners Butte on the Willamette River (Stone 1986).

- In 1896, the Booth-Kelly company moved into the area. It would grow to be one of the largest of Lane County's sawmills and timber companies and changed what had been up to this time a simple milling and logging industry into an industrial force.

1.6.2 Settlement patterns

Settlements in the Willamette Valley sprung up along the river between the gallery forests and the prairie and between the prairie and the hillslope forests (Towle 1982). Setbacks from streams and rivers were necessary to avoid flooding. However, streams and rivers were primarily avenues for transportation so proximity to them increased convenience. In addition, prairies and bottomland that were naturally moist were settled first because, "it was thought that, during the dry summers, only such lands would be productive" (Walling 1884). Hillslope forests provided wood for construction and fuel while the prairies provided open ground for cultivation and grazing (Towle 1982). Settlers focused the majority of their efforts and impacts on the prairie which was more amenable to clearing and development.

Three factors contributed to the effect of increased forest cover in the Willamette Valley after settlement (Towle 1982). The first is that Willamette Valley settlers concentrated their settlements on the prairie. They cultivated only a small portion of the land they settled and left the rest open to grazing. Later, cultivation actually decreased because of struggles with poor drainage, and many cultivated plots were abandoned to natural succession. The second is that their heavy presence in the prairie caused the native Americans to cease their annual fires that maintained the prairie ecosystem. And, third, because of the availability of open land, timber harvest, especially of hillside and oak forests, was not a major activity until the early 20th century. Bottomland forests were selectively harvested during this period, especially because their proximity to water facilitated transport of logs. However, while this forested area initially shrank, it later increased up to the early 20th century as Douglas-fir and Oregon oak forests encroached on the Valley floor.

Eugene and Springfield sprung from small scale, diversified homestead farms and ranches. Agriculture in the form of crop production of wheat, hops, and other crops on the prairie and vegetables on the floodplains, and animal production of cattle, sheep, and goats on the hillslopes was critical to the survival and growth of the urban centers in the study area. However, it was not until the late 1930s that agriculture became a defining characteristic of the Eugene-Springfield region. The growth of agriculture had the following effects on the local watersheds:

- Introduction of non-native plants and crops
- Lower summer flows due to irrigation
- Installation of revetments along rivers
- Floodplain timber harvest
- Land drainage
- Grazing of cattle and sheep

1.7 Post-Settlement Conditions (after 1900)

Timeline

- In 1900, the Eugene City population was 3236 and the Springfield population was 353. Its exact square mileage is unknown for this year. However, in 1862, when Eugene City was incorporated, its boundaries extended one half mile in each cardinal direction from the four sides of the County Courthouse. In 1864, this area was reduced to 148 acres (Central Lane Planning Commission 1959).

- In 1903, ground was broken for a new electric power plant in Springfield. In 1905, the power plant and a substation in Eugene were sold to the Willamette Valley Company.

- In 1911, the Eugene Electric and Water Board began operations as a public, municipal company after a 1906 epidemic of typhoid fever spread through the city via the city water wells. Power was generated at the Walterville Power Plant and sent to Eugene and Springfield (Stone 1986).

- The grass seed industry began in the southern Willamette Valley in the early 1900s. Initially, crops consisted of clover, vetch, oats, and cheat. However, when perennial ryegrass was introduced in the mid-1930s, the region's grass seed landscape gained a solid foundation (Thieman 2000). In the late 1930s, the federal government subsidized grass seed test plots in the Eugene-Springfield area for use on the eroded hillsides of the Tennessee Valley because its prairie soils were well suited to the crop (Towle 1982, 79). Fire, the management tool of prairie maintenance, was employed to control disease, increase seed yield, and clear fields too soggy for heavy farm equipment. As a result, the grass seed industry had a significant effect upon the economy and ecology of the southern Willamette Valley.

- Grass seed and other crops benefited from the modernization of agriculture that occurred in the 20th century. The availability of tractors, large plows, and pesticides allowed farmers to increase the acres they managed over a season. As a result, land in the river-alluvium geology surrounding Eugene and Springfield was increasingly tiled and drained to meet the demand for viable fields.

- In 1943, the first flight left the Eugene Municipal Airport. As of September, 2002, the airport currently serves 50 flights daily.

- In 1949, Weyerhaeuser opened its "integrated facility" in Springfield as the first highly efficient mill built without a "teepee waste burner" (Sensel 1999).

- From 1949 to 1966, the U.S. Army Corps of Engineers constructed dams and reservoirs in the upper reaches of the McKenzie River and the Coast Fork and Middle Fork Willamette Rivers.

- In 1950, the Eugene population was 35,879 and the Springfield population was 10,807.

- In the 1950s, the U.S. Army Corps of Engineers began a major push to install revetments along the Willamette River near Eugene and Springfield.

- In 1960, Eugene added a secondary treatment to their sewage treatment facility that drains into the Willamette River. The secondary treatment removed a larger percentage of organic matter from the wastewater before releasing it into the river (Thieman 2000).

- In the 1960s the gravel mining industry began mining gravel along the banks and gravel bars of the Willamette River, its forks and the McKenzie River.

- In 1964-65, a major rain-on-snow event and resulting flood affected the entire Willamette Valley from Eugene to Portland. The flooding in Eugene and Springfield was muted from historical levels because of the reservoirs on the larger rivers.

- In 1979, Springfield developed a master plan for drainage systems in the eastern portion of the city, east of 42^{nd} Street (Brown and Caldwell 1979). In response to continued flooding frequency in West Springfield, a similar master plan was developed in 1983 for this portion of the City.

- In 1992, the City of Eugene and Lane County adopted the West Eugene Wetlands Plan. The Plan was then adopted by the Oregon Division of State Lands and the US Army Corps of Engineers in 1994. It was the first wetland conservation plan of its kind adopted by state and federal agencies in the United States and has since gone into action to create the West Eugene Wetlands Program.

- In 1997, the Eugene population was 123,718 and the Springfield population was 49,430. The combined total area of both cities was 51.5 square miles.

Snapshot - 1960

The following water resource description was obtained from information compiled in the 1959 Eugene-Springfield Metropolitan Development Plan (Central Lane County Planning Commission). In the late 1950s, Amazon Creek was referred to as Amazon Slough. Drainage remained a significant concern in many neighborhoods in both Eugene and Springfield. Identified issues and their neighborhoods are as follows:

Eugene

- Danebo-Bethel - Lack of sanitary sewers was identified as a critical concern.
- Bailey Hill – Subjected to winter flooding. Improvements that included channel lining had just been completed on Amazon Slough and more lining was predicted farther down the channel. City sewers needed to be extended.
- Willakenzie – Flooding remained a problem but the recent installation of controls on Lookout Dam had already begun to help reduce winter levels. Expectations were high for the completion of the Q Street Floodway.
- River Road – Former stream bed channels were still quite evident and there was the expectation that gravel mining would increase.

Springfield

- Game Bird (area between the Pacific Freeway, Harlow Road, and the railroad) – Significant drainage problems. A flood control system was under construction.
- North Fifth Street – Most of central Springfield underwent periodic flooding each winter.

1.8 Summary

The geology of the study area is a result of a series of inundations caused by glacial melting, tectonic uplift, and catastrophic floods. Upland historic vegetation patterns have been heavily influenced by aboriginal disturbances, primarily seasonal fires. Riparian vegetation next to small channels tended to be wetland seasonal prairie. River riparian forests were extensive and primarily dominated by hardwoods. Rivers and streams interacted freely and frequently with their floodplain.

As European settlement increased in the study area, controlling the rivers and channels that seasonally separated settlers from Portland and other northern neighbors became critically important. The Willamette River was dredged and cleaned to facilitate navigation. Sloughs were channeled to bring power in the form of mill races to Eugene and Springfield. Seasonally dry swales and other low areas were channeled to control and divert winter flows through the cities. Eventually, the Willamette's large river tributaries were dammed for hydroelectric power and flood control.

These flow moderation measures and the continued growth of the study area present citizens and planners with the challenge of maintaining and, sometimes, recreating healthy aquatic habitats in a highly altered system. The remainder of this report will examine the current condition of the aquatic systems in the study area and, by considering the findings together, propose recommendations for future action planning to meet MECT management goals.

2. Channel Conditions and Riparian Habitat

In this section we discuss rivers and non-river water types separately. Rivers include their main channel, side channels, and alcoves. The non-river waters include streams (both natural and excavated), drainage channels, sloughs, gravel pit ponds, other excavated ponds, and natural ponds. Different techniques were used to evaluate channel and riparian vegetation characteristics for the two groups.

Rivers were evaluated by dividing the MECT rivers into reaches and using aerial photographs and field visits to derive information. The information is summarized by reaches or groups of reaches. We divided the river into 28 reaches that ranged from 0.4 mile to 2.2 miles in length (average of 1.3 miles). A reach was delineated such that it encompassed a unique channel condition. Segments of relatively straight channel with few side channels or alcoves were segregated from segments with meandering channels with many side channels or alcoves (Map 10a). Alcoves are like side channels except they have no upstream surface connection to the main channel during lower flows. Reaches also ended and began at river confluences.

Non-river waters were evaluated by dividing into many short reaches (more than 1000) and characteristics were assigned to each reach using existing GIS layers, field visits, aerial photographs, and maps. A reach is a length of waterway or perimeter of pond with uniform characteristics. Field visits were made to the one-third of segments where we could get access. Characteristics of the other two-thirds of segments were estimated using information on upstream and downstream field-visited reaches and aerial photographs. A majority of those segments not visited in the field were minor waterways such as drainage channels.

2.1 Rivers

The MECT study area is dominated by the channel and floodplains of four converging rivers, including 18.0 miles of the lower McKenzie River, 12.5 miles of the Willamette River, 7.0 miles of the lower Middle Fork Willamette River, and 4.6 miles of the lower Coast Fork Willamette River. Included are over 13 miles of side channels (excluding man-made or highly altered natural features such as the Springfield Mill Race, Eugene Mill Race, Alton Baker Canoe Canal, and the Delta Ponds complex) and 4 miles of alcoves along with the 42 miles of main channel (Table 2, Map 4).

Table 2. Current channel characteristics by segment for rivers within the study area. Determined by measuring from 2000 aerial photographs. See Maps 6-12 for illustration of river reaches.

Segment	Main channel (miles)	Side channels (miles)	Alcoves (miles)
Lower Willamette (reach 2)	0.8	0.8	0.3
McKenzie (reaches 3-14)	18.0	7.9	2.2
Upper Willamette (reaches 15-20)	11.7	2.7	0.7
Middle Fork Will. (reaches 21-25)	7.0	1.2	0.8
Coast Fork Will. (reaches 26-28)	4.6	0.6	0.0
Total (2-28)	42.1	13.2	4.0

2.1.1 Large wood in rivers

Large wood forms complex features within channels that are preferred habitat of Chinook salmon and other fish. The regular flow of the water is disrupted by large wood in the channel and creates deep pools, sorted gravels, nooks and crannies for fish to rest in slow water and then dart into fast water areas to retrieve food, and it provides cover from predators. Large wood is also a favored substrate by some aquatic insects and therefore is a boost to the food base of fish. In addition, when large wood is present in large quantities, it can alter the overall geomorphology of the river by initiating island and side channel development. These features provide specialized habitat for fish in the form of low-velocity water and gravel deposits favorable for aquatic insects.

The hydrology, geometry, and banks of rivers in the study area have been altered during the last 150 years to increase use of the river and adjacent land. One of the earliest changes began in the late 1800s when a large number of snags and log jams were removed from the channel to promote navigation and the driving of commercial logs down the river to sawmills in Eugene, Coburg, and downstream. Between 1870 and 1911, nearly 400 logs per mile of river were snagged out of the Willamette River from Eugene to Albany (Sedell and Froggatt 1984). Removing log jams from a river influences the channel in several ways: 1) the channel becomes narrower and straighter with fewer side channels and meanders, 2) the bedload of the river becomes more coarse due to the higher velocity water resulting from a straighter and less-obstructed channel, and 3) the reduced meandering decreases the amount of finer material that can be incorporated into the channel bottom when banks are undercut.

Few logs are found in the rivers today. For example, the lower McKenzie River (downstream of Hendricks Bridge) now averages only 1.2 single logs per mile and 0.15 log jams per mile (Alsea Geospatial et al. 2001). The current scarcity is due to continued intentional removal of wood (often for firewood), trapping of logs at the reservoirs, reduced channel meandering that would normally undercut streamside trees, and reduced numbers of older trees growing along the river. Much of the loss of older streamside trees has occurred in recent decades. In the lower McKenzie River, the percentage of main channel river bank supporting trees greater than 40 years old decreased from 37% to 12% between 1944 and 2000 (Alsea Geospatial et al. 2001).

2.1.2 River peak flows

The hydrology of the rivers, and consequently their geometry, were altered significantly following construction of upstream flood control reservoirs from 1942 to 1968. Current values for the 100-year instantaneous peak flow range from 62% of normal for the Coast Fork Willamette River to 22% of normal for the Middle Fork Willamette River (Figure 5). To put this in perspective, the February, 1996 flood on the McKenzie River was the highest on record since completion of the two upstream reservoirs. Yet, flows greater than the 1996 flood occurred about four times per decade prior to dam construction.

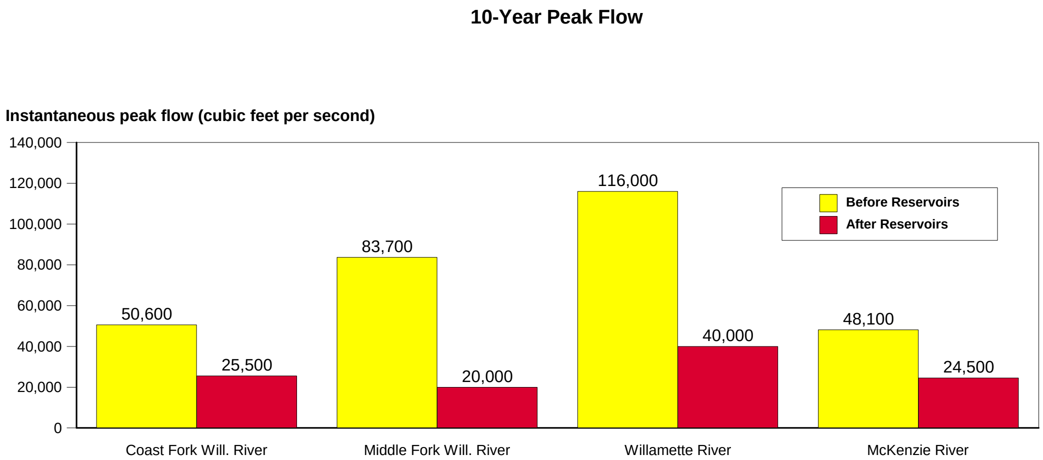
Reducing peak flows of a river limits its ability to meander, create new side channels, ponds, and alcoves, and keep off-channel features from readily filling with fine sediments (Miller et al. 1995, Van Steeter and Pitlick 1998, Friedman et al. 1998). Consequently, the river becomes straighter, the channel less complex, and the substrate coarser. A river without flood storage reservoirs and riprapped banks is more capable of meandering across its flood plain, entraining smaller-sized sediments stored in the banks, and depositing them on the inside of downstream bends or on top of low riverside terraces.

Dams are capable of trapping gravel and fine sediments in their reservoirs. However, observations of the reservoirs when they are empty reveal that, except for limited sediment wedges at the heads of the reservoirs where rivers enter, there is little sedimentation within the reservoirs. Stumps cut at the time of reservoir establishment (35 to 50 years ago) are still readily visible at the reservoir’s bottom surfaces. Because most of the Willamette basin reservoirs are emptied during the winter (except during major runoff events), river water is entrenched along the axis of the reservoir and is therefore capable of transporting much of its load of suspended sediment and bedload downstream through and beyond the dam.

2.1.3 Gravel extraction

Another major change to the rivers was the extraction of gravel from channels, and later, from adjacent flood plains. Aerial photographs from 1944 show extensive mining of gravel within the main channel of the Willamette River upstream of Skinner Butte and downstream of the current Interstate 5 bridge (reach 18, Map 10a). At that time, gravel bars lined 44% of the riverbanks. Currently, only 2% of the riverbank length in reach 18 is bordered by gravel bars. Beginning in the late 1960s, extensive gravel mining within channels also occurred at the mouth of the McKenzie River (reaches 3-4), within the Willamette River immediately upstream of the McKenzie River confluence (reach 15), and at the mouth of the Coast Fork Willamette River (reach 26).

The mouth of the McKenzie River once occupied an active flood plain between one-half to one mile wide with two major channels and numerous small side channels (Andrus et al. 2000). The river has since been forced into the northern of the two major channels and the remainder of the delta to the south has been diked and is currently being mined for gravel. Prior to mining, the lower Coast Fork Willamette River (reach 21 and 26) meandered across a wide flood plain and paralleled the Middle Fork Willamette River for several miles. Gravel extraction (sometime after 1944) along its main course left a wide and deep trench that the river currently occupies.



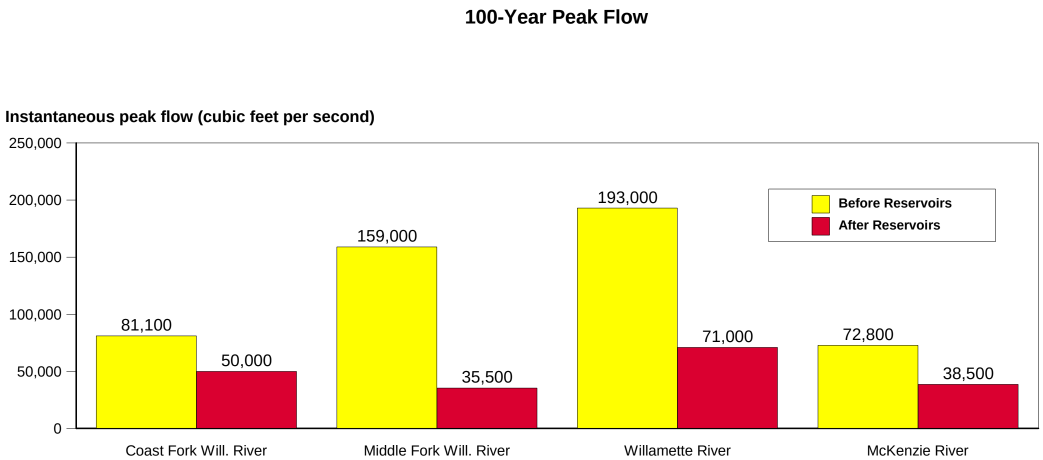


Figure 5. Changes in 10-year and 100-year peak flows due to upstream reservoirs for rivers in the study area. Gauging sites for the various rivers include: Goshen for the Coast Fork Willamette River, Jasper for the Middle Fork Willamette River, Springfield for the Willamette River, and Vida for the McKenzie River. Information provided by U.S. Corps of Engineers in 2002 (unpublished data).

2.1.4 Riprap

Over the last six decades, some river banks in the study area have been lined with riprap (large angular rock overlying the banks about 3 to 5 feet deep) to prevent channel meandering. Most riprap is placed on the outside banks of the river where the water is fastest. Overall, 17 percent of river banks in the study area are riprapped (Table 3). Riprap is most common in the McKenzie River downstream of the Interstate Highway 5 bridge, upper Willamette River (between the McKenzie River confluence and the Coast Fork Willamette River confluence) and in the Middle Fork Willamette River (Figure 6). Only three reaches have no riprapped banks. The seven reaches with the highest density of riprap are summarized in Table 4.

While riprap is effective at preventing river meandering and protecting property, it has some biological drawbacks. First, a number of native fish tend to avoid riprap banks. The reason is unknown, but may include a lack of low-velocity zones for feeding and the deep water that invariably develops along riprapped banks. Second, riprap tends to simplify the river channel and prevent it from forming diverse habitat features such as side channels, alcoves, and gravel bars.

Table 3. Length of riprapped main channel relative to total bank length in year 2000. Riprap along rivers was inventoried in the field by boat throughout the study area.

	Riprapped bank length (miles)	Total bank length* (miles)	% bank with riprap
Overall (reaches 2-28)	14.5	84.2	17
Lower Willamette River (reach 2)	0.0	1.6	0
McKenzie River (reaches 3-14)	4.6	36.1	12
Upper Willamette River (reaches 15-21)	5.2	23.3	22
Middle Fork Willamette River (reaches 22-25)	3.4	14.0	24
Coast Fork Willamette River (reaches 26-28)	1.4	9.2	15

* Assumed to be twice the thalweg length.

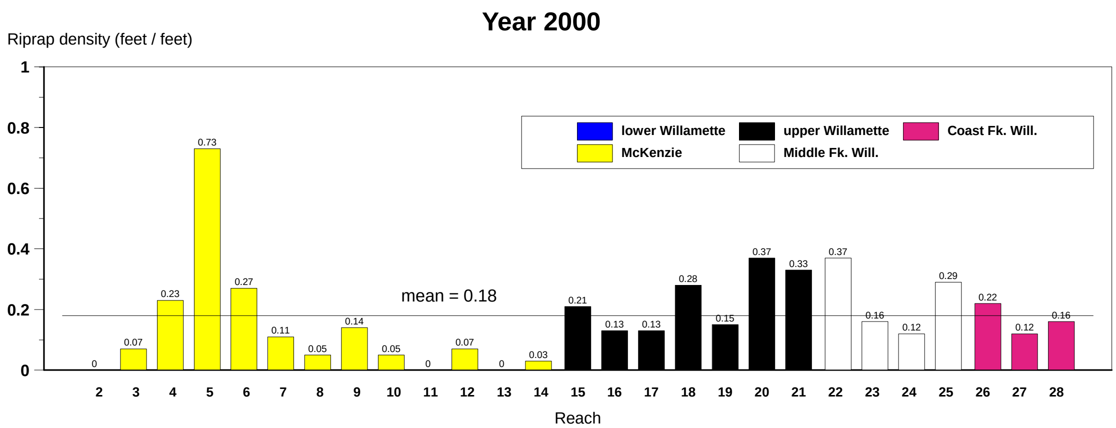


Figure 6. Riprap density (feet of riprapped bank per feet of river total river bank in a reach) for the 27 river reaches in the MECT study area.

Table 4. Seven highest ranking river reaches for riprap density in year 2000.

Ranking	Reach	River	Year 2000 length (feet/feet)*
1	5	McKenzie	0.73
2	22	Middle Fork Will.	0.37
3	20	Upper Willamette	0.37
4	21	Upper Willamette	0.31
5	25	Middle Fork Will.	0.29
6	18	Upper Willamette	0.28
7	6	McKenzie	0.27

***** Feet of riprapped bank per feet of river total river bank in a reach.

2.1.5 River geomorphology

River reach boundaries were marked on year 2000 aerial photographs and replicated on the pre-reservoir 1944 aerial photographs. The 1944 photos were the oldest located that had sufficient quality to identify water and bank features and that covered the entire study area.

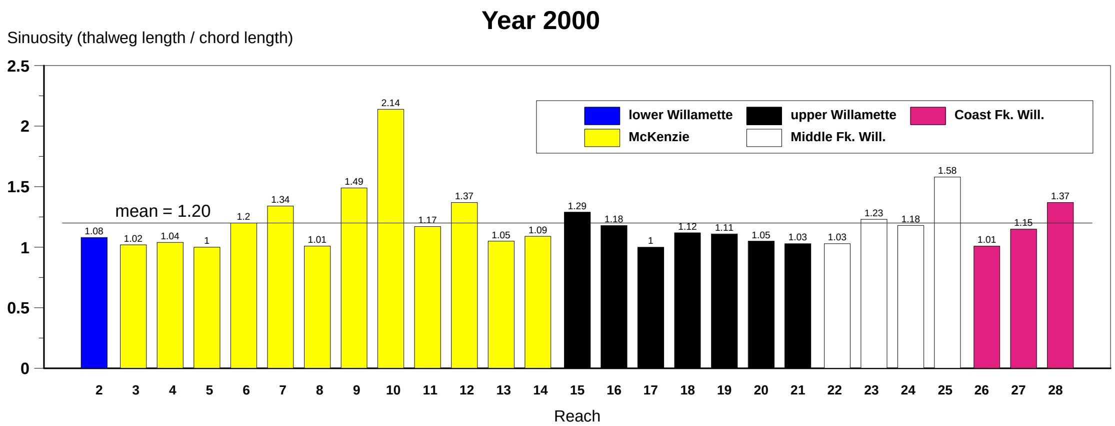
The following measurements were made from aerial photographs for each reach:

1. Thalweg length (length of the path where most of the water flows).
2. Chord length (straight-line length from beginning to ending of reach).
3. Cumulative length of side channels.
4. Cumulative length of alcoves.
5. Length of main channel bank bordered by a gravel bar.
6. Sinuosity of each reach (calculated by dividing thalweg length by chord length).

The above measurements were selected to describe river geomorphology because they directly relate to fish habitat quality. A reach with high sinuosity usually has a diverse array of fish habitat features including varied water depth, water velocity, and sediment size. A reach with greater side channel length usually has a greater degree of habitat diversity for fish. Side channels can provide early season feeding areas, refuge from fast-flowing water, and protection from main channel predator fish. A reach with greater alcove length usually can provide a range of specialized fish habitat features. Alcoves are often used by native fish for breeding and rearing. The still and shallow water during the summer often promotes growth of aquatic plants and associated food webs. Finally, a reach with abundant gravel bordering the banks usually has a greater abundance of aquatic insects and other food items for fish.

Channel length and sinuosity

Between 1944 and 2000, the length of the rivers in the study area decreased 3.5 miles or 8%. Overall, sinuosity also decreased 8%. The decrease in reach 2 was largely an artifact of the mouth of the McKenzie River moving upstream several miles. Sinuosity declines were most significant in the McKenzie River and the Coast Fork Willamette River (Figure 7) and are related to deliberate attempts to keep the rivers from meandering. Some decline in sinuosity occurred prior to the 1944 aerial photographs, but the extent is unknown.



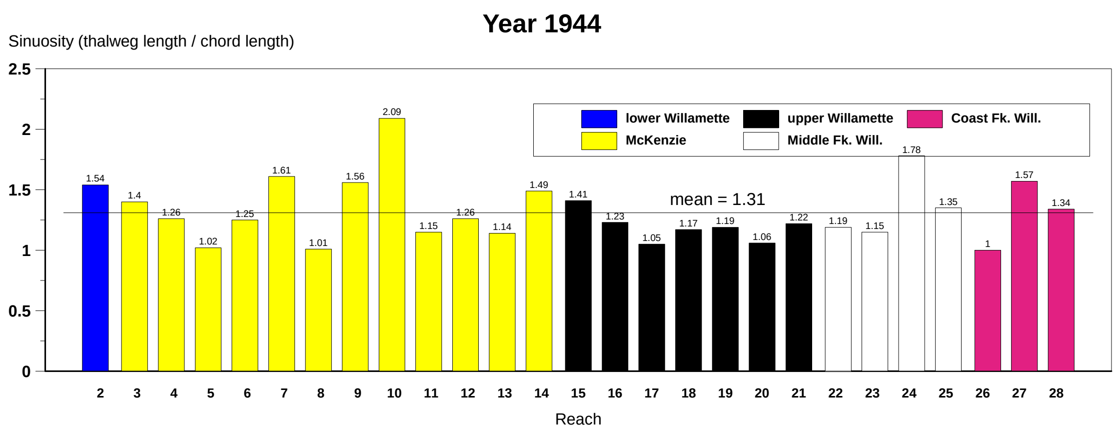


Figure 7. Channel sinuosity by reach for current conditions (2000) and pre-reservoir conditions (1944). See Map 10a for a display of river reach boundaries.

Reaches that currently have the highest sinuosity occur mostly in the McKenzie River near Springfield (Table 5) or the Middle Fork of the Willamette River. Also, a reach immediately upstream of the McKenzie River confluence has high sinuosity. Because of their current high sinuosity, these reaches would be most appropriate for protection.

<u>Table 5</u>. Seven highest ranking river reaches for channel sinuosity in year 2000.

Ranking	Reach	River	Year 2000 sinuosity (feet/feet)
1	10	McKenzie	2.14
2	25	Middle Fork Will.	1.58
3	9	McKenzie	1.49
4	28	Middle Fork Will.	1.37
5	12	McKenzie	1.37
6	7	McKenzie	1.34
7	15	Upper Willamette	1.29

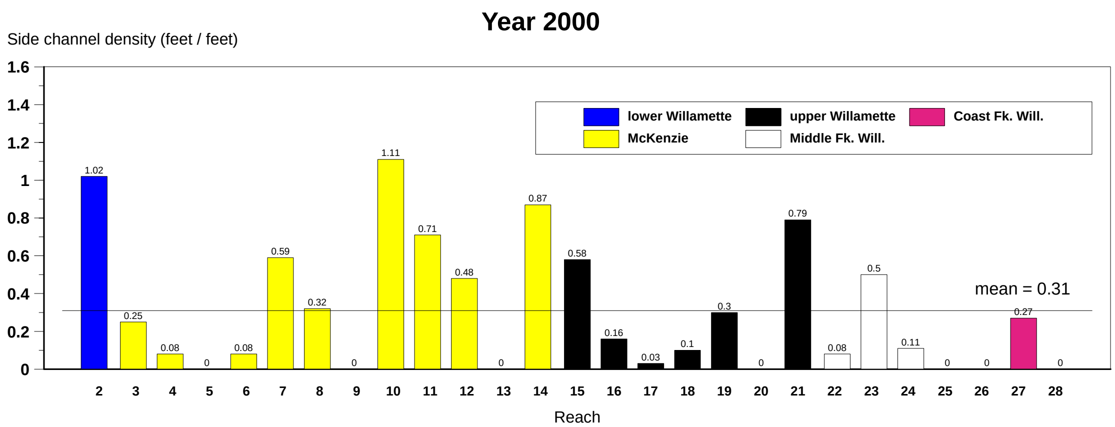
Reaches that had the greatest amount of sinuosity loss (Table 6) would be most appropriate for <u>restoration</u>, assuming that other factors, such as adjacent deep gravel pit ponds, allowed such restoration. These high priority restoration reaches occur in the lower McKenzie River and scattered reaches in the Middle Fork Willamette River, Lower Willamette River, and Coast Fork Willamette River. Restoring the sinuosity to reaches 3 and 4 may be hindered by the diked and riprapped banks and the adjacent gravel pits in this area.

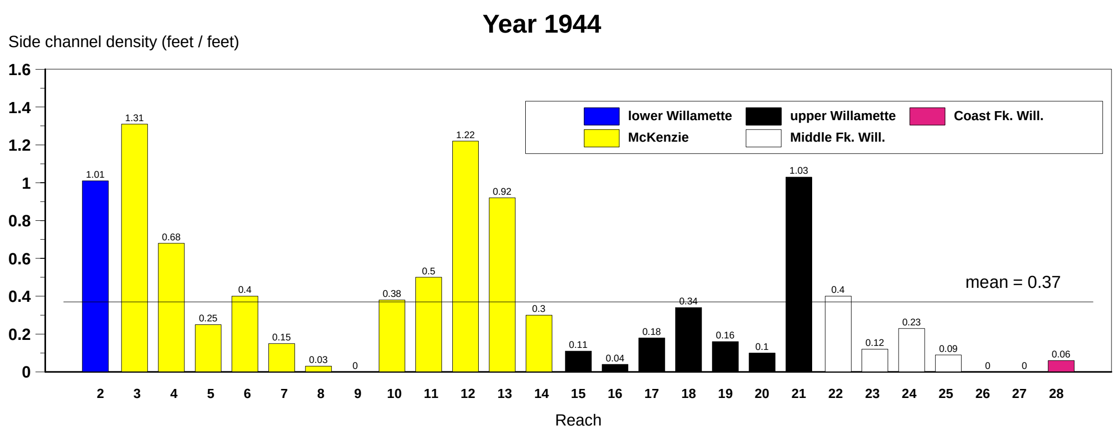
<u>Table 6</u>. Seven highest ranking river reaches for loss in channel sinuosity between year 1944 and year 2000.

Ranking	Reach	River	Year 1944 sinuosity (feet/feet)	Year 2000 sinuosity (feet/feet)	Sinuosity loss (feet/feet)
1	24	Middle Fork Will.	1.78	1.18	0.60
2	2	Lower Willamette	1.54	1.08	0.46
3	27	Coast Fork Will.	1.57	1.15	0.42
4	14	McKenzie	1.49	1.09	0.40
5	3	McKenzie	1.40	1.02	0.39
6	7	McKenzie	1.61	1.34	0.26
7	4	McKenzie	1.26	1.04	0.22

Side channel abundance

Between 1944 and 2000, the length of side channels associated with rivers in the study area declined 2.4 miles, or a 15% loss. Side channel losses were most significant in the McKenzie River (23% decline), with much of the loss occurring downstream of the Interstate Highway 5 bridge where extensive gravel mining occurs. Currently, 7 of the 27 reaches lack side channels, while only 3 reaches lacked side channels in 1944 (Figure 8).





<u>Figure 8</u>. Side channel density by reach for current conditions (2000) and pre-reservoir conditions (1944). See Map 10a for a display of river reach boundaries.

Reaches that currently have the highest density of side channels include McKenzie River reaches near Springfield and two Willamette River reaches immediately above and below the McKenzie River confluence (Table 7). Reach 21 on the Middle Fork Willamette River is also high. Because of their current high density of side channels, these reaches would be high priority candidates for protection.

Nearly all reaches with the greatest loss of side channels occur in the McKenzie River, especially in the most downstream section that has extensive gravel mining (Table 8). Reach 22 in the Middle Fork Willamette River has also undergone a large loss of side channels. Those reaches with the largest loss in side channel length between 1944 and 2000 would be top candidates for restoration, depending on physical and economic barriers to restoration.

<u>Table 7</u>. Seven highest ranking river reaches for per unit side channel length in year 2000.

Ranking	Reach	River	Year 2000 length (feet/feet)
1	10	McKenzie	1.11
2	2	Lower Willamette	1.02
3	14	McKenzie	0.87
4	21	Middle Fork Will.	0.79
5	11	McKenzie	0.71
6	7	McKenzie	0.59
7	15	Upper Willamette	0.58

<u>Table 8</u>. Seven highest ranking river reaches for loss in per unit side channel length between year 1944 and year 2000.

Ranking	Reach	River	Year 1944 length (feet/feet)	Year 2000 length (feet/feet)	Side channel loss (feet/feet)
1	3	McKenzie	1.31	0.25	1.06
2	13	McKenzie	0.93	0.00	0.92
3	12	McKenzie	1.22	0.48	0.74
4	4	McKenzie	0.68	0.08	0.60
5	22	Middle Fork Will.	0.40	0.08	0.32
6	6	McKenzie	0.40	0.08	0.32
7	5	McKenzie	0.25	0.00	0.25

Alcove abundance

Between 1944 and 2000, the length of alcoves associated with rivers in the study area declined 2.6 miles, or a 39% loss. Alcove losses were most significant in the McKenzie River (42% decline) and in the upper Willamette River (45% decline). Currently, nearly half of the 27 reaches lack alcoves, while only one-quarter of the reaches lacked alcoves in 1944 (Figure 9).

Reaches that currently have the highest density of alcoves include the lower McKenzie River and two Willamette River reaches immediately above and below the McKenzie River confluence (Table 9). Reach 22 on the Middle Fork Willamette River is also high. Because of their current high density of alcoves, these reaches would be priority candidates for protection.

A majority of reaches with the greatest loss in per unit alcove length occur in the McKenzie River (Table 10a). Reach 22 on the Middle Fork Willamette River has also undergone a large loss of alcoves. Those reaches with the largest loss in alcove length between 1944 and 2000 would be top candidates for restoration, depending on physical and economic barriers to restoration.

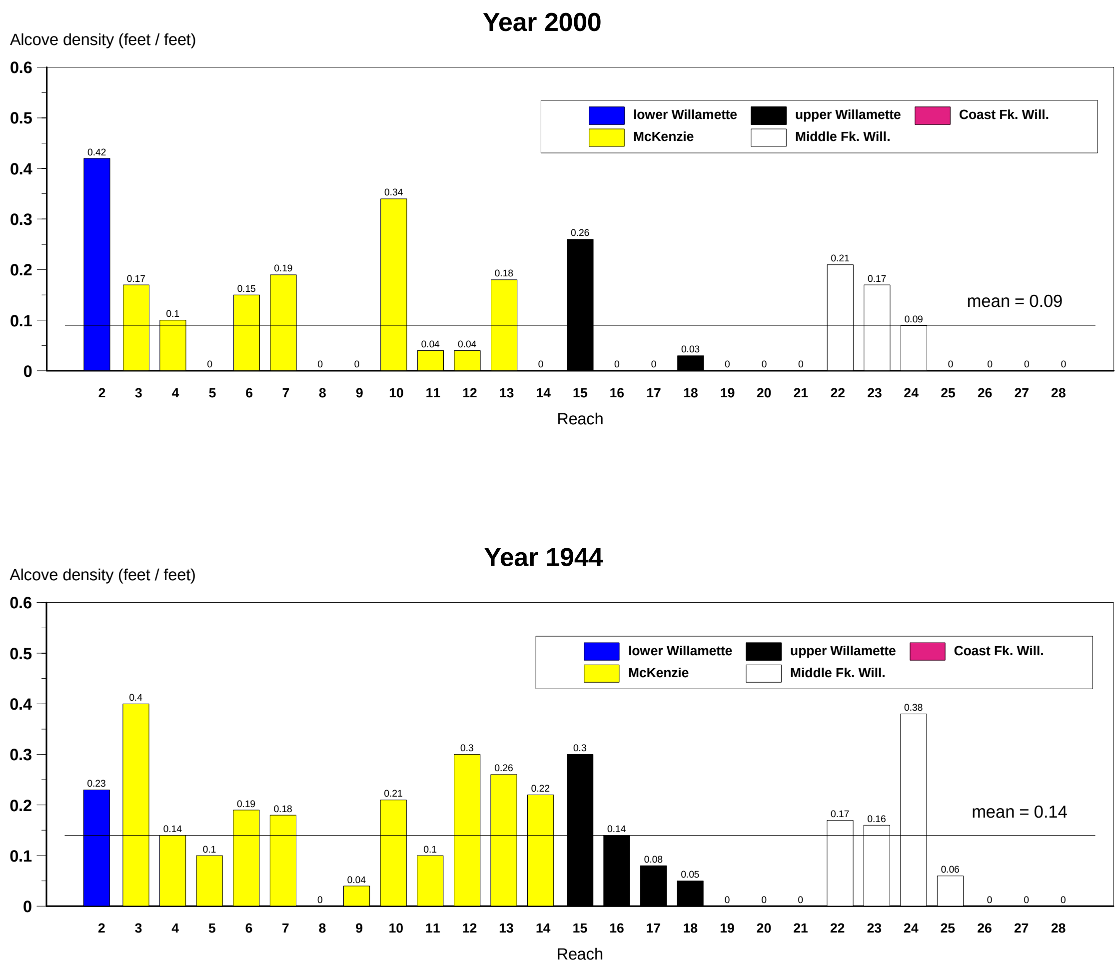


Figure 9. Alcove density by reach for current conditions (2000) and pre-reservoir conditions (1944). See Map 10a for a display of river reach boundaries.

Table 9. Seven highest ranking river reaches for per unit alcove length in year 2000.

Ranking	Reach	River	Year 2000 length (feet/feet)
1	2	Lower Willamette	0.42
2	10	McKenzie	0.34
3	15	Upper Willamette	0.26
4	22	Middle Fork Will.	0.21
5	7	McKenzie	0.19
6	13	McKenzie	0.18
7	3	McKenzie	0.17

Table 10. **Seven highest ranking river reaches for loss in per unit alcove length between year 1944 and year 2000.**

Ranking	Reach	River	Year 1944 length (feet/feet)	Year 2000 length (feet/feet)	Alcove loss (feet/feet)
1	24	Middle Fork Will.	0.38	0.09	0.28
2	12	McKenzie	0.30	0.04	0.26
3	3	McKenzie	0.40	0.17	0.23
4	14	McKenzie	0.22	0.00	0.22
5	16	Upper Willamette	0.14	0.00	0.14
6	5	McKenzie	0.10	0.00	0.10
7	17	Upper Willamette	0.08	0.00	0.08

Gravel bar abundance along the main channel

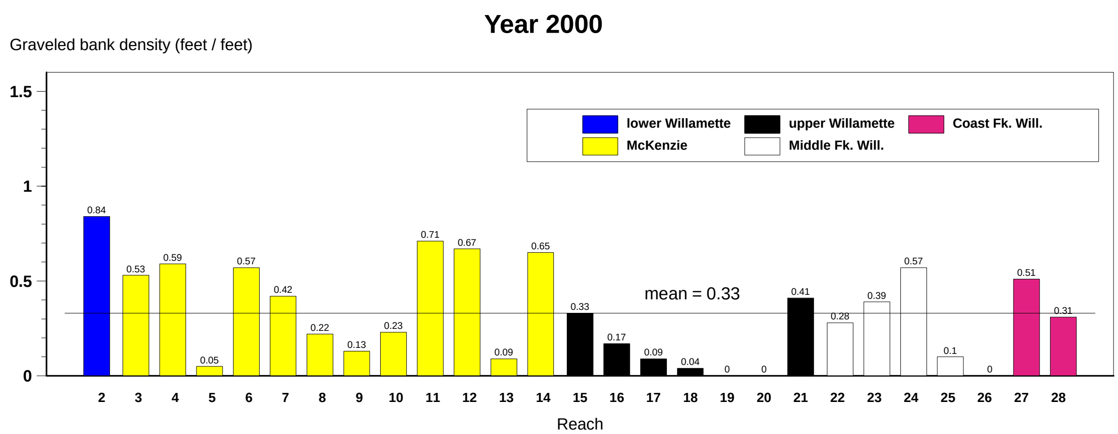
Between 1944 and 2000, the length of river bank bordered by bare gravel in the study area declined by 16.4 miles, or a 54% loss (Figure 10). Gravel bar losses were most significant in the Upper Willamette River (84% decline), in the Coast Fork Willamette River (69% decline), and in the Middle Fork Willamette River (65% decline). The decline in unvegetated gravel bars can be attributed to gravel removal, the reduction in peak flows following dam construction, and an influx of introduced plant species such as reed canarygrass and blackberry that readily invade low-lying gravel areas of the river.

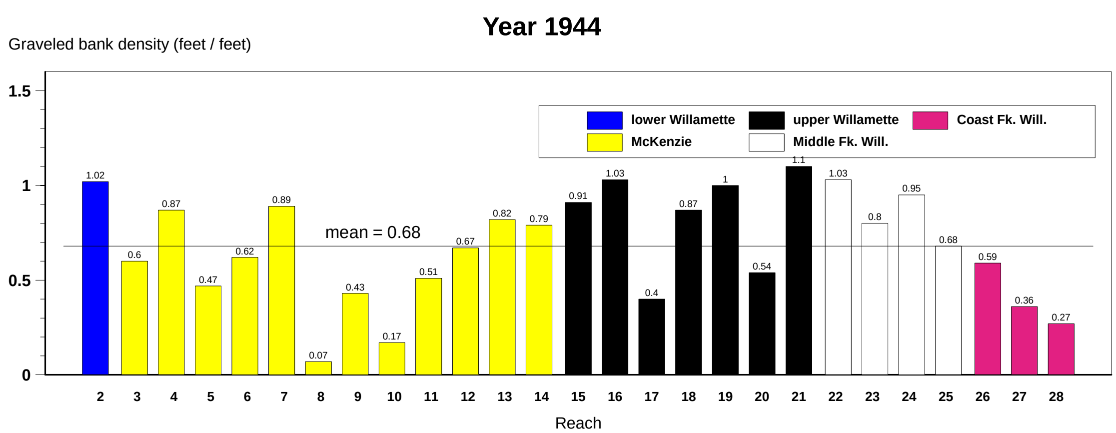
Areas that currently have the highest abundance of bare gravel bars include reaches in the McKenzie River and the Willamette River reach immediately above the McKenzie River confluence (Table 11). Reach 24 on the Middle Fork Willamette River is also high. Because of their current high density of bare gravel bars, these reaches would be candidates for protection.

Table 11. **Seven highest ranking river reaches for per unit gravel bar length in year 2000.**

Ranking	Reach	River	Year 2000 length (feet/feet)
1	2	Lower Willamette	0.84
2	11	McKenzie	0.71
3	12	McKenzie	0.67
4	14	McKenzie	0.65
5	4	McKenzie	0.59
6	24	Middle Fork Will.	0.57
7	6	McKenzie	0.57

A majority of reaches with the greatest loss of bare gravel bars occur in the upper Willamette River near downtown Eugene and a few scattered sites in each of the other three rivers (Table 12). Those reaches with the largest loss in gravel bar length between 1944 and 2000 would be top candidates for restoration, depending on physical and economic barriers to restoration. Sites near downtown Eugene would be difficult to restore because extensive gravel mining removed much of the aggregate during the 1940s and 1950s and the west side of the main channel is crowded by riprapped bank and buildings. It is probably not realistic to expect that gravel bars can be restored to this area since the peak flows needed to initiate river meandering in the Middle Fork Willamette River and the uptake of gravels from retreating banks would inundate a significant amount of human infrastructure between Dexter Dam and the McKenzie River confluence. Reservoir management currently dampens peak flows by about 78%. The alternative to increasing peak flows to get gravel deposition in the Eugene stretch of the Willamette River is to extract it from near-river sites and place it in the channel. This would involve a tremendous cost and the benefits resulting from this cost would be relatively small considering that Chinook salmon are not capable of spawning here (the reservoirs create water that is too warm in the fall).





<u>Figure 10</u>. Gravel bar density by reach for current conditions (2000) and pre-reservoir conditions (1944). See Map 10a for a display of river reach boundaries.

Table 12. Seven highest ranking river reaches for loss in per unit gravel bar length between year 1944 and year 2000.

Ranking	Reach	River	Year 1944 length (feet/feet)	Year 2000 length (feet/feet)	Gravel bar loss (feet/feet)
1	19	Upper Willamette	1.00	0.00	1.00
2	16	Upper Willamette	1.03	0.17	0.86
3	18	Upper Willamette	0.87	0.04	0.83
4	22	Middle Fork Will.	1.03	0.28	0.75
5	13	McKenzie	0.82	0.09	0.73
6	21	Middle Fork Will.	1.10	0.41	0.69
7	26	Coast Fork Will.	0.59	0.00	0.59

A summary of physical characteristics of each study area river for the two time periods are displayed in Table 13.

Table 13. Summary of physical characteristics of river segments in 1944 and 2000.

	Year 1944	Year 2000	Percent change
Overall (reaches 2-28)			
Main channel; length of thalweg (miles)	45.62	42.09	-8
Main channel; length of chord distance (miles)	34.81	34.81	0
Sinuosity	1.31	1.21	-8
Side channel; length (miles)	15.65	13.22	-15
Alcove; length (miles)	6.58	4.01	-39
Gravel bar; length of main channel bank (miles)	30.19	13.77	-54
Lower Willamette River (reach 2)			
Main channel; length of thalweg (miles)	1.33	0.81	-39
Main channel; length of chord distance (miles)	0.86	0.75	-13
Sinuosity	1.54	1.08	-30
Side channel; length (miles)	1.34	0.83	-39
Alcove; length (miles)	0.30	0.34	+13
Gravel bar; length of main channel bank (miles)	1.36	0.68	-50
McKenzie River (reaches 3-14)			
Main channel; length of thalweg (miles)	19.68	18.04	-8
Main channel; length of chord distance (miles)	14.52	14.40	-1
Sinuosity	1.36	1.25	-8
Side channel; length (miles)	10.29	7.89	-23
Alcove; length (miles)	3.73	2.15	-42
Gravel bar; length of main channel bank (miles)	11.03	7.58	-31
Upper Willamette River (reaches 15-21)			
Main channel; length of thalweg (miles)	12.13	11.67	-4
Main channel; length of chord distance (miles)	10.19	10.30	+1
Sinuosity	1.19	1.13	-5
Side channel; length (miles)	2.50	2.70	+8
Alcove; length (miles)	3.73	0.73	-45
Gravel bar; length of main channel bank (miles)	10.00	1.63	-84
Middle Fork Willamette River (reaches 22-25)			
Main channel; length of thalweg (miles)	7.12	6.98	-2
Main channel; length of chord distance (miles)	5.47	5.58	+2
Sinuosity	1.30	1.25	-4
Side channel; length (miles)	1.39	1.24	-11
Alcove; length (miles)	1.22	0.79	-35
Gravel bar; length of main channel bank (miles)	5.99	2.17	-65
Coast Fork Willamette River (reaches 26-28)			
Main channel; length of thalweg (miles)	5.36	4.59	-14
Main channel; length of chord distance (miles)	3.77	3.77	0
Sinuosity	1.42	1.22	-14
Side channel; length (miles)	0.13	0.57	+345
Alcove; length (miles)	0.00	0.00	0
Gravel bar; length of main channel bank (miles)	1.81	0.57	-69

2.1.6 Fish habitat index based on geomorphology

The four above-mentioned channel characteristics were combined into a single index of fish habitat quality so that the reaches could be ranked according to overall fish habitat quality based on geomorphology. The data was then transformed in the following way. For the series of values associated with each parameter (sinuosity, side channel density, alcove density, and bare gravel bar density), the values were standardized. This was accomplished by applying the following equation:

Standardized value = (X – Xmin) / (Xmax –Xmin)

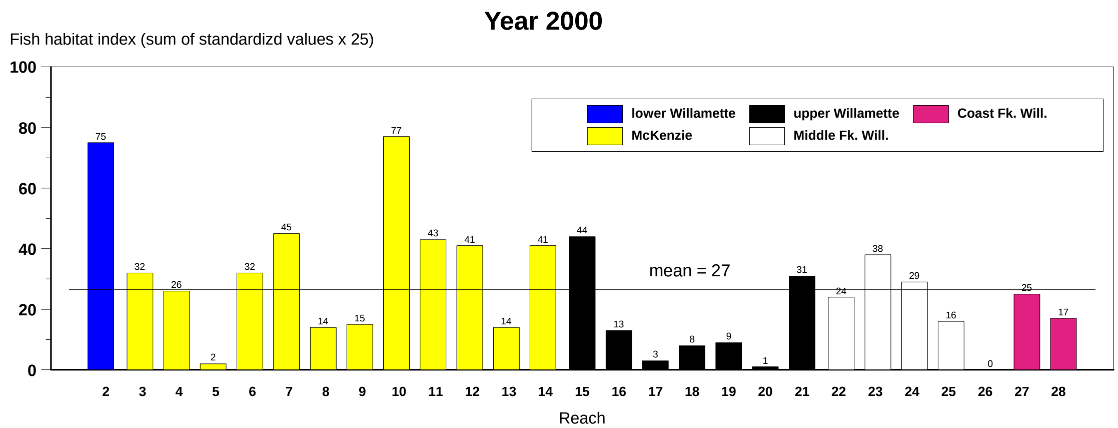
where: X is the value for the reach,
Xmin is the minimum value among the 27 reaches, and
Xmax is the maximum value among the 27 reaches.

This transformation resulted in a list of values that ranged from 0 to 1 for each parameter, with 1 being the highest value and 0 being the lowest value.

The standardized values for the four parameters was added and then multiplied by 25 in order to end up with an index that ranged from 0 to 100. This was called the fish habitat index. It was assumed that each of the four parameters had equal weight in defining fish habitat quality. Reaches with a high fish habitat index (a theoretical maximum of 100) were considered the best habitat and reaches with a low fish habitat index (a theoretical minimum of 0) were considered the worst habitat. This was done separately for both 2000 and 1944 conditions (Figure 11).

The fish habitat index is currently greatest in reaches of the McKenzie River within and upstream of Springfield and two Willamette River reaches immediately upstream and downstream of the McKenzie River confluence (Table 14). Reach 13, the only upper McKenzie River reach that does not currently have a high fish habitat ranking, had the greatest loss in fish habitat index between 1944 and 2000 (Figure 11). Other reaches with unusually high losses in fish habitat index include reach 12 and reach 3 in the McKenzie River (Table 15). Reaches 13 and 12 would be high priority for restoration because of the scarcity of human development next to the river. However, improvements for reach 3 would be more difficult because of the adjacent gravel mining and riprapped banks.

Reaches 22 and 24 in the Middle Fork Willamette also had large losses in fish habitat quality and would be candidates for restoration. Reach 24 holds special promise because of the lack of development and river-adjacent gravel ponds. Losses in fish habitat were high in two upper Willamette River reaches (16 and 18), but restoring complexity to these reaches would be frustrated by extensive development and riprap along the west bank and the removal of in-channel gravel during the 1940s and 1950s.



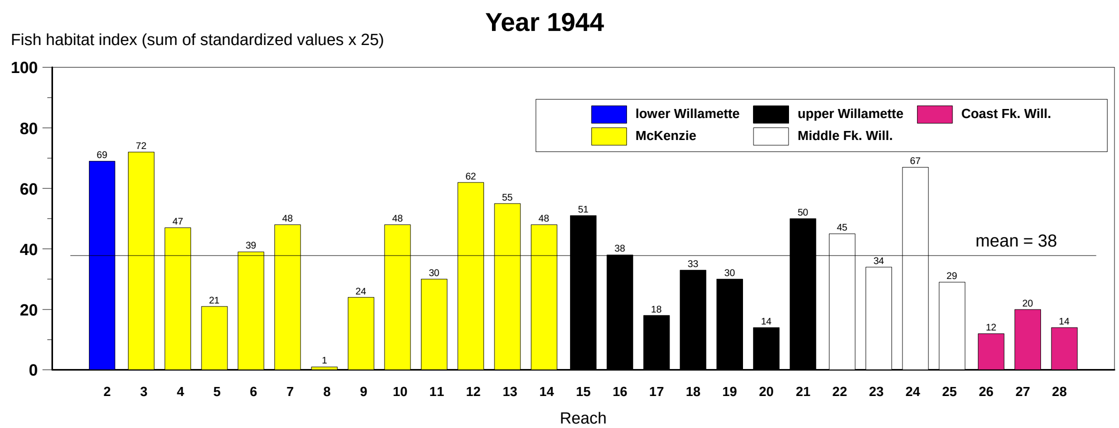


Figure 11. Fish habitat index by reach for current conditions (2000) and pre-reservoir conditions (1944). See Map 10a for a display of river reach boundaries. Fish habitat index was determined by summing the standardized values for sinuosity, side channel length, alcove length, and length of main channel bank bordered by gravel bars and then multiplying by 25.

Table 14. Seven highest ranking river reaches for fish habitat index in year 2000.

Ranking	Reach	River	Year 2000 index
1	10	McKenzie	77
2	2	Lower Willamette	75
3	7	McKenzie	45
4	15	Upper Willamette	44
5	11	McKenzie	43
6	12	McKenzie	41
7	14	McKenzie	41

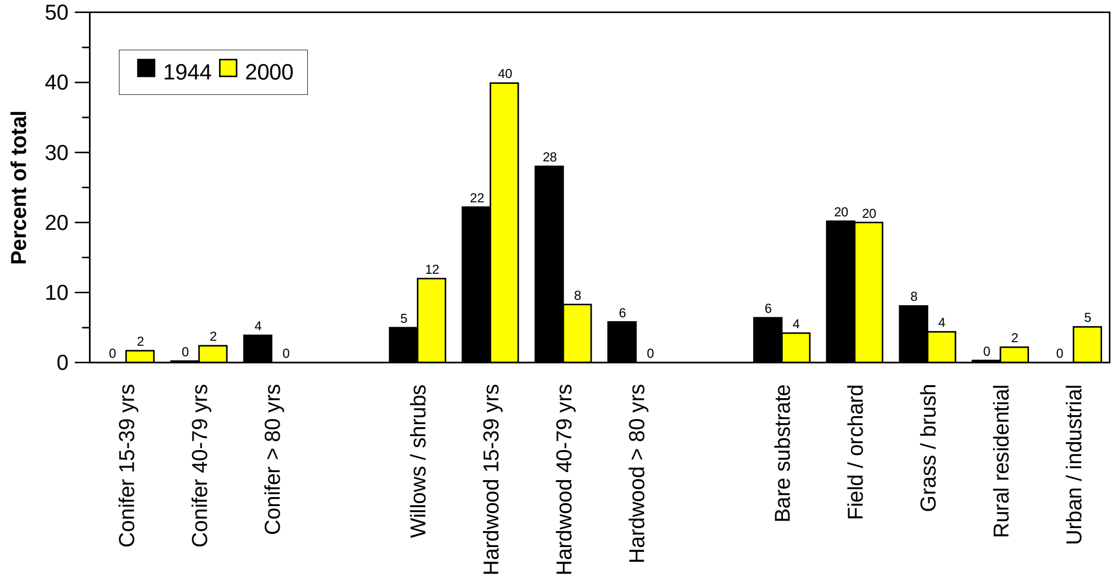
Table 15. Seven highest ranking river reaches for loss in fish habitat index between year 1944 and year 2000.

Ranking	Reach	River	Year 1944 index	Year 2000 Index	Fish habitat index loss
1	13	McKenzie	55	14	41
2	3	McKenzie	72	32	40
3	24	Middle Fork Will.	67	29	38
4	16	Upper Willamette	38	13	25
5	18	Upper Willamette	33	8	25
6	22	Middle Fork Will.	45	24	21
7	12	McKenzie	62	41	21

2.1.7 Riparian vegetation alongside rivers

Along with changes in channel geomorphology, riparian vegetation next to the rivers has also changed over the last six decades. An example of this change for the McKenzie River from reach 2-14 is provided using aerial photographs from 1944 and 2000 (Alsea Geospatial et al. 2001). These reaches encompass the extent of the McKenzie River that falls within the MECT study area. Vegetation types were evaluated 500 feet each side of the river and the areas by vegetation type were tabulated for each reach.

Results from this evaluation indicate that the percent total area within 500 feet of the river comprised of fields and orchards has not changed, but the percent occupied by hardwood and shrubs has increased considerably (Figure 12). In 1944, only about one-quarter of the area supported willows, shrubs, and hardwoods less than 40 years old. This area increased to over one-half of the area by 2000. Correspondingly, there were sharp declines in the area of hardwoods greater than 40 years old, bare substrate, and grass. The muting of peak flows by reservoirs has allowed vegetation to encroach upon the river edges, while harvest of older trees for timber and development has depleted older age classes of trees. Rural residential and urban development was only 0.3% of the area in 1944 because of the flood hazard, but increased to 7.3% by 2000.



<u>Figure 12</u>. Changes in vegetation and land use for the McKenzie River (reaches 2-14) between 1944 and 2000 (Alsea Geospatial et al. 2001). Calculated using the area of land 500 feet each side of the river. The 500 feet wrapped around side channels and alcoves. Included in the calculation was the vegetation on islands of land between the main channel and side channels or alcoves.

The changes in riparian vegetation and land use over the last six decades have likely contributed to a decline in fish habitat. Young vegetation encroaching upon the river has stabilized gravel bars and has probably resulted in less gravel bar movement, which can negatively affect the abundance of aquatic insects and periphyton used by fish for food. Also, a river with heavily-vegetated lower banks is less likely to meander, thereby slowing down the processes that create and modify off-channel features along the river. The scarcity of large trees along the river contributes to the deficit of large wood in the river. This wood creates channel roughness features that fish can use to find cover and maintain desirable feeding spots.

Much of the interaction between land and water occurs within the narrow corridor that is within 100 feet of the river edge. For example, trees growing close to the stream are those most likely to contribute large wood, litter, bank hardening via their roots, and shade. It was determined that the current composition of riparian vegetation (within 100 feet of the main channel) for all rivers throughout the study area using 2000 aerial photographs and expressed categories as a percent of the total bank length (Table 16).

Table 16. Summary of percent current vegetation, gravel bars, and development within 100 feet of the edge of rivers within the study area by groups of reaches. Developed areas includes roads, paved or graveled lots, dikes, gravel extraction areas, or buildings.

	Overall (#2-28)	Lower Willamette (#2)	Lower McKenzie (#3-14)	Upper Willamette (#15-21)	Middle Fk. Willamette (#22-25)	Coast Fk. Willamette (#26-28)
Hardwood trees	57.2%	32.4%	50.3%	64.1%	48.2%	77.7%
Mixed conifer and hardwood trees	1.9	0.0	0.2	0.0	11.4	0.0
Shrubs (including willows)	15.9	39.7	20.5	10.8	15.4	13.4
Grass, pasture, fields	8.0	0.0	7.7	10.7	7.6	5.0
Orchards (filberts)	0.9	0.0	0.0	0.0	4.5	0.0
Gravel bars	11.2	27.9	16.3	4.8	12.9	4.0
Developed areas	4.9	0.0	5.0	9.5	0.0	0.0
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Overall, vegetation of various types dominates the 100-foot-wide corridor next to study area rivers. Less than 5% of bank length is developed in this zone. Hardwood trees occupied more than 50% of river banks. Conifer trees are nearly absent. Development along the upper Willamette River reaches is the highest among the rivers, but still makes up less than 10% of river banks. While development along the west bank of this section of river is widespread, it is usually set back from the edge of the river more than 100 feet. Development within the 100-foot corridor does not exist for lower Willamette, Middle Fork Willamette, and Coast Fork Willamette reaches.

The percentage of banks occupied by shrubs is greatest along lower Willamette River and lower McKenzie River reaches. Here, the river was once lined by extensive areas of gravel bars. Since peak flows have been dampened at reservoirs, shrubs have established themselves close to the water edge. Shrubs growing along study area rivers are a combination of native species, such as willows, and exotic species, such as blackberry and Scotch broom. Hardwood trees are mostly young with only a few patches greater than 80 years old. Nevertheless, other than those trees located between riverfront houses and the water, few cases where observed where trees had recently been removed. The growth of ash and cottonwood trees can be rapid when located near water and many of these hardwood stands will begin developing mature characteristics in a few decades.

2.1.8 Conclusions, recommended actions, and information gaps about river geomorphology and vegetation

The fish habitat index developed for this project provides an objective way for determining physical habitat quality that can be extracted from historic aerial photographs, thereby allowing a comparison of pre-reservoir conditions with the present. For all reaches combined, each of the four parameters that make up the index have declined since 1944. Main channel sinuosity declined the least (8%) while gravel bar abundance declined the most (54%). Declines in fish habitat quality probably also occurred prior to 1944, but there were no available data with which we could quantify these changes. Among those pre-1944 changes were the clearing and straightening of channels to allow log drives and boat traffic.

With exceptions, reaches that had good physical fish habitat in 1944 still retain those characteristics today. Reaches 7 and 10 through 14 of the lower McKenzie had some of the best habitat in 1944 and all except reach 13 still have above-average habitat. This portion of the McKenzie River is a depositional area with a low gradient and a wide river meander belt and would be qualified as high priority for protection (reaches 7, 10-12, and 14) and restoration (reach 13). Indeed, the reach rated as highest for physical fish habitat among all study area reaches (reach 10) currently has a high level of protection due to the establishment of the Weyerhaeuser-McKenzie Nature Reserve on much of the south bank and conservation easements (established by the McKenzie Land Trust) on much of the north bank. The siting of riverfront homes along the edges of the McKenzie River, common upstream of the study area, is beginning to extend downstream into reaches 8-14 of the study, thereby making it more difficult to retain river characteristics that create high-quality fish habitat.

The McKenzie River downstream of Interstate 5 once had exceptional fish habitat due to its delta-like characteristics. This area has been and will continue to be mined for gravel along the boundaries of the main channel. Opportunities to restore the original geometry of the river are limited by deep gravel pits behind the confining riverside dikes. Simple solutions such as running the river through the mined-out pits are not feasible because much of the river’s gravel load would be trapped in the pits. Trapping of the gravel would rob downstream reaches of gravel replenishment. Nevertheless, there may be ways to shuttle a portion of the river (minus its gravel load) into abandoned gravel pits in a controlled fashion thereby providing unique habitat features beneficial to native fish.

Willamette River reaches 2 and 15, located immediately downstream and upstream of the McKenzie River confluence have high quality fish habitat that would be high priority for protection. Reach 15 is bordered by gravel pits and faces some of the same constraints as the lower McKenzie River reaches. However, the flood plain is wide in reach 15 and there are more opportunities for the river to meander. Reach 24 in the Middle Fork Willamette River once had some of the highest quality fish habitat in the study area and habitat quality is still above average. This reach would be high priority for restoration since its historic flood plain has yet to be developed. Re-introducing channel complexity would be most challenging in Middle Fork Willamette River reaches since it is the study area river that has suffered the greatest reduction in peak flows (a 4.5-fold decrease in the 100-year peak discharge). Nevertheless, channel features, such as alcoves, have been mechanically excavated in other reaches of the Willamette with good results. However, the cost of excavation is high and the permitting process difficult.

Upstream reservoirs are still the most powerful influence on fish habitat in rivers of the study area. Reservoirs will continue to be managed so that peak flows are dampened due to development in the historic flood plain and this will prevent the high flows needed to create channel meandering that results in sinuosity, side channels, alcoves, and bare gravel bars. The dikes and riprapped banks also contribute to a lack of river meandering. Nevertheless, in most areas, dikes and riprapped banks are not widespread. Continuing to allow site development at the edge of the river and its low flood plains will put further pressure on the Corps of Engineers to dampen peak flows at upstream reservoirs in order to minimize economic losses during high water and to approve future riprap projects to protect development from river meandering.

The edges of the rivers in the study area are more heavily vegetated than prior to reservoirs, a time when unfettered peak flows kept vegetation from establishing in a wide swath. Also, trees are much younger due to timber harvest and land clearing and exotic species of vegetation are crowding out native plants. While the heavily vegetated banks help keep the river from meandering, this also leads to declining fish habitat quality as gravels are immobilized and river complexity is reduced.

The best opportunity to improve vegetative conditions along study area rivers is to convert areas choked with exotic brush species to native trees and shrubs. Because native grass, shrub, and tree species are naturally adapted to habitats within the study area, they require less effort (E.g., less water and fertilizer) to establish and maintain and they provide habitat benefits to wildlife species that are adapted to using them for food and shelter. Unfortunately, the exotic species most prevalent are those most difficult to eliminate. Blackberry, Scotch broom, and reed canarygrass rapidly re-colonize areas that are simply cleared by grubbing. Scotch broom and reed canarygrass can be controlled by glyphosate-based herbicides, but will likely require repeated applications over a period of a decade. Blackberry requires more toxic compounds to control. Alternative techniques for blackberry and weed control, such as repeated mowing or goat grazing, have been successful but it is difficult to concurrently establish native vegetation. Planting areas with bare river deposits is not recommended since high flows will usually wash away the plants.

The option to re-establish widespread areas of bare sediments along river edges, as existed prior to dam construction, is probably not realistic. The tenacity of exotic plants and the public’s reluctance to use herbicides near water, probably precludes restoration of this important river feature.

Concerns over lawsuits have caused some towns along the Willamette River (Albany, Corvallis, Independence) to remove large native riparian trees in portions of their riverside parks. Some hold the belief that native trees, such as cottonwood, are too dangerous during wind storms and, instead of siting structures and playground equipment in open areas, have removed the trees instead. Intentional policy decisions made on tree removal in parks today can prevent haphazard and widespread tree removal in parks over the long term.

Recommendations:

1. Efforts to protect segments of the river from development would benefit fish most if focused on reaches that currently have high quality physical habitat. High quality reaches include reaches 7, 10-12, and 14 on the McKenzie River and the two reaches of the Willamette River immediately upstream and downstream of the McKenzie River confluence.

2. Efforts to restore segments of the river would benefit fish most if focused on reaches that have the largest difference between historic and current physical habitat quality <u>and</u> have no serious barriers to restoration, such as adjacent deep gravel pit mines or buildings. Such reaches include #12 and 13 on the McKenzie River and #22 and 24 of the Middle Fork Willamette River.

3. Large wood is scarce in study area rivers. The supply of large wood is limited by reservoirs and it is being removed from rivers as quickly as it enters. Increasing large wood abundance could be accomplished by encouraging the Corps of Engineers to truck wood trapped at reservoirs and put in the river downstream of the dam and by passing local ordinances that prohibit the removal of wood from rivers.

4. Riprap along river banks degrades fish habitat. About 17% of study area river banks are already riprapped. Local ordinances, along with firm enforcement, can be used to limit further expansion of riprap.

5. Peak flows are the sculptors of river channels and much fish habitat is lost when peak flows are muted by upstream reservoirs. While development along rivers prevents a return to historic peak flow regimes, some increase in peak flow magnitude and frequency is possible without flooding downstream landowners. In order to accomplish this, close coordination with the Corps of Engineers and Lane County would be needed.

6. Although tree planting is a common restoration activity, few opportunities exist for planting along study area rivers without first investing in extensive weed and brush control. These efforts need to extend beyond the time of planting in order to avoid tree mortality.

7. Riparian stands along rivers are young compared to historic conditions. Young trees provide rivers with fewer pieces of large wood than do older stands. Trees along rivers are commonly cut for improving views to the river, increasing open areas around houses, or for firewood. Local ordinances can be used to promote the growing of larger trees near rivers, especially conifer trees.

Information gaps:
None

2.2 Water types other than rivers

Deciding on terminology for defining the many non-river waterways that lace the MECT study area was difficult. Some waterway segments were named as streams yet their excavated channels and small size gave them the same appearance as drainage ditches. Furthermore, a variety of names show up on maps to describe linear water features in the study area including, channel, ditch, stream, slough, waterway, mill race, and diversion channel. What the water feature looked like did not necessarily match what is commonly ascribed to these names. Matters were simplified in this assessment by grouping water types into the following classes:

- Waterway not artificially confined; includes streams with natural channels.
- Waterway artificially confined; includes streams that have been excavated, lined with concrete, or banks consisting of fill material (other than riprap), as well as, excavated channels that do not coincide with a historic stream course.
- Sloughs; includes wide channels with standing water that were once major channels of the river, but now contain little flow during the summer.
- Mill races; includes excavated channels or partially excavated-partially natural channels that are elevated above the current river flood plain, once were used to power machinery, and have water pumped or diverted into them from the river (Springfield Mill Race and Eugene Mill Race).
- Gravel pit ponds; includes active and abandoned ponds resulting from the mining of gravel along rivers.
- Other excavated ponds; includes other excavated ponds that are not a result of gravel mining.
- Natural ponds; includes ponds that are not a result of human excavation.

Sections of waterways that have been piped or buried were not addressed in this study. Three short waterway sections within Springfield were inadvertently omitted from this survey (River Glen Channel, Sportsway Channel, Astor Channel).

2.2.1 Magnitude of peak flow increases for streams

Impervious surfaces, such as roofs, pavement, and compacted soil, can cause urbanized streams to exhibit increased peak flows. Precipitation flowing over an impervious surface is shuttled downstream more rapidly than precipitation falling on and filtering through natural soils. This results in higher peaks and a shorter runoff period.

A modeling study of six small streams in Connecticut indicated that peak flows in urban basins were 1.5 to 6.1 times greater than peak flows in rural basins for the 2-year flow and 1.1 to 4.3 times greater for the 100-year flow. The lower end of this range applied to where 30% of the basin was served by storm sewers and the higher end of this range applied to where 90% of the area was served by storm sewers (Weiss 1990).

More locally, a modeling study of small urbanized drainages that flow into Cedar Creek in Springfield showed that peak flows were 2.5 to 3 times greater than if the area was not urbanized (CH2M Hill, Inc. 1984). Estimated peak flows (100-year) using an empirical method for undeveloped drainages was compared with a recently-completed FEMA modeling effort of an urbanized watershed in Salem, Oregon. The peak flow estimates for urbanized conditions were

3-fold greater than estimates assuming the watershed was not urbanized (Andrus, unpublished data).

Both of these Springfield and Salem drainages had most of their area served by storm sewers (an estimated 60 to 90 %), but increases in their 100-year peak flows were somewhat lower than for the modeled Connecticut urban basins. Unlike the skeletal and porous soils of Connecticut, Willamette Valley soils are generally high in clay and do not readily transport water subsurface once they are wet. Therefore, even under natural conditions, Willamette Valley bottom watersheds rapidly expand their surface drainage network during heavy rains through a series of ephemeral channels. Consequently, the difference in permeability between natural conditions and paved conditions is not as great as would be expected for areas with highly porous soils.

A regression analysis of 24 monitored basins in the Portland, Oregon, and Vancouver, Washington, metropolitan area indicated that total urbanization of an undeveloped basin can increase peak discharge as much as 3.5 times and almost double the volume of storm runoff. Variation in peak flow magnitude among the 24 basins was best explained by watershed area, area of undeveloped land (parks, forests, vacant lots, and agriculture) and length of street gutters (miles/sq.mi.). Peak flow magnitude increased with the length of street gutters, but was moderated by the amount of undeveloped land (Laenen 1980).

During a previous assessment, estimates of percent impervious surface were determined for small stormwater sub-basins throughout the MECT study area (Map 13). Percent impervious surface in the most densely developed areas (downtown Eugene, Gateway area, Valley River center) ranged from 58 to 75. The middle section of Amazon Creek is heavily affected by impervious surfaces. However, we did not have resources in this assessment to assign an index to each waterway in the study area showing to what degree each reach is influenced by upstream impervious surface.

Table 17. Acres of impervious surface by major drainage basin (Map 13) by percent impervious surface class.

Drainage basin	Acres for each percent impervious surface class						
	0 to 11.5%	11.5 to 23.0%	23.0 to 32.6%	32.6 to 40.4%	40.4 to 48.5%	48.5 to 58.3%	58.3 to 75.0%
Eugene							
River Road – Santa Clara	1312	4166	632	2546	1363	302	*102*
Bethel – Danebo	2422	1816	1392	1091	1520	797	*267*
Willow Creek	1422	867	247	0	0	31	*0*
Willamette River	685	3367	121	501	411	895	*570*
Willakenzie	1599	565	821	1144	2128	812	*223*
Amazon	1237	2322	1646	2049	2845	902	*112*
Ridgeline	166	175	119	0	0	0	*0*
Laural Hill	168	309	97	78	0	0	*24*
Total Eugene acres	*9011*	*13586*	*5073*	*7409*	*8267*	*3740*	*1299*
Springfield							
North Gateway	127	591	232	123	0	128	0
West Springfield Q Street	0	00	272	195	756	654	76
Willamette River	0	0	45	373	0	0	0
Glenwood	0	0	0	735	0	0	0
Dorris Ranch	508	123	0	0	0	0	0
W. Spring. Hayden Bridge	0	658	540	404	61	0	0
Q Street Floodway	0	0	0	0	1789	502	50
Mill Race	477	343	0	41	368	16	0
Jasper	261	0	312	235	0	0	0
Jasper – Natron	1030	1328	0	87	0	0	0
South Cedar Creek	683	0	608	271	0	0	0
North Cedar Creek	1675	0	0	0	0	0	0
Weyerhaeuser outfall	0	0	487	1238	826	0	0
Total Springfield acres	*4760*	*3042*	*2496*	*3702*	*3800*	*1300*	*126*
Study area totals	*13772*	*16629*	*7569*	*11111*	*12067*	*5040*	*1425*
Study area totals; %	*21%*	*25%*	*11%*	*16%*	*18%*	*7%*	*2%*

Increases in peak flow affect fish by increasing velocity and thereby subjecting fish to involuntary downstream movement during runoff periods. Their ability to move back upstreams to their original position may be hampered by small jumps created by culverts and other instream infrastructure. It is also a large expenditure in energy for a fish to move back upstream. When fish are concentrated in downstream reaches of a watershed, food supplies can become scarce or summer water conditions may cause their demise. High-velocity water also impairs the ability of a fish to feed. Increasing water velocity usually decreases the ability of fish to hold a position in the channel and catch the drift floating downstream. The stormwater causing the increases in peak flow is typically turbid and, since most fish are sight-feeders, this decreases their ability to locate food sources.

Increases in peak flow can lead to channel incision in some soil and geology types. This has been noted for the glacial till soils in the Seattle, Washington, area. However, the slopes and soils bounding study area streams are resistant to erosion, bounded mainly by hard clay or highly weathered rock. There is no evidence of channel incision except where the channel was intentionally excavated to increase its capacity.

2.2.2 Channel characterization

During late winter and early spring of 2002, the channels of all non-river waters within the study area were characterized. Non-river waterways included mill races, natural and excavated non-river channels, natural and constructed ponds, and sloughs. In some instances where a slough appeared to function more as part of a river system than as a unique non-river channel, it was not included in the non-river data assessment. This is the case for Keizer Slough and Maple Island Slough.

About one-third of the water type reaches within the study area were surveyed in the field. Access limitations prevented the remaining two-thirds from being field surveyed. For these, aerial photos and field observations of upstream and downstream or adjacent reaches were used to assist with the characterization.

Water type reaches were assigned the channel characteristics shown in Table 18a:

Table 18a. Channel characteristics assigned to each non-river reach.

Parameter	*Classes*	*Comments*
Size	Small (< 2 cfs average annual flow) Medium (2-10 cfs average annual flow) Large (> 10 cfs average annual flow)	Using method developed by the Oregon Department of Forestry. Assigned to only waterways, mill races, and sloughs.
Channel confinement	Not confined Confined, steep hillslopes Naturally confined, high banks Channel excavated Flood plain filled Bermed	Assigned to only waterways, mill races, and sloughs.
Bank material	Natural material Fill Riprap Concrete	Each side characterized for linear water types. Perimeter characterized for ponds.
Geology	Basalt hillslope Missoula flood deposit River alluvium	

In this analysis, linear features such as waterways, mill races, and sloughs are reported in terms of length of channel. For ponds, the perimeter is reported.

The total length of artificially confined waterways in the study area was greater than the total length of waterways that were not artificially confined (Figure 13 and Map 4). Mill races and sloughs were a minor component of the total length of linear water types. The summed perimeter of all ponds was 53 miles, with about one-half being gravel pit ponds.

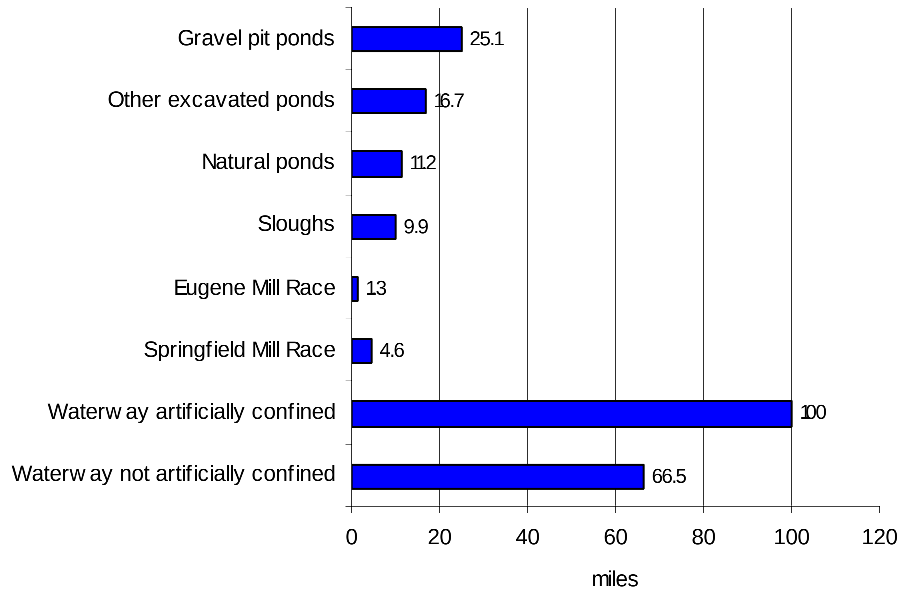


Figure 13. Lengths and perimeters of study area water types excluding rivers and their side channels and alcoves (miles).

2.2.3 Channel size

Channel size is an indicator of the amount of living space available to fish. It can also indicate whether or not the stream has water during the dry season since most small streams in the southern Willamette Valley dry up during the summer. Maps prepared by the Oregon Department of Forestry (ODF) and Oregon Department of Fish and Wildlife (ODFW), which note breaks between stream size classes based on average annual flow, were used to assign stream size to the waterway reaches examined in the study area. Average annual flow can be estimated using an empirical relationship that takes into account upstream drainage area and average annual precipitation. Since sloughs and mill races do not have defined watershed boundaries within the ODF/ODFW system and were therefore not assigned a channel size, their size class was determined by observation in the spring, a time when flows approximate average annual flow.

Nearly 80% of the length of waterway not artificially confined and 73% of the length of waterway artificially confined were in the small size class. The Springfield Mill Race was medium-sized and the Eugene Mill Race was all small-sized. Sloughs were divided among the three size classes (Figure 14). Within the Willamette Valley, most small-sized streams dry up or have water levels low enough to inhibit adult fish passage during the dry season. Therefore, asuming that most of the study area’s small streams dry up by late summer, a relatively small portion of the area’s waterways would be capable of providing year-round fish habitat.

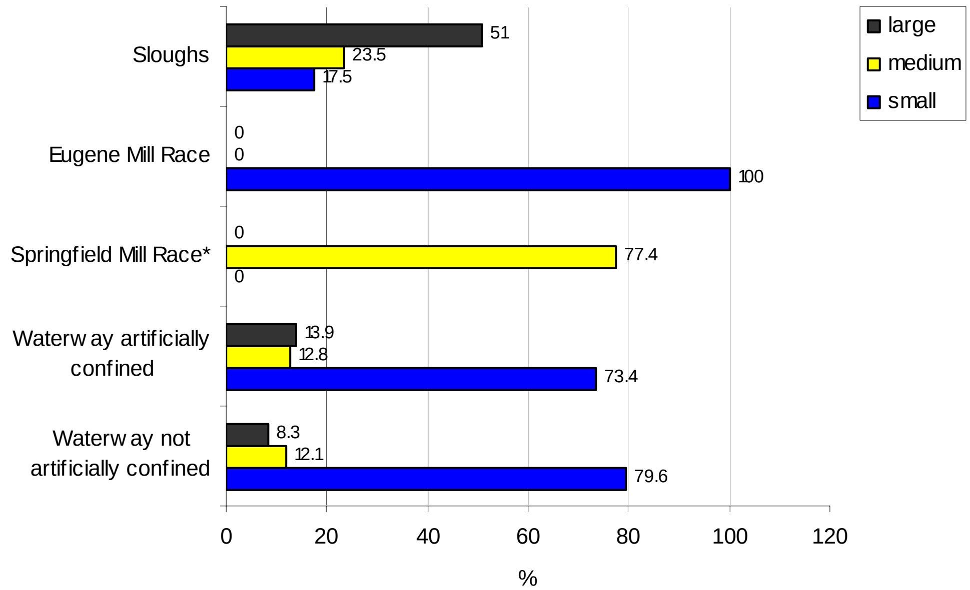


Figure 14. Channel size distribution percentages for four water types by length, excluding rivers and their side channels and alcoves. *22.6% of the length of the Springfield Mill Race is composed of the Mill Pond which was not assigned a stream size.

2.2.4 Channel confinement

Channel confinement influences a channel's connection to its floodplain. A channel reach that has been excavated deeply in order to increase its flow capacity has limited potential to interact with its floodplain. In contrast, a channel that regularly overtops its banks and meanders across the floodplain often develops features that are favorable for fish. These features include:

- Refuge and escape from high velocities
- Greater access to terrestrial food sources
- Potential for increased variety in substrate
- Side channels and alcove formation
- Capture of large wood

Artificial confinement of waterways in the study area is largely a result of excavation (Table 18b). The length of waterways lined with concrete or bordered by fill material is relatively small.

Table 18b. Length of confined waterways by type of artificial confinement. Includes streams, mill races, sloughs, ponds, gravel pits and other channels.

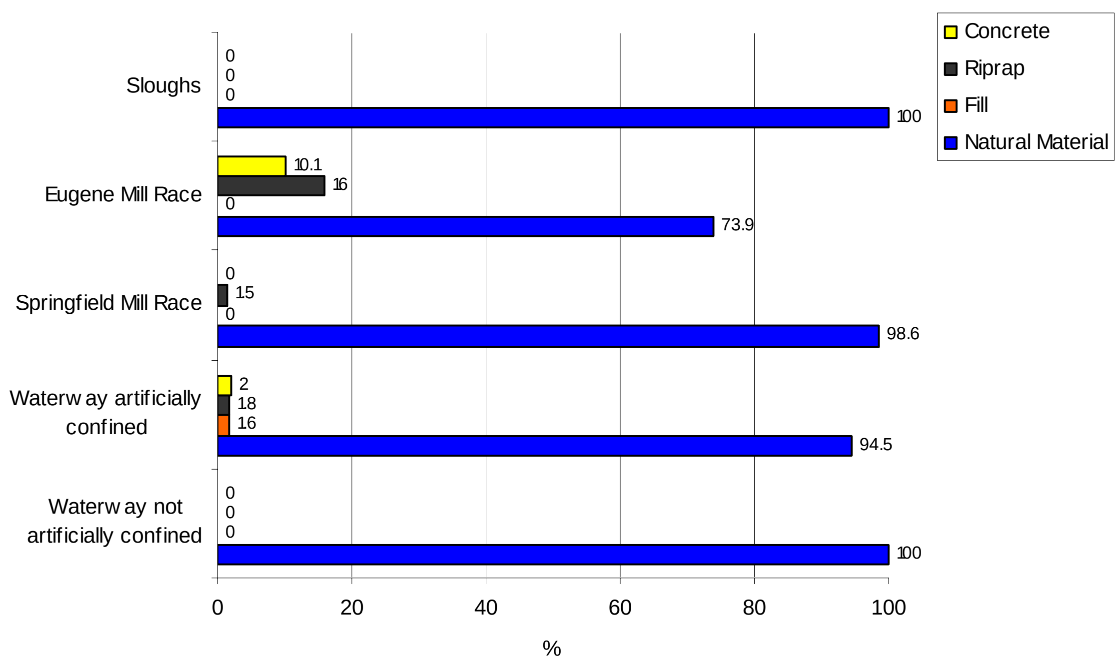
Type of artificial confinement	# miles
Excavated	106.3
Lined with concrete	3.2
Bordered by fill material	3.5

Artificially confined waterways are most common in the Amazon Creek watershed, Santa Clara area, Q-street floodway, and the North Beltline Floodway. Other major tributaries, such as Cedar Creek, Willow Creek, Pudding Creek, and Russell Creek and sloughs such as Patterson Slough, Jasper Road Slough, and Dodson Slough have mostly channels that are not artificially confined. The two mill races were created from historic natural water courses. However, whereas the upper Springfield Mill Race retains its natural confinement features, its lower half and all of the Eugene Mill Race have been excavated. The Eugene Mill Race also has a section of concrete bank confinement on it.

2.2.5 Channel bank material

The material comprising the bank of a water body can influence the quality of fish and wildlife habitat. Channels with natural material are usually convoluted with small pockets that provide slack water and niches for fish and their food supply. In contrast, channels bordered with foreign material such as fill, riprap, and concrete are not favorable habitat for fish and wildlife, although some species of fish, such as redside shiner, are attracted to riprapped banks with their many small hiding areas.

Nearly all banks in the study area consist of natural material (Figure 15, Map 6). Portions of banks along middle Amazon Creek between 24th Street and the County Fairgrounds, the Q-street floodway between 10th and 16th Street, 72nd Street Channel, and the Eugene Mill Race are lined with concrete. Mill races also have more riprap along their banks than other waterways. Overall, riprap along non-river waterways is scarce compared to the amount bordering rivers.



<u>Figure 15</u>. Bank material distribution along four water types (% of total bank length).

2.2.6 Geology

The geology over which a water course flows can influence the quality of habitat for fish and other aquatic organisms. As discussed in Section 1.1, the study area has three primary geologic formations; basalt geology, Missoula flood deposits, and river alluvium (Map 5). Stream reaches in basalt geology usually have a steeper gradient than reaches elsewhere in the study area. They will also often have a coarser substrate which promotes the colonization of aquatic insects. Furthermore, because the fractured basalt geology is capable of holding water into the dry season, these reaches tend to experience an influx of cold water during the summer.

The Missoula flood deposit geology, which sits between the basalt geology and the river alluvium, probably offers the least favorable habitat for fish and other aquatic organisms. The bank and bed material is fine-textured which limits the available habitat for aquatic insects and causes them to receive little subsurface flow during the summer.

Stream reaches in the river alluvium geology type often benefit from subsurface river flow that can supplement channel flow and provide cool water during warm summers. Since the rivers have previously scoured away the fine Missoula flood deposits, the substrate often consists of gravel and cobbles, which is favorable for aquatic insects and fish. During floods, these channels fill with river water and become zones for fish to find refuge from fast water.

Field visits of individual stream reaches to map the breaks between the three geology types. This worked well when defining the break between basalt and Missoula flood deposits. The break between Missoula flood deposits and other geologic formations was often less clear since small channels sometimes flowed across remnant patches of the Missoula flood deposits that had not been scoured away by the rivers.

We overlaid delineations from the USGS geology map with the field observations (Map 5) and found they were in general agreement. Where they differed we usually let the field observation determine the geology of the stream reach.

Most waterways flowing over basalt geology or Missoula flood deposit geology were small, while waterways flowing through river alluvium geology were divided among the three size classes (Figure 16).

While the basalt geology streams would normally have high quality habitat from fall to spring due to their gradient, substrate, and groundwater inputs, these reaches are probably intermittent during the summer. Fish inhabiting these waters in the spring need to escape downstream to larger system reaches where water is cooler and abundant year-round. Because of limited groundwater exchange in the Missoula deposit geology, cool water would more likely be found in the medium and large alluvium geology reaches or in the rivers rather than streams in the Missoula flood deposit reaches. Blockages to downstream fish movement rarely occur since fish can withstand large drops in channel elevation.

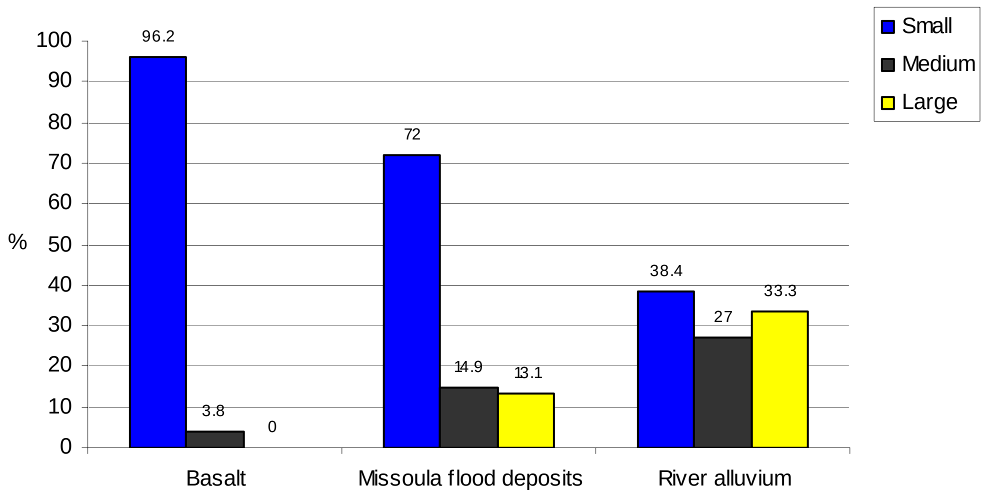


Figure 16. Geology type by stream size class (% of total length).

2.2.7 Overall physical condition of non-river waterways

We constructed a simple model of how we thought the channel characteristics discussed above relate to overall fish and macroinvertebrate habitat for waterways (Table 19a). The amount of impervious surface within each sub-watershed was also added to reflect the effects of increased peak flow and other stormwater influences on habitat (Map 13). Each parameter category was assigned a subjective position along the scale between highest habitat quality to lowest habitat quality. For example, the three geology parameters are positioned so that river alluvium provides the highest quality and Missoula flood deposits the lowest quality. The basalt geology was intermediate but more similar to the river alluvium than the Missoula flood deposits. For lack of qualitative information, we assumed that each parameter contributed equally to fish habitat quality. Other aspects of fish habitat, such as abundance of large wood, are not included in this table due to the lack of information. In general, when viewing streams in the study area, the observation is that large wood was scarce.

Reaches of waterways were searched for that had combinations of parameters which pointed towards the highest habitat quality or lowest habitat quality using Table 19a as a rule.

<u>Table 19a</u>. Highest and lowest quality habitat assignments for five parameters that define channel condition.

Parameter	***Highest habitat quality*** … ***Lowest habitat quality***
Stream size Summer Otherwise	 Medium Large Small Medium Small Large
Channel confinement	Not confined; Confined (hill slopes); Confined (high banks); Confined (fill material); Bermed; Excavated
Bank material	Natural; Fill material; Riprap; Concrete
Geology	River alluvium; Basalt geology; Missoula flood deposits
Impervious surface	0-25%; 26-45%; >45%

Pudding Creek was the only medium sized, non-confined, natural bank material, river alluvium waterway in the study area, indicating that its reaches present high quality fish habitat. When the query was expanded to include large sized waterways, Cedar Creek, the Jasper Road Slough, the canoe canal and Patterson Slough, and the confluence section of Dodson Slough with the Willamette River were also identified as having combinations of channel features that consistently pointed towards high habitat quality. Nevertheless, this ranking considers only physical habitat conditions. Water quality conditions (as discussed in the next chapter) may trump physical conditions in some of these waters.

Reaches in the upper Amazon Creek and Willow Creek basins, Russell Creek, Laurel Hill Creek, 75th Street Creek (which flows north into Gray Creek), Debrick Slough, Keizer Slough, and Thompson Slough along the Middle Fork also emerged has having the potential for high quality fish habitat when the query was expanded to include small sized streams and waterways situated on basalt geology.

Headwater reaches of Amazon and Willow Creek have high fish habitat quality characteristics. However, particularly in Amazon Creek, these reaches are isolated from the lower channel reaches by disconnected channels (piped subsurface for long distances). Efforts to improve habitat for fish in these reaches may be of low priority since fish have no way to re-populate these reaches after they dry up in the summer.

The Q Street Floodway stretch between 10th and 16th Streets and Amazon Creek between 24th Street and the County Fairgrounds exhibited the lowest quality fish habitat in the study area.

Few reaches in the study area actually are influenced by concrete banks. By adjusting the query to not select reaches with this bank characteristic, many more reaches were highlighted as having potentially low fish habitat quality based on small stream size, excavated channels, and a Missoula flood deposit geology. All the small channels in the lower Amazon Creek basin, the Santa Clara area including portions of Spring Creek and Flat Creek, Quarry Creek, the east-west portion of Gray Creek, the 69th Street Channel, SCS Channel #6, the 48th Street Channel, Gilham

Creek, the Q Street Floodway, and the North Beltline Floodway were identified as having poor fish habitat quality.

2.2.8 Piping of urban streams

Though not surveyed, it became clear from aerial photos, GIS layers, and observed stormwater pipe outlets along surveyed streams, that an important consideration in channel and riparian condition within the study area is the re-routing of headwater and mid-reach surface flow into underground pipes. A large number of channels in the headwater hills and on the valley edge have been buried and piped as the need for land to develop has increased. The surface headwater channel to mid-order channel network in Upper Amazon Creek and the South Eugene Hills area, for example, has been severely dissected (Map 7). Most of the middle channel reaches are now routed underground and emerge, often dramatically, in the lower larger streams. As development has crept farther upslope in the upper South Eugene Hills area, it is highly likely that numerous spring outlets have also been buried or interrupted.

Effectively removing mid-headwater reach channels from their surface interaction has ecologic and hydrologic consequences. Historically, these reaches were sources of large wood to the channel systems on the valley floor. This function has been eliminated, leaving valley floor streams without the structural input and ecological function that large wood contributes. From an ecological habitat perspective, headwater reaches also add nutrients, contribute bedload and sediment which replenishes lower channels, and support large communities of macroinvertebrates. These important sources that replenish and feed lower stream reaches are not available, adding to the difficulty in promoting fish habitat in lower non-river reaches.

Hydrologically, the piped channels collect and focus flow in larger volumes than might have historically been routed downstream because connections between floodplain, groundwater exchange, and transpiring vegetation have been removed. During field surveys, residents on Augusta Avenue in Eugene, north of 26th Street, recounted the extremes in flow observed from an underground piped channel that emerges at the top of their property. The pipe is a 24 inch cement round culvert and drains, according to the residents, a 250-acre area above them that has been developed over the past five years. Prior to the increase in development, the residents did not recall unusual flow emerging from the pipe. However, during recent first September/October storm events, flow emerging from the pipe filled the entire pipe and carried such force that it shot thirty feet through the air before striking a boulder revetment the residents installed downstream.

This particular instance, brought to the attention of the assessment team by chance encounter, illustrates the importance of thoroughly assessing and re-assessing impervious surface layer basin position and extent. A disconnect between watershed headwater reaches and lower reaches combined with the re-routing of flows from groundwater storage across impervious surfaces and into subsurface pipes has significant implications for downstream channel restoration and waterway maintenance efforts. Both Eugene and Springfield city planners have an opportunity to proactively address the influence and effects of future development on:

- Natural springs

- Subsurface flow interruption
- Design of channels and/or development around surface channels
- Selection of pervious surface construction materials in areas that currently serve as groundwater storage areas
- Connectivity of waterways from headwaters to river confluence

2.2.9 Channel condition summary

The channel condition of non-river waterways within the study area is, in part, a factor of underlying geology, channel size, channel confinement, and bank material. Factors such as gradient play a very minor role because, other than within the basalt geology reaches in the Upper Amazon basin or the South Eugene Hills, channel gradients are uniformly low. The geologic character of a reach and its influences on fish habitat provides a better descriptor of channel condition response.

As a determinant of fish and macroinvertebrate habitat quality, basalt and river alluvium geologies provide higher quality habitat than the Missoula flood deposit geology. Unfortunately, the waterway reaches flowing over basalt formations have been, for the most part, disconnected from the lower waterway reaches by either water quality barriers or physical barriers such as underground piping of channels and development. The reaches flowing over basalt geology are also generally small in size, further limiting their year round potential for fish habitat.

The channel reaches running over river alluvium (Map 5) offer the best potential for fish habitat in the study area. They are close to the groundwater flow influences of the river systems and their substrates provide a diverse habitat for aquatic macroinvertebrate colonization. These reaches also tend to have the greatest proportion of medium and large-sized channels which increases their ability to provide year round fish use. Unfortunately, because of peak flow moderation from the reservoirs and urban stormflow management, the length of available habitat within this scour-dependent geologic type is limited.

The Missoula flood deposit geology is the predominant geologic type in the study area and sits between the river alluvium and basalt formations. It is also the geologic type most affected by urbanization and agriculture. At one time, the Missoula flood deposit geology likely offered a rich refuge during high flows for fish; providing while flooded, slower velocities and food sources of submerged terrestrial plants and insects. As high flows receded, these rich flood deposits contributed nutrients to the stream and river systems while eroding to provide new areas of river alluvium. Currently, however, the Missoula flood deposit geology offers low quality fish habitat because its fine sediment substrates provide limited habitat potential for aquatic macroinvertebrates and it remains disconnected from its floodplain by controlled flows and management history of excavation. Though many small-sized channels cut through Missoula flood deposits, there are more medium and large-sized channels than in the basalt formation. These could, depending on many other factors, provide year round fish habitat.

Channel confinement is a defining and limiting factor in the watershed function of the study area. Artificially confined channels make up just under half of the non-river waterways and of these, over 90% are confined by excavation. As a result, approximately half of the non-river waterways are separated from their floodplains. However, because most of the non-river waterway banks within the study consist of natural materials and only small portions are currently affected by riprap or concrete, opportunities to easily reduce channel confinement are possible.

2.2.10 Riparian vegetation and land use

Riparian vegetation contributes directly and indirectly to fish habitat quality. In its various forms, riparian vegetation has the potential to:

- Moderate stream and air temperature and humidity
- Contribute detritus used by macroinvertebrates which are then incorporated into stream nutrient cycling
- Secure stream banks with roots, thereby reducing bank erosion
- Filter groundwater for pollutants
- Contribute large wood that adds to stream structure and fish habitat
- Create habitat diversity for fish, amphibians, mammals, insects, and birds

Riparian vegetation in the study area is relatively diverse. The diversity is a function of the variety of landforms and land uses found within the study area.

During late winter and early spring 2002, vegetative and land use characteristics for all waterway reaches (except river reaches) accessible from public land, roads, or private invitation were surveyed. The remaining waterway reaches were surveyed using aerial photos. Riparian vegetation by type, cover, and land use assessments made in the field were used to verify vegetation calls made on the aerial photos. Parameters and classes are shown in Table 19b.

Table 19b. Vegetation characteristics assigned to each non-river reach.

Parameter	Classes	Comments
Vegetation type	Gravel bar Grass/weeds Ornamental landscape / mowed lawn Blackberry, reed canarygrass, or other aggressive exotics Short native deciduous species, brush Hardwoods <40 years old Hardwoods >40 years old Conifers <40 years old Conifers >40 years Crops (grass seed most common) Orchards (filberts most common) None-soil None-paved lot or road None-gravel lot or road None-buildings	Vegetation growing within 50 feet of water's edge for waterways and 100 feet for rivers and ponds. Each side of a reach is inventoried separately. An included vegetation type must occupy at least 25% of the area, as viewed from the air so up to four vegetation types were allowed per reach per bank.
Vegetative cover	0-33% 34-66% 67-100%	Percent vegetative cover over water
Land use	Residential yards Roads / railroad Buildings Industrial Public park, open space Other undeveloped, urban Gravel extraction Agriculture Forestry Other undeveloped, rural Parking lots Golf course	Determined for each side of the reach. This is the actual use not the zoned use.

Riparian vegetation

Grass and weeds was the most common riparian vegetation class along non-river waters (Figure 17). The community structure of this class is similar to the wet seasonal prairie that historically occupied hydric areas next to waterways. However, the species composition between the two differs significantly. Much of the current grass community is comprised of reed canary grass (*Phalaris arundinacea*), an invasive exotic that colonizes rapidly and competes against native grass species or mowed introduced grass species.

Some current urban vegetation management practices may encourage the persistence of grass and weeds while discouraging the growth of native species, especially shrubs and trees such as willow, cottonwood, bigleaf maple and alder. Amazon Creek riparian vegetation, for example, is managed by mowing the upper banks and bank tops (Guay et.al. 2000). Channels and ditches flowing alongside roads, parks, and residential or commercial lots are commonly managed by mowing or other control measures for safety, aesthetic, or pest control reasons.

The most common overstory vegetation class is hardwood trees younger than 40 years (Figure 17). Based on field survey observation, Oregon ash, cottonwood, and red and white alder make up most of this vegetation class along with non-native trees planted in residential areas.

Native and exotic shrubs make up the second most frequently observed riparian vegetation class (V2) in the study area. This might be expected because shrubs can be present in the understory of hardwood riparian habitats and as the overstory in communities with no tree overstory. The most common native shrub species are willow species, rose, and snowberry. The most common exotic shrub species are Armenian blackberry and Scotch broom. In exotic shrub communities, Armenian blackberry often form extensive monocultures where few other plants survive under its dense clumps. The reproductive strategies of Armenian blackberry include extensive seed dispersal via wildlife and aggressive runner growth. These allow it to rapidly increase its coverage and prevent easy eradication.

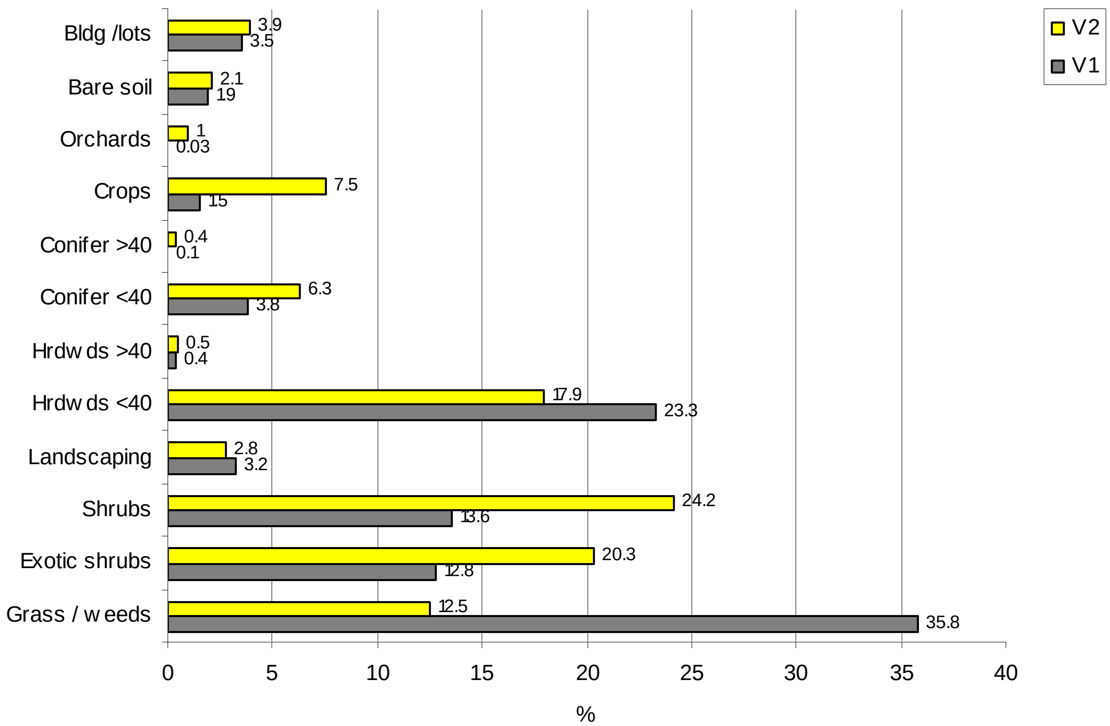


Figure 17. V1 (most common) and V2 (second most common) vegetation classes along study area waterways (% of bank miles).

Predominant vegetation class is not the sole indicator of riparian function or health. Associations of a vegetation classes observed together often more clearly describe how a riparian community could be managed and what its successional path might be. For example, a hardwood dominated riparian stand with an exotic shrub understory might require a different management approach than a hardwood-dominated riparian stand with either a conifer association or a native shrub understory given the same management objectives.

Of the four major vegetation classes, shrubs and young hardwoods and grass/weeds and exotic shrubs were most often associated with each other (Table 20). That is, if one was dominant, it was likely the other was co-dominant. Grass/weeds, exotic shrubs, and native shrubs were more likely to have bare soil, buildings, or gravel/paved lots next to them than young hardwoods. Shrubs were associated with grass/weeds and, particularly, exotic shrubs. Young riparian hardwood stands were the only vegetation class to be associated with a young conifer component. Young hardwood stands were least likely to have bare soil, buildings, or gravel/paved lots next to them.

Table 20. Dominant and associated co-dominant riparian vegetation (%) for water types other than rivers.

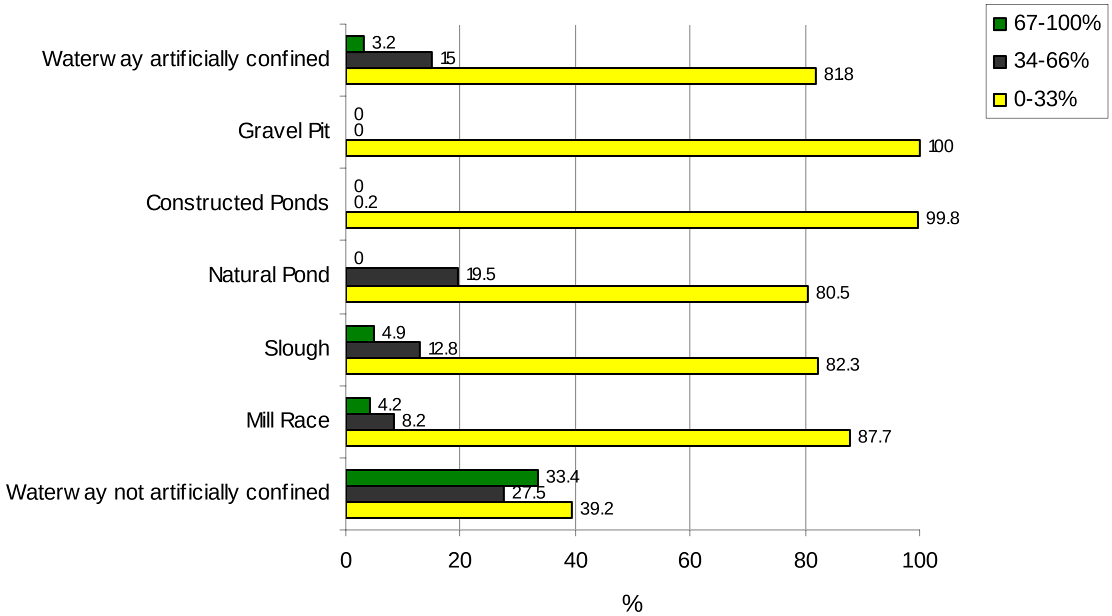
Co-dominant vegetation (V2)	***Dominant vegetation (V1)***			
	Grass/weeds	Exotic shrubs	Shrubs	Young hardwoods
Grass/weeds	-	35.5	12.4	6.6
Exotic shrubs	29.8	-	17.4	9.3
Shrubs	11.5	38.2	-	37.2
Young hardwoods	13.2	11.3	36.5	-
Young conifer	1.1	1.3	0.5	18.0
Orchards/crops	11.6	0.3	11.1	7.6
Bare soil/bldgs	6.79	6.87	6.54	0.36

Exotic plant species are ubiquitous throughout the study area. Of all the surveyed riparian channel reaches, 40.3% (134.7 miles) contain grass/weeds and 31.3% (104.5 miles) contain exotic shrubs as at least 25% of their cover. Often these communities are highly invasive and difficult to eradicate. The grass/weed category was most often a measure of reed canary grass cover. In addition to reed canary grass, other common invasive species in the study area are Armenian blackberry, purple loosestrife (*Lythrum salicaria*), roughstalk bluegrass (*Poa trivialis*), nipplewort (*Lapsana communis*), and English ivy (*Hedera helix*) (Titus et. al. 1996). Additional invasive species that are relatively new to riparian communities in the Willamette Valley, but should be watched and managed for, include butterfly bush (*Buddleia* ssp.) and Japanese knotweed (*Polygonum cuspidatum*). For a complete list of invasive species compiled by the Native Plant Society of Oregon for Lane County, see their Emerald Chapter website at http://www.emeraldnpso.org/inv_ornmtls.html.

Canopy channel cover

Percent canopy channel cover can offer insight into both the vertical structure of the riparian community and the exposure of the waterway to solar radiation inputs which causes increases in water temperature. Over 70% of non-river reaches had less than 33% cover. Only 13% of study area non-river reaches had greater than 67% cover. Waterways not artificially excavated have the highest percentage of heavily shaded reaches and the most balanced distribution of cover (Figure 18).

Natural ponds, constructed ponds, and gravel pits have large areas of surface water that riparian vegetation on their borders cannot shade. Cover percentages will naturally be lower on these systems. Natural ponds did have slightly more cover than constructed ponds.



<u>Figure 18</u>. Canopy cover class for the various water types (% of length).

Waterways that were artificially confined, sloughs or natural ponds, rarely had much overhead cover. Though they are similar to waterways that are not artificially confined, their management and associated land uses tend to be different. They tend to be next to roads or other developed areas and are managed to convey water during the rainy season.

Adjacent land use

Despite the urban focus of the assessment and urbanization's influences on many of the study area waterways, more channel miles are bordered by agriculture than any other land use (Figure 19). Other land uses that affected more than 10% of total bank length were residential, undeveloped urban, and undeveloped rural (Figure 19, Map 8). The majority of waterway banks in the study area (58%) are bordered by land uses that are not associated with development (public land/parks, undeveloped urban, agriculture, forestry, and undeveloped rural).

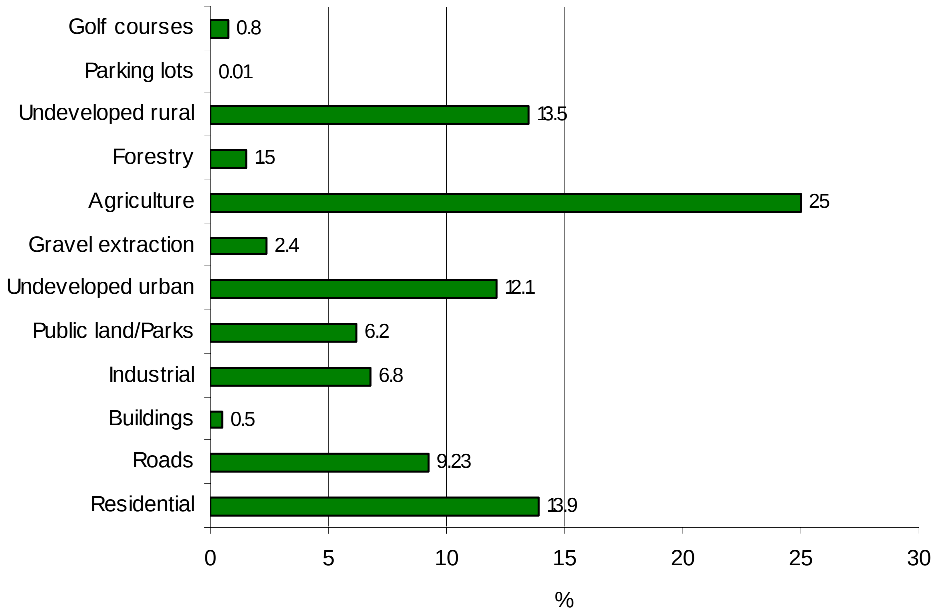


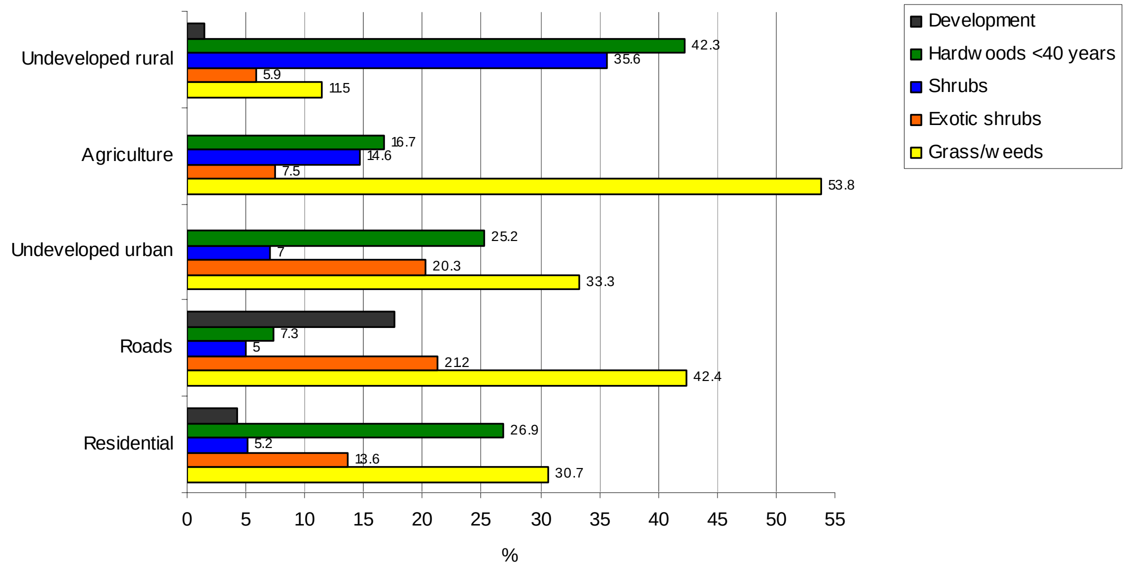
Figure 19. Dominant land use categories adjacent to study area waterways (% of bank length).

Certain riparian vegetation types are commonly associated with specific land uses along waterways. Figure 20 illustrates the primary vegetation types found in or next to each of the seven major land use categories along study area waterways. The criteria for selecting a "primary" vegetation class was that it had to be present along at least 15% of one (not all) major land use category.

In the undeveloped rural areas, hardwoods form the dominant riparian vegetation type. The emerging pattern of grass/weeds being less prevalent in this area, while hardwoods and shrubs are more dominant, illustrates a shift from historic vegetation patterns. This shift is likely a result of the absence of fire and the introduction of successfully adapted species.

Grass is the most common riparian vegetation type for residential areas, roads, undeveloped urban areas, and agriculture (grass seed fields were counted as agriculture). Riparian areas next to roads and agriculture fields will likely always associate with a high amount of grass because of safety considerations and crop selection. However, there may be flexibility in residential and undeveloped urban spaces to diversify this riparian vegetation community. Community education and action efforts would be drivers for this change.

Residential, undeveloped urban, and undeveloped rural land uses adjacent to waterways have the highest percentages of young hardwoods among all land use categories. As expected, grass/weeds are common in all the land use categories. Interestingly, however, this grass/weed community is lowest along undeveloped rural waterways where lack of management might be assumed to encourage its development.



<u>Figure 20</u>. Riparian vegetation classes associated with seven major land uses adjacent to study area waterways (% of total length).

2.2.11 Riparian conditions by water feature

Based on the general data interpretation completed above, certain patterns in riparian vegetation, channel form, and potential fish habitat begin to emerge. Though interesting and useful in describing the study area as a whole, summaries of study area riparian areas generated from lumping data into gross categories do not move managers much closer to understanding their management area or developing useful action plans. To bring the summaries closer to an on-the-ground assessment level, riparian focus areas were created by:

1. Identifying distinct breaks in vegetation, geology, and/or channel type and
2. Overlaying these either within a stormwater drainage area boundary or joining together a number of stormwater drainage areas that encompass homogenous water types.

The following riparian vegetation summaries for non-river riparian focus areas provide an appropriate level of riparian detail for an analysis unguided by specific action plan questions. MECT members are encouraged to query the GIS and field assessment database with specific questions for channel- and/or street-specific information. The collected information is structured to facilitate doing so easily.

Amazon, Willow and Russell Creek headwaters

This focus area encompasses the headwater channels within the:

- Willow Creek basin down to the confluence with Amazon Creek (WC on Map 14)
- Upper Amazon Creek basin down to Snell Street
- Russell Creek down to the I-5 crossing (southern-most portion of WR on Map 14)

Channels within these headwater areas with basalt geology are almost entirely designated as "waterway not artificially confined." There are some reaches confined by excavation on Willow Creek within the channel paralleling and just south of 20th Street, from 20th to the confluence, and on a portion of the east fork near the beginning of Gimple Hill Road and on Amazon Creek by Willamette Street and below Martin Street. There is only one observed pond in the Amazon Creek headwaters. It is a spring-fed pond located on a slump in the hillside. Because there are reportedly many springs in the area, more such ponds may exist. Three ponds were observed in the Willow Creek area. Large constructed ponds are found in the Russell Creek area near Lane Community College.

Most adjacent land use in this area consists of parks and other public open spaces, undeveloped urban land, and residences. Public parks and open spaces are primarily along Willow Creek and portions of Amazon Creek. Residences are located primarily along the disconnected channels in the middle headwater reaches of Amazon and Russell Creeks. Development often includes routing creeks, especially smaller ones, subsurface through pipes which break up the channel system. Undeveloped urban land exists primarily in the upper South Eugene Hills and Russell Creek area. However, during the field assessment, new and clearly planned development for this area was observed. It will likely soon transition to residential land use.

Riparian vegetation in this area consists predominantly of an overstory community of hardwood and conifer trees younger than 40 years. Reaches in the lower end of Willow Creek and the riparian area surrounding the ponds at Lane Community College are bordered by a grass/weed community. Grass and weeds also exist as the second most common vegetation type on portions of Willow Creek. There is little to no ornamental landscaping or exotic shrubs within the riparian areas in this region. A small area of exotic shrubs borders the stretch of upper Amazon Creek near Willamette Street where it is also confined by excavation. Exotic shrubs are associated with grass/weed communities around the ponds near the Lane Community College and near the portion of Willow Creek flowing beside Willow Creek Lane.

This predominance of overstory riparian vegetation contributes to the high shading levels observed within these upper reaches; the highest in the study area (Map 9). These upper reaches have consistently greater than 33% vegetative cover over their entire lengths until the waterways leave the basalt geology and transition to Missoula Flood deposit geology and increased urbanization.

Were downstream channel conditions adequate to provide fish an unstressful conduit to these headwater reaches, these reaches would have a high potential to provide good fish habitat, even seasonally, as in Willow Creek. Unfortunately, conditions lower in the basin almost completely prevent this area from being considered viable as fish habitat. It is, however, an important area in terms of nutrient and macroinvertebrate productivity and groundwater storage. The relatively complex communities of riparian area vegetation provide channels with a variety of inputs including wood, detritus, bank stability, and shading.

Lower Amazon Creek basin

Once Amazon Creek leaves the headwater reaches, its channel condition becomes fairly homogeneous throughout the rest of the study area until it passes into the West Eugene Wetlands. As a result, we set the upper boundary for the “Lower” Amazon Creek focus area at Snell Street. From here it extends downstream to the study edge boundary. It incorporates all of the Amazon (AM) and Bethel-Danebo (BD) stormwater drainage basins on Map 14. Below Snell Street, waterways making up the Lower Amazon Creek basin are confined. Most channel reaches within the West Eugene Wetlands project have been unconfined so that they can reconnect during high flows with the wetland. Reaches within the West Eugene Wetlands near the edges of the project near roads are confined by channel berming, however, to prevent flooding. Quite a few constructed and natural ponds exist in the center portion of this area

Land use adjacent to the channels in this riparian focus area transitions from primarily parks and public open spaces in the Amazon Park area to industrial near 11th Street, back to a combination of public open spaces near the West Eugene wetlands and then out to agricultural uses at the edge of the study area boundary. Scattered within these dominant land use types are residential yards near 18th Street in Eugene and the Roosevelt Channel and Marshal Ditch. Undeveloped urban land is often located next to the multiple disconnected channels in the center of the focus area between Seneca and Bertelsen Roads.

Descending from the headwater focus area on Amazon Creek, riparian vegetation consists of a transitioning community of hardwoods, mowed grass, and exotic shrubs. At 24th Street, the riparian vegetation is replaced by a cement channel covered by invasive ivies and other exotics. Beginning just west of the County Fairgrounds, the predominant riparian vegetation type becomes grass and weeds, often associated with exotic shrubs as channels spread out toward the study area boundary. Reaches along the West Eugene wetlands, the Amazon Creek Diversion Channel, Beltline Road, the A2 Channel, and the Roosevelt Channel are all surrounded by grass. Historically, this area consisted of wet seasonal and dry prairie vegetation. Grass communities along channels are natural features, though the association with exotic shrubs and the lack of seasonal flooding to encourage more wet-tolerant species is not part of the historic vegetation condition. A young hardwood community is present along the Marshal Ditch. New riparian plantings have gone in alongside the creek widening project near Acorn Street Bridge. However, those currently are not affecting the channel.

As a result of limited overstory species within the riparian community, the Lower Amazon Creek basin has very few reaches with vegetative cover greater than 33%. Reaches that do have greater than 33% cover exist along the Marshal Ditch, where hardwood vegetation was observed, and along isolated reaches in the area between Beltline and Bertelsen and near Royal Street.

The Lower Amazon focus area has been heavily influenced by past flood management actions. Excavation has both created channels where they might not have existed and separated these channels from riparian resources. Development and other land uses have further altered the riparian vegetative community. Nutria are quite abundant along reaches of Amazon Creek which will increase the difficulty of successfully growing shrubs and hardwoods to improve stream shading or water quality. Large projects, such as the West Eugene Wetlands, are likely having somewhat of an effect on local and downstream water quality. The potential beneficial effects of smaller projects, such as the stream widening project near Acorn Bridge, may, unfortunately, be overwhelmed by the overall detrimental water quality inputs and habitat influences contributed by adjacent land uses and engineered channel features.

Santa Clara area

This area includes all of the River Road-Santa Clara (RS) stormwater drainage basin on Map 14. Almost all of the waterways within the Santa Clara area, including the A-1 Channel and the waterways around the airport, are confined. Reaches around the airport are confined by channel berming while the remaining reaches are confined by excavation. Reaches near the northern edge of the study area boundary in the East Santa Clara Waterway and Spring Creek and a few channels running through the agricultural land in the northwest and between 99W N and River Road are unexcavated. Natural and constructed ponds are found in the central industrial area between the NW Expressway and 99W and then out along the western and northern edge of the study area boundary.

The Santa Clara area channels are predominantly surrounded by agriculture. Spring Creek and Flat Creek are closely surrounded by residential land use. Road curvature within housing developments off River Road even mimics the sinuousity of Spring Creek as it winds through one of the larger subdivisions. A small block of undeveloped urban land and industry border channels located below Beltline Road and in between the NW Expressway and 99W.

Likely a result of its high agricultural component, the most common riparian vegetation type in the Santa Clara area is grass and weeds, particularly on the western side of the focus area between the study area boundary and the NW Expressway. Channels in this area run through historically dry or seasonal wet prairies. Hardwoods and other taller overstory species would not be expected. However, as land use transitions from agriculture to residential toward the central and east side of the focus area, grass dominated riparian areas begin to co-exist more often with a dense community of exotic shrubs, such as Armenian blackberry. This vegetation association is not typical of the historic vegetation in the area. In the undeveloped urban area between the NW Expressway and 99W, exotic shrubs also make up the most common riparian vegetation.

Hardwoods younger than 40 years start to form a more important part of the riparian community along reaches of Flat Creek, Spring Creek, and the East Santa Clara Waterway. These areas also contain more ornamental landscaping within the riparian area because of high residential densities.

Shaded reaches exist in segments of Spring Creek and Flat Creek where hardwood trees and shrubs are more common. However, because of the predominance of the grass/weed community in the riparian areas in this area, more than half of the reaches have less than 33% vegetative cover.

The Santa Clara area is basically divided between agricultural and residential areas. Though agricultural channels might have the potential to regain some of their natural flow-controlled processes, they are often ditched and their floodplains tiled. Riparian vegetation is closely managed and limited in size. Channels flowing through dense residential areas are closely confined by back yards and streets and have very little room to move. They are also heavily influenced by stormwater drainage and nonpoint source pollutants contributed by overland flow. This area has limited potential for healthy fish habitat without significant education and channel restoration efforts.

Cedar Creek area

The Cedar Creek riparian assessment area includes the North Cedar Creek (NCC), Weyerhaeuser Outfall (WO), and South Cedar Creek (SCC) stormwater drainage basins on Map 14. All of Cedar Creek is made up of unexcavated channel reaches except for the section within the Weyerhaeuser Outfall. Channels surrounding the 48th Street Channel and Gray Creek are also confined by excavation. A large area of constructed ponds exists as part of the Weyerhaeuser Outfall between Keizer Slough and Cedar Creek.

Land use adjacent to Cedar Creek is primarily agriculture for almost all of its length within the study area. Small reach segments of undeveloped rural land are present beginning at both lower confluences with the McKenzie River, then again significantly just west of 69th Street and then along Thurston Road. Residential land use is common along short reaches of Cedar Creek and along the 48th Street Channel and channels bordering Weyerhaeuser Road (48th Street Channels), 69th Street and 72nd Street.

The most common vegetation classes along Cedar Creek are hardwoods younger than 40 years, shrubs, and grass/weeds. Hardwoods and shrubs are found along most reaches of Cedar Creek. Grass and weeds were observed on channel segments between 69th Street and Weaver Road, along Thurston Road and just south of Thurston Road near 72nd. Grass is also located near the 48th Street Channel. Conifers younger than 40 years are found along reaches near Thurston Road. Exotic vegetation is a primary riparian vegetation class along a small reach of the 48th and Highbanks Channel adjacent to I-105 to the north of a small portion of G Street and the west of 52nd Street. The second most common vegetation type along this particular reach is conifers younger than 40 years. There are also a few isolated reaches with crops and one with an orchard as the primary riparian vegetation type.

Most of the reaches in this focus area have less than 33% cover over them. In particular, a long reach of Cedar Creek around the first lower confluence with the McKenzie River, the 48th Street Channel, and channels along I-105, 68th and 71st Streets have low vegetative cover. However, the predominance of young hardwoods and shrubs as riparian vegetation does create reaches, especially in upper Cedar Creek, with greater than 33% cover. Very few reaches have more than 67% cover.

The Cedar Creek area contains potential for restoration, prevention, and conservation. Residential influences, particularly with current sewage management systems, have the potential to detrimentally affect the excavated channels that flow through neighborhoods and drain into Cedar Creek. Cedar Creek, with its surrounding agricultural land use, has both the potential to experience negative influences such as nonpoint source pollutants, ditching, and tiling as well as the potential for riparian vegetation management and restoration and for providing the creek room to move to respond to flow processes. The influence of the nearby McKenzie River cannot be underestimated. Groundwater exchange between the two systems is likely quite prevalent and the potential for fish use from the McKenzie is obvious. Riparian vegetation and water quality should be managed with fish habitat parameters in mind in most decisions relating to this area.

Willakenzie

The Willakenzie area is a fragmented area from the perspective of its non-river waterways and their riparian function and interaction. This region encompasses the Willakenzie (WK) stormwater drainage basin on Map 14. Channels within this area are primarily excavated and disconnected from each other except for the major floodways. This area contains constructed ponds and abandoned and active gravel mining pits primarily along its western border.

This area contains a wide variety of land uses. Roads influence the North Beltline Floodway, Q Street Floodway and channels associated with Debrick Slough. Industry abuts portions of the Q Street Floodway north of Patterson Slough and the Canoe Canal and channels associated with Debrick Slough just west of the Delta Highway. Residential land use borders channels coming off the northwest side of Debrick Slough, by Green Acres Road, and north of Cal Young Road. A golf course north of 105 with some channel influence also defines this focus area.

Associated with the wide range of land uses are a diversity of riparian vegetation types discontinuously scattered throughout. The most common vegetation type is exotic shrubs. Reaches where this vegetation type is predominant exist along the North Beltline Floodway, the Q Street Floodway, and near the Delta Highway. Ornamental vegetation used in landscaping is also a common dominant riparian vegetation class. These vegetation classes are associated with residential areas and the golf course. Young hardwoods and shrubs exist in isolated channel reaches along Debrick Slough, the North Beltline Floodway and the Q Street Floodway as second most common vegetation types. Young hardwoods are far less common as the dominant riparian vegetation class along channels in this area. Grass and weeds are also not often the predominant vegetation type.

Many of the fragmented channels, the Q Street Floodway and the western portions of North Beltline going into Dodson Slough have less than 33% cover. The eastern portion of the North Beltline Floodway, fragmented channels in the center of the area, and the confluence channel of Debrick Slough with the Willamette River have between 33% and 67% cover. Some of that cover is provided by dense exotic shrubs rather than a tree overstory. The north/south oriented reaches of Gilham Creek have greater than 33% cover. A center section has greater than 67% cover on this creek.

Bordered on two sides by the Willamette River and the McKenzie River and containing a number of sloughs, the Willakenzie area has the potential to offer off-channel fish habitat for species using the Willamette and McKenzie Rivers. To maintain and/or create clean, healthy water and potential habitat for these fish, riparian areas along channeled waterways could be managed for communities that include a diverse overstory and understory of native plants. Historically, this area likely consisted of a mix of gallery ash forests and upland and wet seasonal prairie (Map 3). Managing for riparian vegetation communities that mimic these characteristics in the appropriate areas (i.e., gallery forests, or at least overstory older hardwoods, alongside the larger rivers) would be an excellent goal for this diverse, multiple land use influenced area.

Q-Street Floodways

This region includes the West Springfield Q Street (WSQ) and Q Street Floodway (QSF) stormwater drainage basins on Map 14. Channels within this area are all confined by excavation. The area contains three constructed ponds in the northeast corner of the area just south of the Irving Slough.

Roads are the predominant land use within riparian areas in this focus area. Channels abut most of Q Street and along Interstate 5. Industry affects channels north of Highway 126 that flow into Irving Slough and channels between 28th Street, Olympic, and Highway 126. Residential land use borders the Q Street Floodway and SCS Channel #6 in the western half of this focus area. There is a very small area of park and public open space adjacent to the Q Street Floodway between Pioneer Parkway and 5th Street. There is no agricultural land use and very little undeveloped rural or urban riparian land.

The Q Street Floodway and the SCS Channel #6 are almost entirely bordered on at least one bank by riparian vegetation consisting of grass and weeds with a subdominant community of exotic shrubs. One reach of the Q Street Floodway has no riparian vegetation and consists of a paved road. Exotic vegetation makes up at least one bank's primary riparian vegetation from Pioneer Parkway to Interstate 5. The channel extending north along Interstate 5 (I-5 Gateway Channel) toward the North Beltline Floodway has shrubs along it. Only a single small reach on Marcola Road just south of its junction with 42nd Street contains a riparian stand with young hardwoods as the most common vegetation type. Young hardwoods make up a secondary riparian vegetation class along channels running into Irving Slough and near the 105/I-5 interchange.

The entire length of the Q Street Floodway within this area has less than 33% cover over it. Many reaches along the North Beltline Floodway also have less than 33% cover as do channels feeding into Irving Slough. The only channel reach to have greater than 33% cover is the curved reach adjacent to the 105/I-5 interchange. This cover is provided by a shrub community with some associated grass and young hardwoods.

Though relatively disconnected from rivers, the channels within this area do feed into the Willamette River and various sloughs that link to the major rivers. Water quality maintenance is a concern. Because of the structure of the channels, the lack of a diverse riparian vegetation community, and the associated land uses, it is unlikely that either the Q Street or North Beltline Floodways would be capable of supporting viable salmonid populations. However, these channels can contribute to the habitat quality of the rivers by providing clean, cool water. Conducting riparian plantings alongside the channels would help reduce stream temperature, reduce overland flow, and increase the filtering of the water entering the channels. Plantings on these stable excavated channels are typically successful because the potential for erosion is minimal. Nutria populations should be examined when planning riparian plantings.

Pudding Creek

Pudding Creek is a fairly simple creek as described by the parameters measured in this assessment. Because of its fairly unmanaged condition and relatively short length within the study area, its characteristics are quite uniform along its entire length. All of Pudding Creek consists of unexcavated channel reaches. Near its confluence with the Middle Fork of the Willamette, there are two large gravel pits. The dominant vegetation class along its length is hardwoods younger than 40 years. The lower reaches have shrubs as the second most common vegetation type and the upper half has conifers younger than 40 as the second most common vegetation class. Despite the association with common overstory vegetation types, Pudding Creek has less than 33% shading over its entire length. The entire length of Pudding Creek is bordered by undeveloped rural land uses.

Pudding Creek offers some of the healthiest fish habitat characteristics of the tributaries in the study area. Because it feeds directly into the Middle Fork of the Willamette River, it should be considered as a source of potential tributary habitat during high flows or for juvenile salmon. If riparian vegetation remains relatively stable and is allowed to mature, this tributary should remain an excellent source of viable habitat.

Springfield Mill Race

The upper portion of the Mill Race, after it enters in from the Middle Fork of the Willamette River, is surrounded by undeveloped rural land. This characteristic persists until 28th Street. After this point, industry dominates along the lower half as it flows along the southern edge of Springfield and then joins with the Willamette River.

Very little of the Mill Race is dominated by exotic vegetation. However, the lower reaches in particular are heavily influenced by surrounding industrial land uses and the city of Springfield. Riparian conditions in these lower reaches consist of pavement, buildings, and gravel lots with some young hardwood trees and shrubs. A long stretch of the Mill Race just above the Mill Pond is bordered by gravel lots. This area coincides with the mills and other industry in the area. The Mill Pond is surrounded by a combination of riparian conditions including bare soil, shrubs, and some young hardwoods.

Almost all the upper portion of the Mill Race riparian vegetation consists of a young hardwood overstory with a native shrub understory. This portion of the Mill Race retains its natural slough character in terms of the interaction between the channel and the riparian vegetation. Despite the predominance of hardwoods in the upper portion of the Mill Race, its entire length has less than 33% cover over it and so water is expected to be warm during the summer. Part of this low cover level may be due to its width and the young age of the hardwoods. Older trees would provide a larger canopy cover.

Eugene Mill Race

Despite its industrial history, today almost all the Eugene Mill Race is surrounded by public parks on at least one side. The exception is a stretch of the Mill Race downstream of Franklin Park that is bordered by industrial buildings on both sides of the channel.

The Mill Race is bordered by shrub vegetation for approximately half of its length in a series of separated reaches. The riparian area of the reach upstream of Agate Street is bordered by industry, pavement, and buildings. The riparian vegetation in the upper reach near Franklin Park consists of young hardwood trees.

More than half of the Mill Race has less than 33% cover. These reaches are found in the lower half, particularly where the channel widens into a small pond. Above these reaches, approximate cover is less than 67% except for the small reach near the upper inlet where cover is greater than 67%. This reach is narrow and coincides with the hardwood riparian vegetation.

Water quality and flow is quite limited as a result of historical management practices and the condition of the inlet on the Willamette River. In addition, the outlet of the Mill Race flows underground through a pipe and, therefore, does not permit fish passage.

Patterson Slough and the Canoe Canal

Land use next to the western portion of Patterson Slough and the Canoe Canal is primarily public land and parks. The north flowing branch of Patterson Slough is bordered by undeveloped urban land.

Riparian vegetation along Patterson Slough is a mix of young and older hardwoods. Older hardwoods (>40 years) exist at the end of the northward extending channel of the slough. Younger hardwoods (<40 years) make up the southern part of that channel. Both young and older stands have native shrubs as their understory community. The riparian vegetation community of the western channel of Patterson Slough and the Canoe Canal is predominantly grass and shrubs. Exotic vegetation makes up very little of this focus area.

The slough and the Canoe Canal have less than 33% cover over their entire lengths.

Jasper Road, Oxley, and Berkshire Slough

Jasper Road Slough lies between the Middle Fork of the Willamette River (to the west) and Jasper Road (to the east). Its confluence lies almost directly under the power lines that cross over the Middle Fork. Oxley and Berkshire Sloughs flow into the Coast Fork of the Willamette River west of I-5 and outside the original study area boundaries near Seavey Loop.

A large portion of land adjacent to these sloughs is rural and undeveloped. Remaining adjacent land use is agricultural. A small portion of Jasper Road Slough parallel to Jasper Road is used as park and other public land as is a small portion of Oxley Slough next to the abandoned gravel pit near its confluence with the Coast Fork.

Most of the riparian vegetation on Jasper and Berkshire Slough is young hardwoods interspersed with shrubs in both the understory and as the predominant vegetation in openings between hardwood stands. Grass and shrubs make up the main vegetation types on Oxley Slough. There is very little exotic vegetation in any of these sloughs.

Cover is predominantly less than 33% on all the sloughs except for areas next to Jasper Road on Jasper Slough and next to the abandoned gravel pit on Oxley Slough. In these areas, cover is mostly less than 67% with small areas of greater than 67%.

Maple Island, Keizer, and Irving Sloughs

Maple Island, Keizer, and Irving Sloughs are sloughs off the McKenzie River. Because of the methodology used to collect data for the non-river riparian field assessment, riparian vegetation data was collected for Irving Slough and the ponds in Keizer Slough. The remaining channels in Keizer Slough and Maple Island were not assessed with the non-river channel methodology since they are immediate side channels of the river.

Irving Slough sits along High Banks Road west of the McKenzie River past Highway 126 and northwest of Marcola Road. The excavated ponds in the Keizer Slough sit at the bend in the Keizer Slough south of Highway 126 and northeast of High Banks Road. Land use around these excavated ponds is undeveloped rural as is land adjacent to Irving Slough northwest of Marcola Road. The portion of Irving Slough that sits along High Banks Road and up to Marcola Road is bordered by industrial land uses. The far upper reaches of this slough are affected by residential land uses.

Riparian vegetation surrounding the excavated ponds consists of shrubs. Shrubs also line the undeveloped rural portions of Irving Slough. Exotic shrubs are not found around Keizer Slough's ponds. However, exotic shrubs are the dominant vegetation along the portions of Irving Slough south of Marcola Road. Where exotic shrubs fall out, the riparian areas in these reaches consist of paved industrial lots. Just northwest of Marcola Road on Irving Slough, the riparian area consists of young hardwoods. Further up in the residential area, riparian vegetation is made up of grass.

Cover around the excavated ponds on Keizer Slough and along most of Irving Slough is less than 33%. The small areas bordered by hardwood trees on Irving Slough have cover levels less than 67%.

Irving Slough appears relatively disconnected from the McKenzie River both geographically and as a result of the heavy industrial land uses along its lower portions. The portions of this slough which would contribute adequate fish habitat sit above these industrial influences and are further removed from the McKenzie River by the slough's northwest orientation. Because Keizer slough channels connecting the excavated ponds to the slough and the McKenzie River were not examined, the role of these ponds in providing fish refuge and habitat remains unclear. However, adjacent land uses do not indicate significant potential effects to pond condition and, riparian vegetation appears healthy. These ponds could provide adequate habitat if they are linked to the McKenzie River via a healthy channel system.

2.2.12 Conclusions, recommended actions, and information gaps for non-river waters

Riparian areas alongside non-river waters in the study area, as a whole, are composed of a relatively diverse but young vegetation community. The type of vegetation next to a particular waterway appears to be a function of the adjacent land use, management actions associated with the land use, and, less commonly, the historical vegetation type common to the area.

Grass/weeds and exotic shrubs represent a large component of non-river channel riparian vegetation. The grass/weed community is similar in form and function to the historic upland prairie vegetation type, but the species composition between current and historical grass communities is quite different. In addition, channel processes, such as flooding, deposition, and erosion, affecting current and historic prairie-type riparian areas differ greatly.

Hardwood tree species and shrubs are also common alongside study area channels. However, these species are almost entirely younger than 40 years old, often mixed with non-native ornamental species, and do not extend for significant distances from the channel border. Their shading and large wood contribution levels are limited.

Social and cultural factors within the urban environment, such as safety, aesthetics, and limited resources encourage the persistence of non-native grass and weeds over native grasses, perennials, shrubs and trees. Within the Eugene and Springfield study area, the influence of these factors are apparent in the existing riparian vegetation composition along most non-river waterways. Amazon Creek riparian vegetation, for example, is managed by mowing the upper banks and bank tops within the public park areas (Guay et.al. 2000). During the field assessment, mowing was observed along the Q Street Floodway as well. Though mowing can be used as a management tool for some native prairie species, in this park setting, regular mowing does not allow for the development of native grass seed heads and tends to create a homogenous plant community. Throughout the study area, channels and ditches flowing alongside roads, parks, and residential or commercial lots are commonly managed by mowing or other control measures for traffic visibility, lawns or ordered landscapes, or to control pests such as rodents.

In addition, resource constraints may limit proactive management with native plant restoration projects along waterways in undeveloped urban or industrial areas. With abundant exotic reproductive sources nearby (e.g., seeds, rhizomes), not actively managing urban riparian areas facilitates the introduction and persistence of exotic species such as Armenian blackberry and reed canary grass.

Other than a few exceptions, current non-river channel riparian areas do not appear to have the necessary characteristics that allow them to interact with waterways in ways that encourage healthy fish habitat. Limiting factors are abundance of exotics, young plant age, limited width, and basin hydrology and channel form management practices. We would suggest that immediate efforts be focused on areas where exceptions to these factors exist, such as on Cedar Creek, Pudding Creek, and slough reaches.

Recommendations:

In order to increase the productive interaction of the study area's riparian vegetation with waterways that will promote fish habitat either locally or in reaches downstream, the following suggested general activities are proposed:

1. In order to increase the age diversity of overstory species, allow young hardwood stands to mature. This will increase the likelihood of improving riparian function in terms of shade, large woody debris inputs, and wildlife habitat.

2. Because native grass, shrub, and tree species grow well within the study area, focus on using native plants in revegetation efforts and, as much as possible, on management strategies that mimic historic habitat conditions that supported these plants through flooding.

3. Because an important concern is to offer as much potential habitat to salmonids as possible, focus monitoring, naturalization of flow regimes, and water quality clean-up efforts on channels which currently have the greatest potential to provide salmonid habitat. These are typically unexcavated channels that are closest to the larger rivers. These include, in order of importance:

- Cedar Creek
- Pudding Creek
- Maple Island and Keizer Slough
- Patterson Slough
- Jasper Road, Oxley, and Berkshire Slough

If restoration monies become available, certain channels within the study area would appear to respond more quickly and with greater habitat results than others. Channels that may be suitable for restoration efforts include:

- Springfield Mill Race
- Lower reaches of Willow Creek

4. Natural and constructed ponds that might be suitable for Chinook rearing and the habitat needs of other native fish will be those that are adjacent to the larger rivers or that are closely connected with non-river channels with beneficial habitat conditions. These ponds exist near or are associated with sloughs. Patterson Slough, Keizer Slough, and Oxley Slough all contain such ponds.

5. Peak flow increases due to urbanization cause fish to be displaced in the high-velocity water. Such peak flow increases can be tempered by including well-designed retention basins during initial development and by widening previously-channelized stream channels through

excavation.

Information gaps:
None

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.

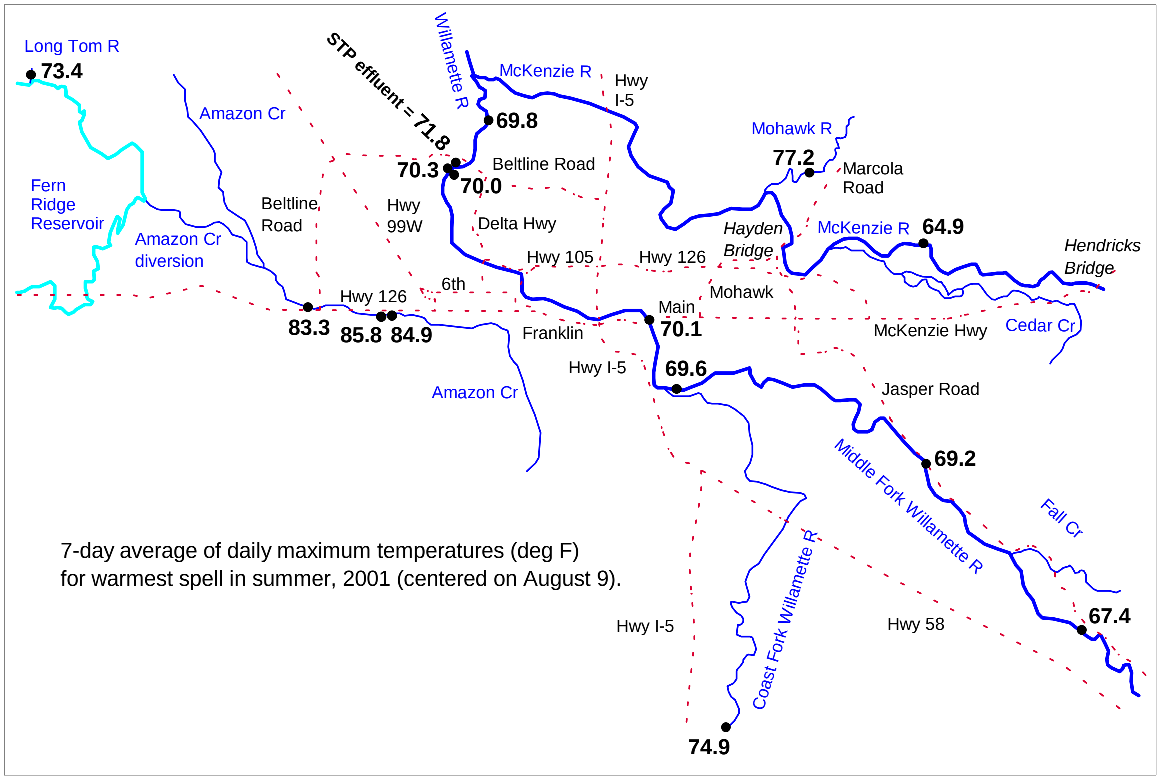
Oil and grease in stormwater discharges is dependent on the magnitude of the rainfall event and the intervening period between events. The quantity of oil and grease in stormwater discharge is also dependent on the area of impervious surface exposed to vehicles and machinery, and the amount of biofiltration/remediation 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.



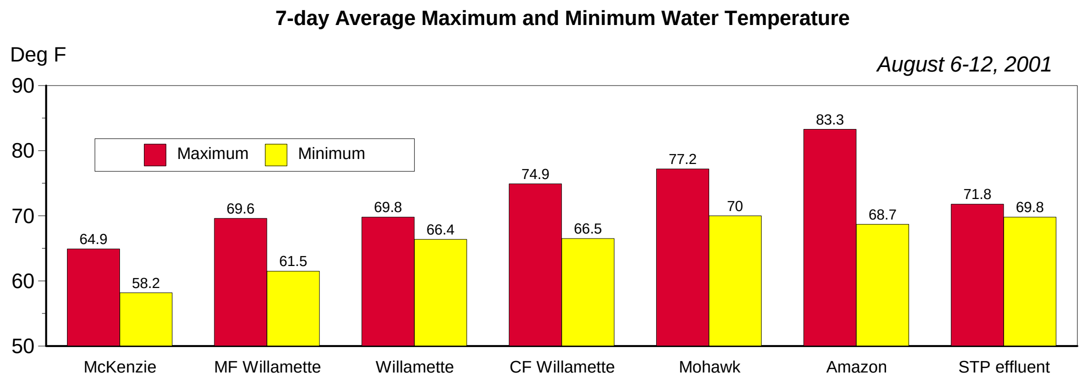
<u>Figure 21.</u> The 7-day average of daily maximum temperatures (˚F) for the warmest spell in summer, 2001 for sites within and around the MECT study area. Sources of data include monitoring conducted by U.S. Geological Service, City of Eugene, and Long Tom Watershed Council. WPCF effluent means wastewater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



<u>Figure 22</u>. **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.

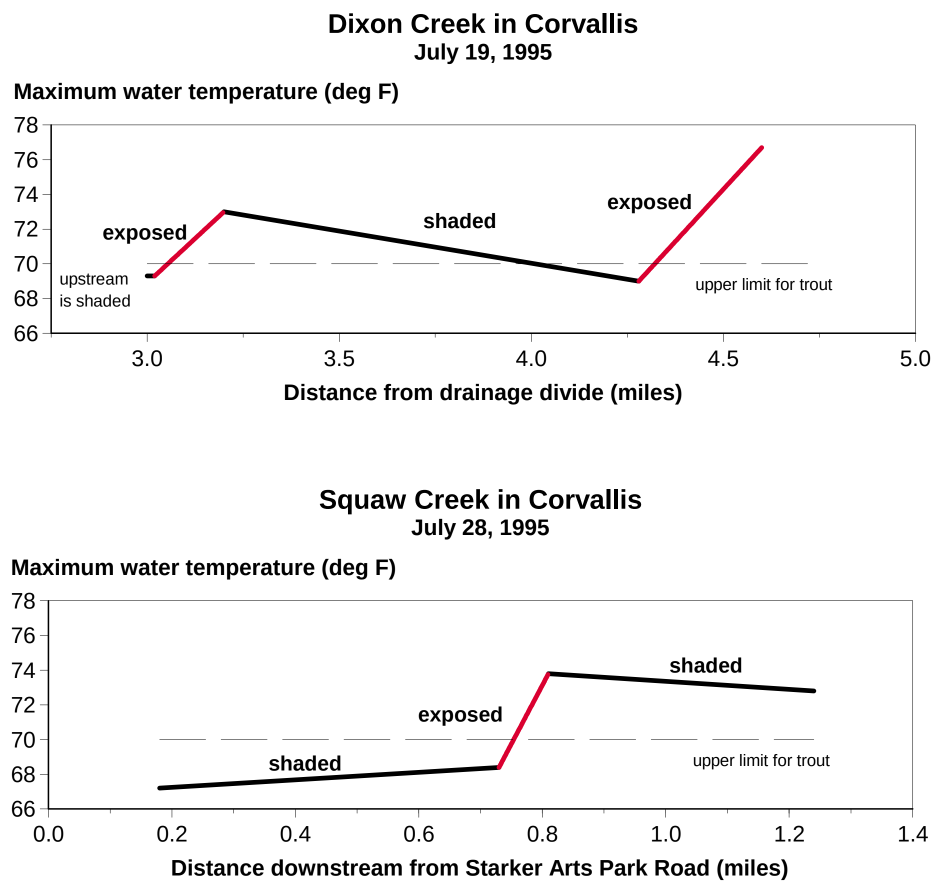


Figure 23. Daily maximum water temperature for two urban streams in Corvallis, Oregon. Data were collected for the Benton County Soil and Water Conservation District in 1995 by C. Andrus. Water warmed in exposed reaches cooled in downstream shaded reaches.

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 3° 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.

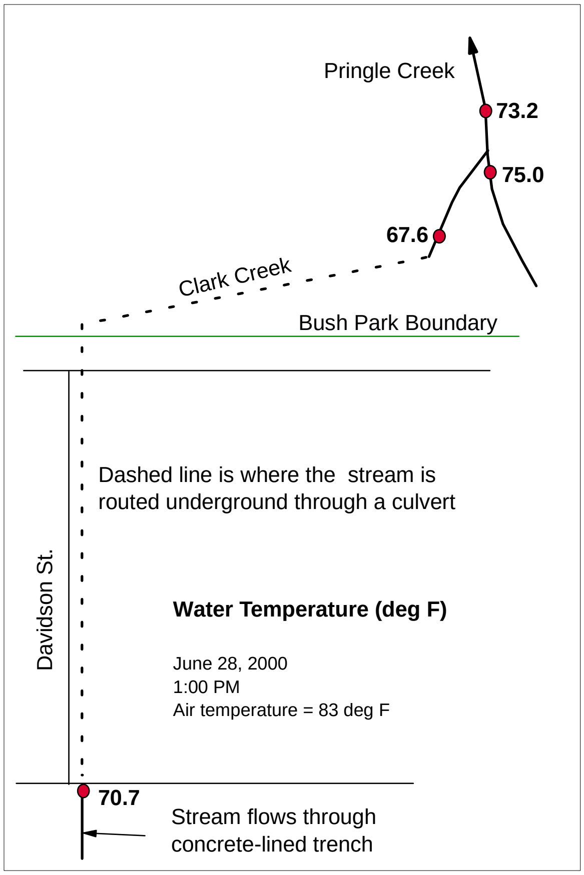


Figure 24. Example for Clark Creek in Salem, an urban stream that cooled when routed underground for a distance. Data were collected for Oregon Watersheds in 2000 by C. Andrus.

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.

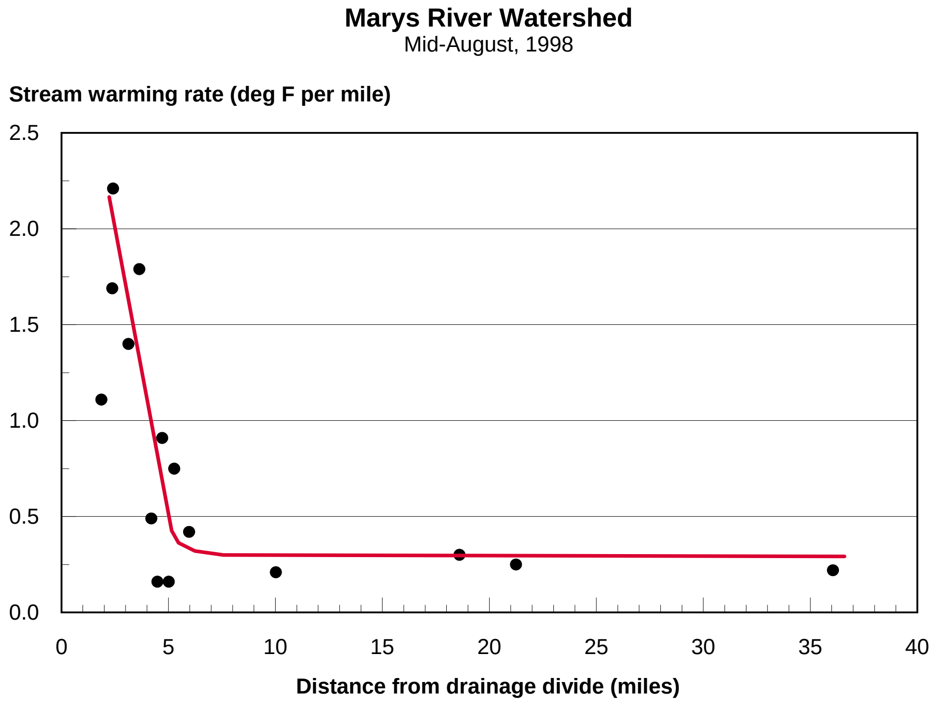


Figure 25. Stream warming rates for streams in the Mary's River Watershed in 1998. Warming rates were highest in reaches closest to the drainage divide and then fell to a low background rate further downstream.

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.

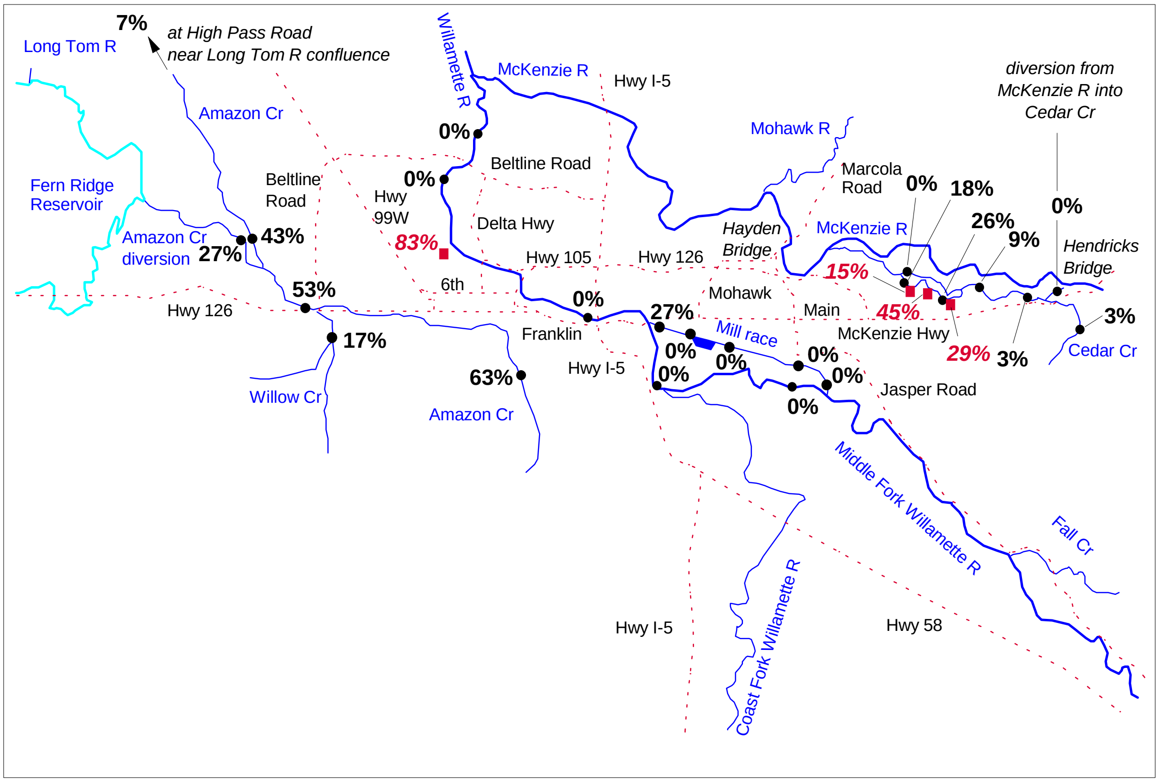
In a study conducted by the University of Washington on a Seattle, Washington, creek in 2000, a wide range of *E. coli* sources were identified. Researches found that about 32% of *E. coli* detected in the creek originated from birds, 20% from dogs, 11% from rodents, and about 3% from human sources (Samadpour, 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.

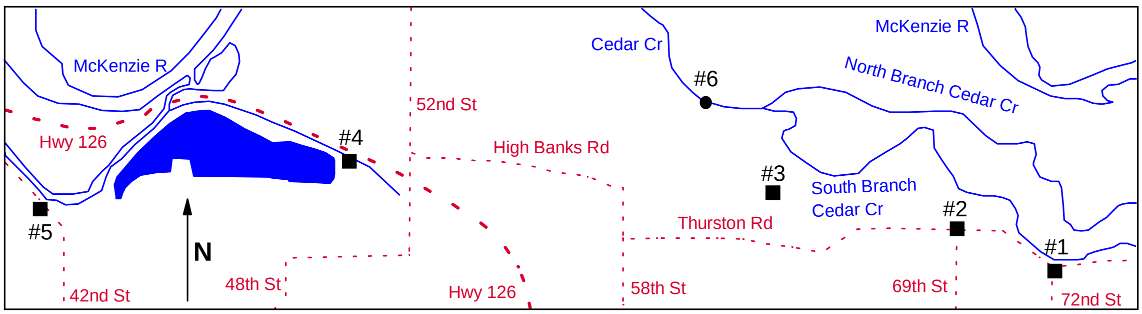


Figure 27. Sites for long-term monitoring in and near the City of Springfield. Squares indicate stormwater sites and circles indicate stream sites. Site #1 is the 72nd Street stormwater site, #2 is the 69th Street stormwater site, #3 is the 64th Street stormwater site, #4 is the 52nd Street stormwater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

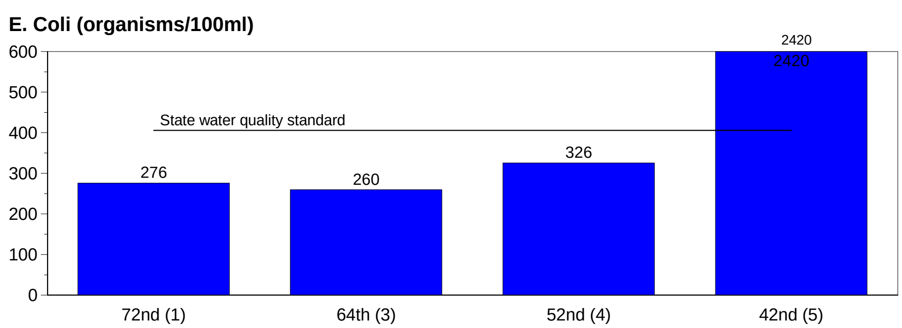


Figure 28. *E. coli* concentrations for 5 stormwater sites in Cedar Creek (downstream of 3 stormwater outfalls) for a storm in early March, 2002. The results are for composite samples taken throughout the storm.

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.

Table 20a. 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

$\mu^{\wedge}$: Mean corrected for censored data
$\sigma^{\wedge}$: 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.

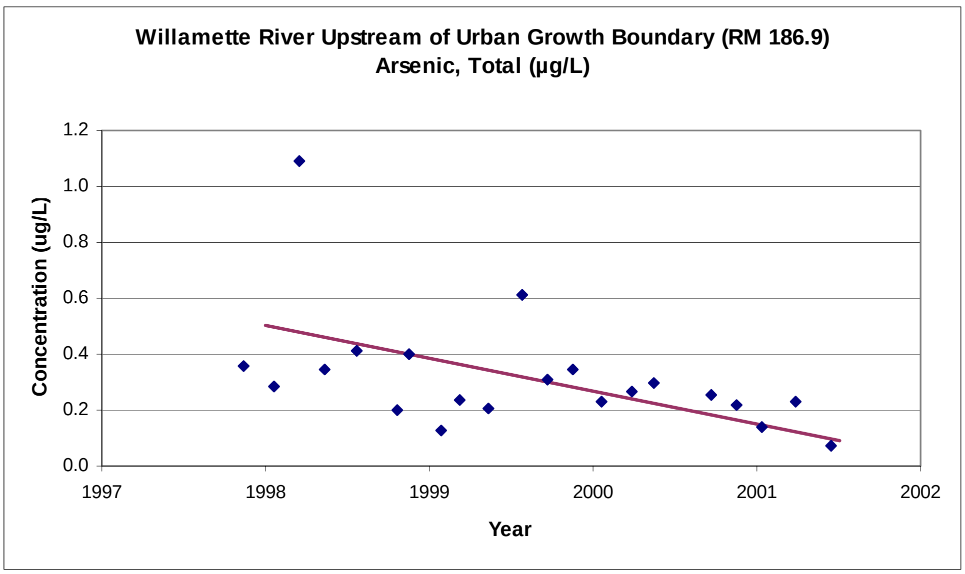
The Oregon Health Division has issued a health advisory for mercury in fish for the Willamette River, recommending that people restrict their diets to the values shown in Table 21c.

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.



<u>Figure 29.</u> 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.

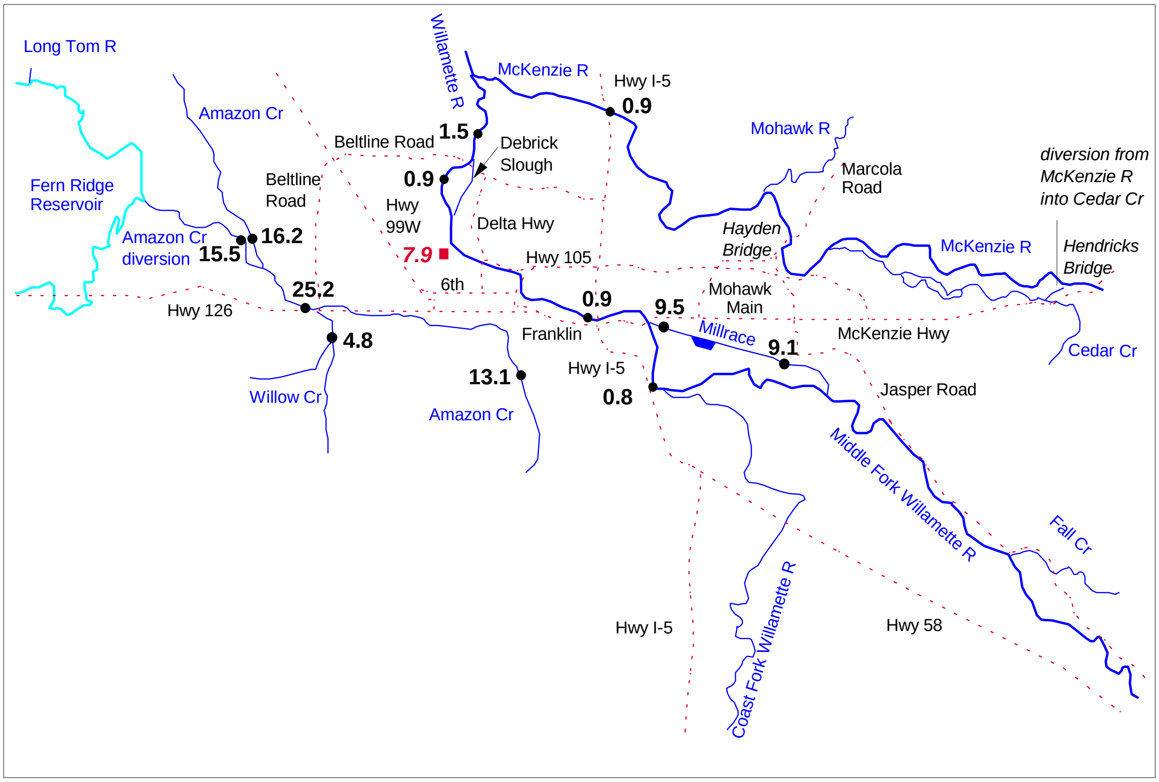


Figure 30. Median values for total zinc concentration (µg/L). Streams or rivers are shown as circles and stormwater drains are shown as red squares and red labeling. Sources of data include the City of Eugene and Student Research Project, Springfield.

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

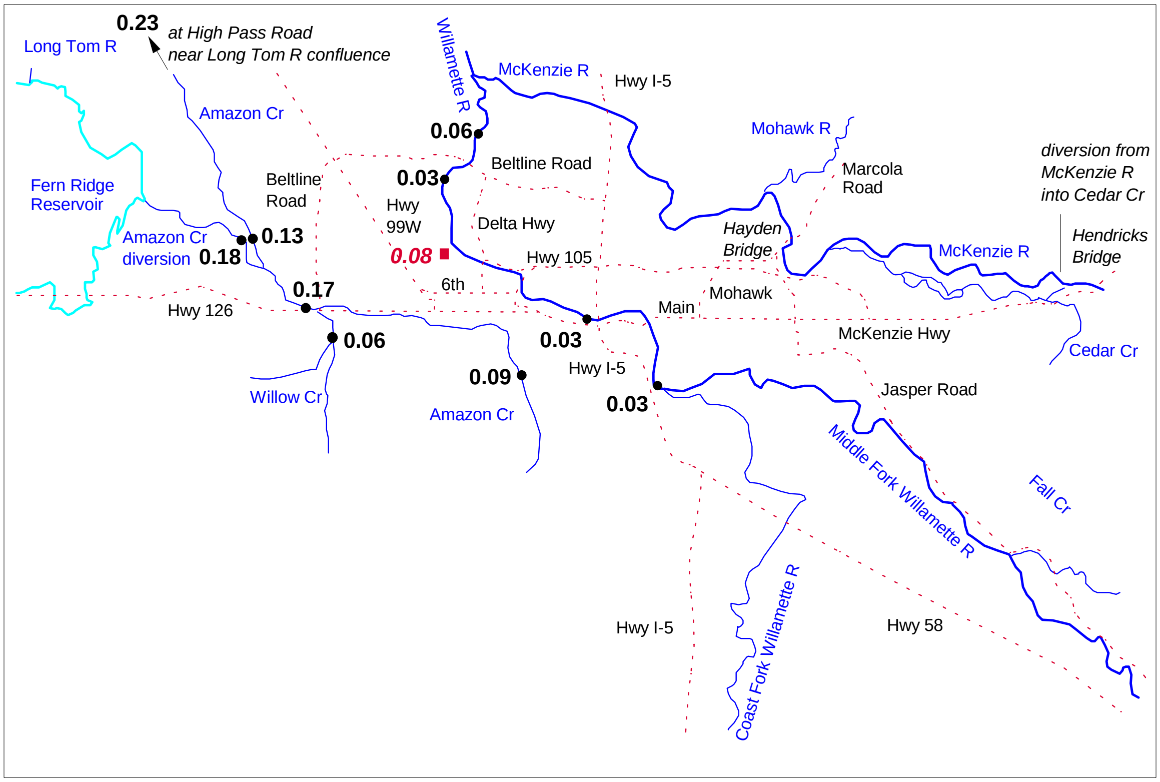
Given the median concentrations for nitrogen and phosphorus in Amazon Creek, a prevalence of suspended and attached algae in the water column would be expected. High algae concentrations combined with high water temperature leads to wide diurnal swings in dissolved oxygen whereby the water column becomes 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.

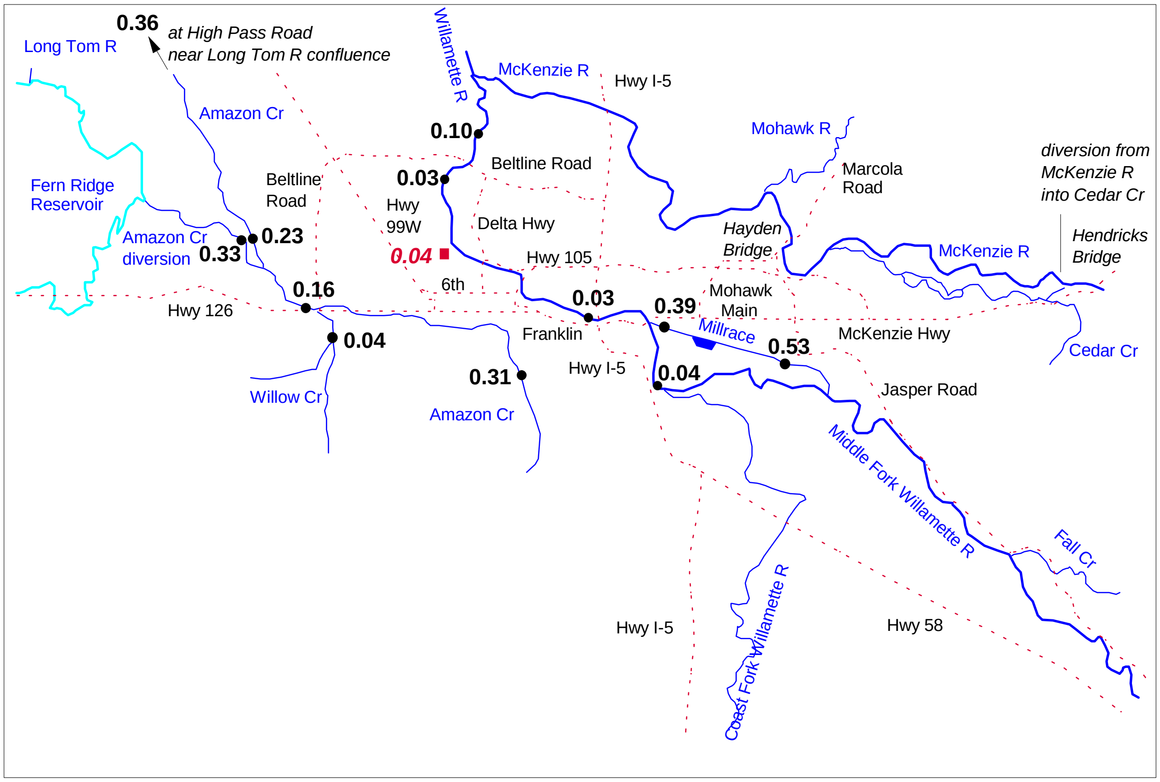
The City of Eugene evaluated historical data for the Amazon basin sites utilizing the Mann-Whitney statistic to determine whether analyte concentration differences exist between upstream and downstream locations from an enhanced wetland area.

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.

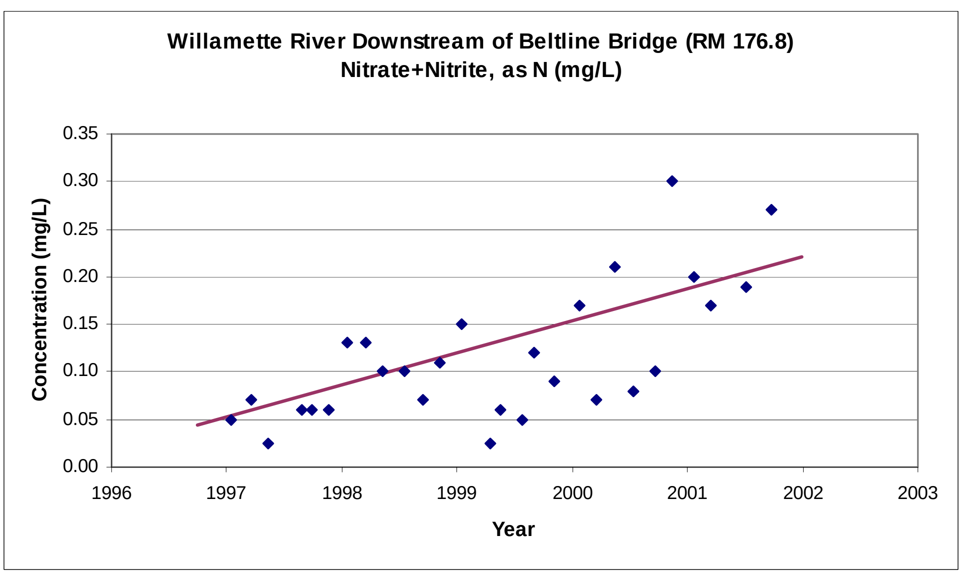
Results of the statistical analysis for the railroad crossing and diversion channel sites suggest total Kjeldahl nitrogen (TKN; inorganic and organic nitrogen) and total phosphorus are significantly different (at $\alpha = 0.05$). On average, the downstream TKN concentration is slightly higher than the 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.



<u>Figure 31</u>. 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.



<u>Figure 32</u>. 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.



<u>Figure 33.</u> 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.

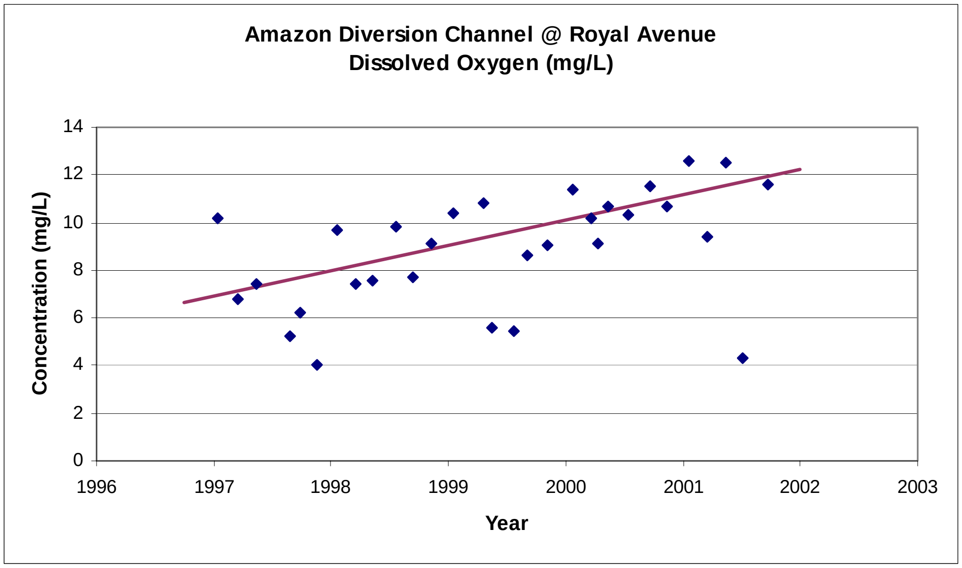
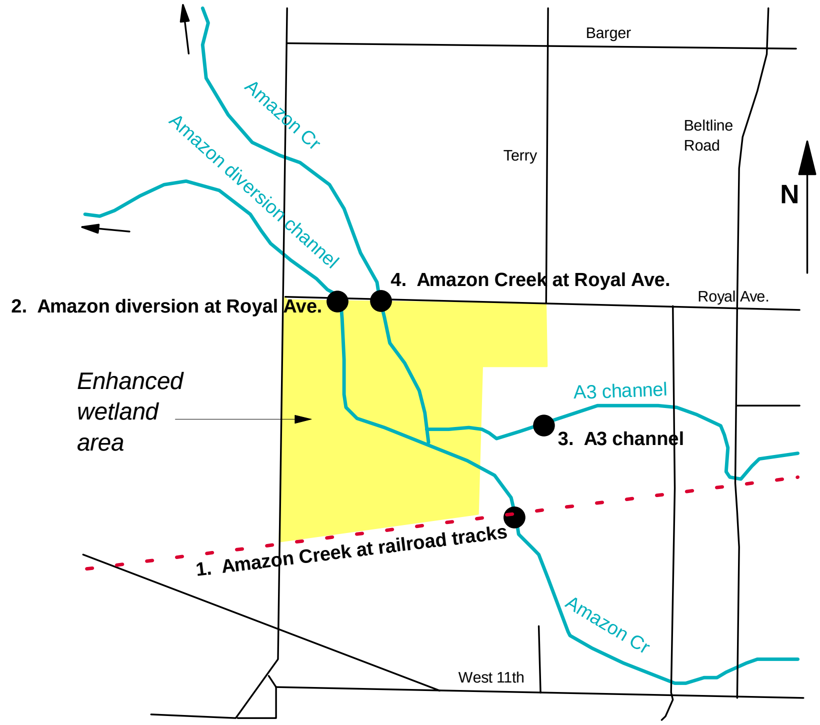


Figure 34. Long-term trend of dissolved oxygen in Amazon Diversion Channel at Royal Avenue downstream of the enhanced wetland area. From the City of Eugene NPDES Annual Stormwater Report, November 2000-November 2001.

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 90^{th} 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/29^{th} 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/29^{th} Avenue site.

Table 21j. 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 α = 0.05 level.

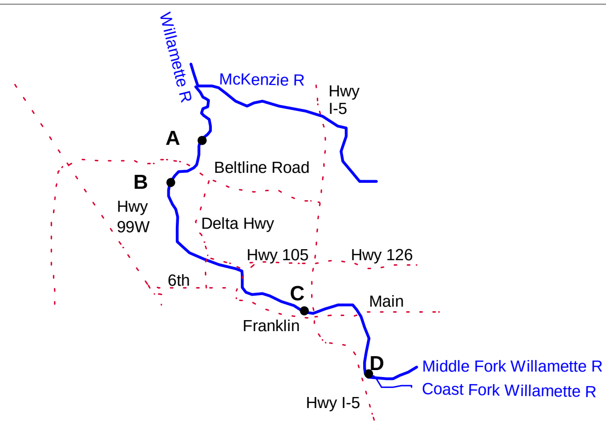
<u>Table 21k.</u> Comparison of average historical concentrations for Amazon Creek basin sites for only those analytes that are statistically different from each other*. From the City of Eugene NPDES Annual Stormwater Report, November 2000-November 2001, for period from 1997 to 2001.

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.

4. Aquatic Organisms

4.1 Fish

Communities of fishes differ among main channels of rivers, off-channel features of rivers, ponds, and streams in the study area, with each water feature providing a unique combination of water temperature, food, cover, and water velocity. Furthermore, fish assemblages change with the seasons and are influenced by the presence of hatchery fish, fishing pressure, and fishing regulations and their enforcement. The seasonal connection of a water body with a main river will also dictate fish community structure and survival of individual species, especially over the summer.

Water bodies within the study area support 24 native and 11 introduced species or stocks of fish (Table 22). Three species are federally listed under the Endangered Species Act, including spring Chinook salmon (Threatened), Oregon chub (Endangered), and bull trout (Threatened). Among the five native species of salmonids (Chinook salmon, cutthroat trout, rainbow trout, mountain whitefish, and bull trout) using water bodies in the study area, all are common except for bull trout. These listed fish species, along with cutthroat and rainbow trout, are considered key species in the future management of rivers and streams in the study area . Their life histories are summarized below.

Table 22. The 24 native and 11 introduced species or stocks of fish found in streams, rivers, and ponds of the MECT study area.

Family	Native	Introduced
Salmonidae	Spring Chinook salmon	
Salmonidae	Cutthroat trout	
Salmonidae	Resident rainbow trout	Hatchery rainbow trout
Salmonidae		Hatchery steelhead trout
Salmonidae	Bull trout	
Salmonidae	Mountain whitefish	
Catostomidae	Largescale sucker	
Catostomidae	Mountain sucker	
Cyprinidae	Redside shiner	
Cyprinidae	Chiselmouth	
Cyprinidae	Peamouth	
Cyprinidae	Northern pikeminnow	
Cyprinidae	Longnose dace	
Cyprinidae	Speckled dace	
Cyprinidae	Leopard dace	
Cyprinidae	Oregon chub	
Pertromyzontidae	Western brook lamprey	
Pertromyzontidae	Pacific lamprey	
Cottidae	Paiute sculpin	
Cottidae	Shorthead sculpin	
Cottidae	Reticulate sculpin	
Cottidae	Torrent sculpin	
Percopsidae	Sand roller	
Gasterosteidae	Three-spine stickleback	
Acipenseridae	White sturgeon	
Ictaluridae		Brown bullhead
Ictaluridae		Yellow bullhead
Poeciliidae		Mosquitofish
Cyprinidae		Goldfish
Centrarchidae		Common carp
Centrarchidae		Bluegill
Centrarchidae		Largemouth bass
Centrarchidae		Smallmouth bass
Centrarchidae		White crappie

Spring Chinook

Spring Chinook salmon occupy the Willamette River within the study area during two life stages. Adults returning to the Willamette basin after 3 to 5 years in the ocean will pass through the area to upstream hatcheries and spawning areas in the McKenzie and Middle Fork Willamette Rivers from May to mid-July. They commonly use deep pools in the main channel and slackwater areas at night to hold. As temperatures rise in the early summer, they move out of the Willamette River into the cooler McKenzie River or Middle Fork Willamette River. Spring Chinook salmon do not spawn in reaches of rivers within the study area.

Eggs hatch and fry emerge from the redds beginning in late winter. Chinook salmon fry move downstream from upper reaches of the McKenzie River and Middle Fork Willamette River beginning in March. They feed in shallow water where the velocity is low. Many of these fry continue to move downstream later in the spring, but a number become resident for up to a year. A portion of these resident juvenile Chinook migrate downstream in the fall. Others will remain in the river until the next spring and then migrate. During the summer, juveniles commonly occupy pools immediately downstream of main channel riffles where they are assured an abundant supply of food. They readily compete with cutthroat and rainbow trout in these pools and become large (up to 8 inches long) by the end of summer (unpublished data, Oregon Department of Fish and Wildlife, Corvallis). It is believed that these year-old migrants are well-suited for survival in the ocean because of their large size when they enter the ocean and because they have practice competing with other fish and avoiding predation (Kirk Schroeder, personal communication, ODFW Research, Corvallis). Newly-released hatchery fish have no practice with avoiding predation and can be found schooling at the surface of the water accompanied by an entourage of cormorants as they migrate downstream.

Summer temperatures in the McKenzie, Middle Fork Willamette, and Willamette River are favorable for juvenile Chinook salmon . Because of the diversion of cool water from the McKenzie River, Cedar Creek also has water that is cool enough to support them in the summer. The occupation of other study area waters by juvenile Chinook salmon during the summer is unknown but may include the Springfield Mill Race and the Alton Baker canoe canal. The inlets that divert water from rivers into the Springfield Mill Race, the Canoe Canal, and Cedar Creek are not screened to prevent juvenile fish from entering at the upstream end. Only Cedar Creek has a way for juvenile fish to voluntarily enter from the downstream end.

During the winter, juvenile Chinook salmon probably use an expanded set of waters in the study area, although little has been done to document their presence. Sampling has revealed that juvenile spring Chinook move into the Mohawk River, into small tributaries of the Willamette River near Albany, and Oak Creek near Corvallis (Gary Galovich, ODFW, Corvallis, personal communication) and into seasonally flooded ponds (Bailey and Baker 2000) during the winter. Presumably, they move into these areas to escape high-velocity water and access terrestrially-based food sources (Bailey and Baker 2000). Waters in the study area that are likely to have juvenile Chinook salmon use only during the winter include the lower portions of East Santa Clara Waterway, Spring Creek, Dodson Slough, Debrick Slough, Russell Creek, Oxley Slough, Pudding Creek, and two small streams on the south bank of the McKenzie River where reaches 10 and 11 connect. In addition, ponds and other off-channel features connected to the main river during high flows also probably have juvenile Chinook salmon. Historically, streams that flow into the Long Tom River did not support spawning or incubation of spring Chinook salmon due to insufficient flows during the spawning period for spring Chinook (Jeff Ziller, ODFW, personal communication). The lower Long Tom system does provide refugia and rearing habitat for juvenile spring Chinook, however, Fern Ridge Dam and a number of irrigation dams block access from those areas into the MECT study area (Jeff Ziller, ODFW, personal communication).

Juvenile spring Chinook salmon found in the waters of the study area can be from one of several types. They can be offspring from either hatchery or wild adults that spawn naturally in the rivers, hatchery juveniles that are not marked as such, either because of a mistake or because they were intentionally released without a clipped adipose fin (usually as fry from a hatchery), or a hatchery fish with a clipped adipose fin. A missing adipose fin will positively identify a fish as being from a hatchery, but an intact adipose fin does not mean they are offspring of wild fish.

There is currently no known successful spawning of “wild” Chinook salmon in the upper Willamette River basin other than in the McKenzie River upstream of Leaburg Dam. Spring Chinook of hatchery origin spawn in Fall Creek, a tributary of the Middle Fork Willamette River, below the dam, but the success of this spawning is questionable because flows in Fall Creek are dramatically raised and lowered, sometimes daily, by the Corps of Engineers to manipulate power production at Dexter Dam (Jeff Ziller, ODFW, Springfield, personal communication). The raising of stream levels can cause spawning redds to become scoured because of high-velocity water or become desiccated when low flows expose them to the air.

Surplus adult spring Chinook salmon from the hatcheries are placed upstream of all six of the major dams in the McKenzie and Middle Fork Willamette Rivers in order for them to spawn in waters upstream of the reservoirs. Although none of the dams have fish passage facilities, some of their offspring are known to successfully move downstream through the turbines or spillways and downstream to the ocean (Jeff Ziller, ODFW, Springfield, personal communication). They return from the ocean and are counted as non-hatchery fish since they do not have a clipped adipose fin.

The spring Chinook entering the McKenzie River are mostly hatchery fish, although about 2,000 are referred to as “wild” (Jeff Ziller, ODFW, personal communication). Spring Chinook are counted at the ladder that goes over Leaburg Dam. Early-spawning salmon with an intact adipose fin are counted as wild and adults without an adipose fin or late-season spawners with an adipose fin are considered to be hatchery fish. A majority of hatchery fish stop at the hatchery short of Leaburg Dam, but it is unknown how many of the hatchery fish going over the dam are misidentified as wild fish.

The number of spring Chinook salmon entering the McKenzie River has been increasing since 1997 (Figure 37). Most likely, this increase is due to improved ocean conditions and restrictions on ocean and river fishing. The Chinook salmon returning to the river in 1993 also benefited from favorable ocean conditions.

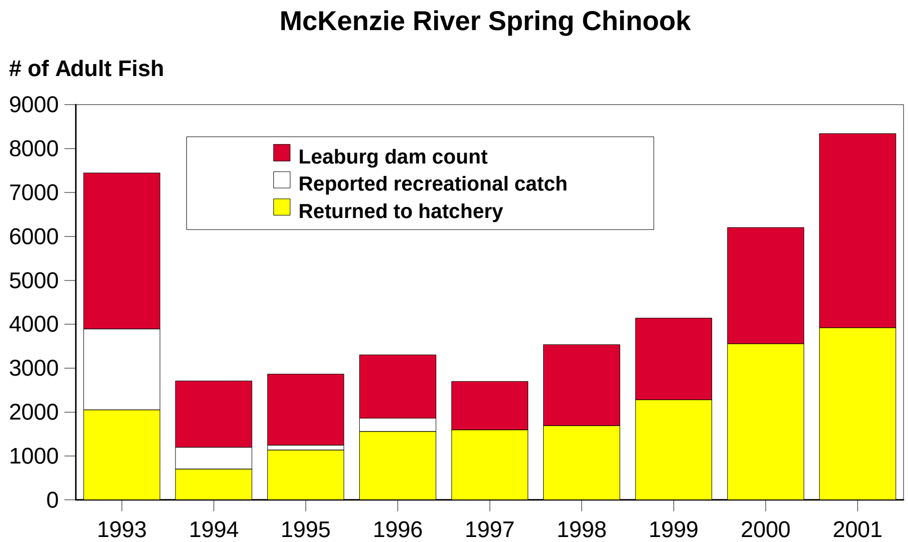


Figure 37. Number of spring Chinook salmon counted at Leaburg Dam, caught at the hatchery, or reported caught from 1993 to 2001 (ODFW web site, Springfield office).

Oregon chub

The Oregon chub is a small minnow found only in the Willamette River basin. At one time the Oregon chub occupied most lowland areas where there was shallow, slow-moving water, such as sloughs, beaver ponds, oxbows and side channels. About 25 isolated populations are known to exist now with most in artificial ponds.

Historically, floods that created Oregon chub habitat were common. When rivers flooded, they scoured new side channels and backwaters while isolating channel segments in other areas to create ponds. Oregon chub were well-suited to these areas and particularly thrived where aquatic vegetation was plentiful. However, upstream reservoirs altered these channel-altering processes by reducing peak flows and preventing river meandering. Habitat loss also resulted from bank riprap, channelization of streams and draining and filling of wetlands. More importantly, exotic species such as bass, bluegill and mosquito fish were introduced to the Willamette basin. These species compete for habitat preferred by Oregon chub or prey on them directly (Scheerer 2000). Sharp declines in a number of established populations occurred after the high water of 1996. The flood transported introduced species into ponds that had previously been isolated from streams and rivers and these fish preyed upon and competed with Oregon chub. Today, most of the stable populations of Oregon chub exist in artificial ponds where introduced fish are purposely excluded (Paul Scheerer, Oregon Department of Fish and Wildlife, Corvallis, personal communication).

In 2001, a small population of Oregon chub was found in backwater features of the McKenzie River (south side of river in reach 12). The area harbored no introduced fish species, probably because the waters are fed by subsurface flow of the river which is too cold for introduced fishes.

A subsequent survey in 2002 resulted in the discovery of Oregon chub in a side channel of the Coast Fork Willamette River near the Interstate 5 bridge (upstream of the study area). Future surveys may reveal the location of other isolated populations within the study area, especially where introduced fish do not thrive.

Bull trout

There have been only two accounts of bull trout in the study area during recent decades. A large adult bull trout (21 inches long) was caught by the Oregon Department of Fish and Wildlife with a seine net at the mouth of the McKenzie River in 2000 and a small adult (12 inches) was confiscated from a fisherman in the lower McKenzie River in 2002. Bull trout are probably rare in the lower McKenzie River since hardly any have been reported and they are easily caught on artificial flies.

Bull trout are more common in the upper McKenzie River where they can find the cold water that is essential for egg development and juvenile rearing. As adults, bull trout expand their territory into warmer water in search of food, which is mainly small fish.

Three populations of bull trout exist in the upper McKenzie River and all are isolated from each other by dams. Only the downstream population located in the main channel of the McKenzie River near the town of McKenzie Bridge can migrate down the McKenzie River. Efforts to increase the spawning success and food supply of bull trout and reduce poaching by anglers have been successful during the last decade. Fishing restrictions do not allow angling for bull trout. Efforts are underway to re-introduce bull trout into upper portions of the Middle Fork Willamette River basin.

Cutthroat and rainbow trout

Cutthroat and rainbow trout are found in study area rivers and cutthroat trout also use connected off-channel areas and seasonally use streams of all sizes in the Willamette River basin. Adult cutthroat trout are often found spawning in the headwaters during late winter or spring. They quickly move downstream after spawning. Juvenile cutthroat trout are rarely found in rivers of the Willamette basin. Instead they stay in their natal streams for the first 2 years and then some move downstream to waters that offer a better food supply (Moring et al. 1988). Some cutthroat become resident in streams their entire lives and have a stunted form (usually less than 8 inches); the others move into the rivers where they can reach a length of up to 16 inches. Certain tributaries of the Mohawk River basin have been identified as important areas for spawning by cutthroat trout that normally reside in rivers of the study area (Huntington 2000).

Native rainbow trout in the upper Willamette River basin (often called redbands) are genetically distinct from steelhead trout naturally found in lower portions of the Willamette. Unlike cutthroat trout, redband rainbow trout spend most of their lives in rivers and large streams.

4.1.1 Fish sampling in study area streams

Fish assemblages for streams within the MECT study area have never been quantified except for sampling of a short reach of Amazon Creek (near the fairgrounds) by the EPA Research Laboratory (Corvallis) in July of 1993 and 1996. Results from this study indicate that all species found in the stream were tolerant of warm water (Figure 38). Most fish were the native redside shiner and speckled dace. Surprisingly, only a few introduced warm water fish were present; usually bluegill and largemouth bass thrive in valley streams with warm water. Water temperature exceeded 80 deg F in this reach during the summer of 2001.

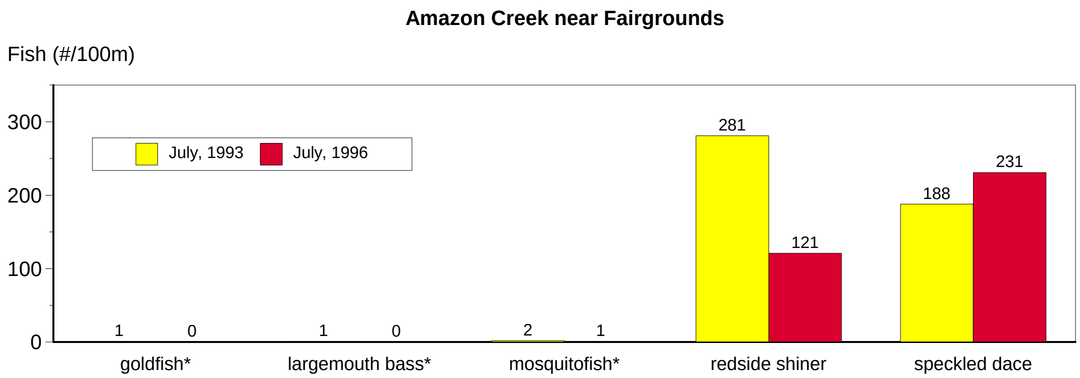


Figure 38. Daytime backpack electrofishing results for a reach of Amazon Creek near the fairgrounds in July, 1993 and 1996. Data provided by EPA Research Laboratory in Corvallis. An asterisk designates that the species has been introduced to the Willamette River basin.

Most streams in the study area have been verified to be fish-bearing or suspected of being fish-bearing for much of their length (Map 11) through informal surveys and sightings conducted over the last few decades. Usually , confirmation of the upper extent of fish use in a stream involves electrofishing during the late winter or early spring, a time when cutthroat trout are at their highest position in the watershed. Cutthroat trout usually hold the most upstream position in small streams of the Willamette River basin, although the upstream extent of fish use will sometimes be defined by the presence of sculpin or redside shiner if cutthroat trout are excluded from the stream by man-made or natural barriers. Most year-round ponds and some of the larger stormwater waterways are also used by fish. Ponds isolated from the rivers usually have fish but are dominated by introduced species.

The source of information used for fish-bearing streams was the detailed USGS maps updated yearly by the Oregon Department of Forestry and Department of Fish and Wildlife. Field surveys are used to define on this map whether or not stream segments are fish-bearing. There are many small streams that have never been surveyed so the information is incomplete. A water body was designated as having possible fish use if it appeared to have the characteristics of a fish-bearing stream or if the local Department of Fish and Wildlife biologist's notes on the Department of Forestry maps indicated that it probably had fish.

The "Essential Indigenous Anadromous Salmonid Habitat" maps produced by the National Marine Fisheries Service are not intended to designate which streams do and do not have fish. These maps show a variety of stream channels, both those that have fish and those that can influence downstream fish-bearing waters.

4.1.2 Fish sampling in study area rivers

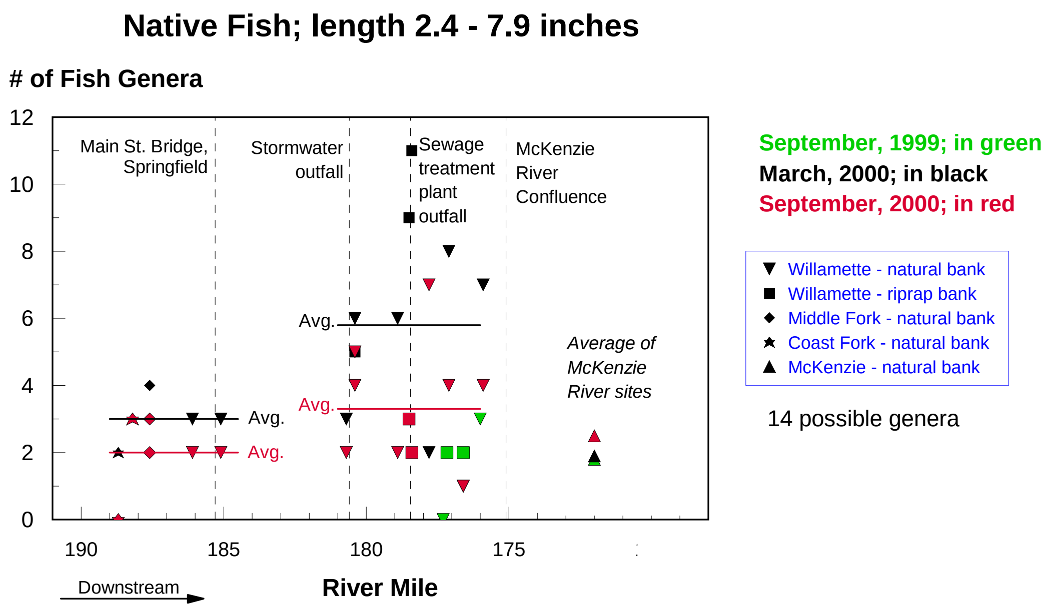
Until recently, there had been no systematic sampling of fish communities in the MECT study area. A study conducted for the McKenzie Watershed Council in September, 1999, and March, 2000 (Andrus et al. 2000), provided information on fish communities within various water types in the McKenzie / Willamette confluence area. This area included the Willamette River downstream of the Beltline Road Bridge to about 4 miles downstream of the McKenzie River confluence and the McKenzie River from its mouth to the Interstate 5 Highway Bridge. Boat electrofishing of the margins of water features with various bank types was conducted at night (a time when fish move close to shore and are less spooked by the sampling boat) in early spring and again in late summer. Main channel reaches, alcoves, gravel pit ponds, and natural ponds were sampled during this study.

Another study, conducted for the City of Eugene, provided information on fish communities along the main channel of the Willamette River from the Middle Fork Willamette / Coast Fork Willamette confluence to the McKenzie River confluence (Andrus et al. 2000) utilizing the same methods and personnel of the confluence study . Sampling occurred in March, 2000, and September, 2000.

Additional information on Willamette River main channel and alcove fish assemblages was obtained from a study sponsored by the EPA Research Laboratory in Corvallis for sites between Corvallis and the McKenzie River confluence for sampling periods in summer, 1988, and March, 1999 (Andrus, unpublished data). Catch results for each of the three studies were pooled and expressed in terms of number of fish caught per 100 feet of bank sampled in the discussions below.

Fish community structure

All reaches of all rivers in the MECT study area support an array of fish species. For small fish (2.4 to 7.9 inches long), the number of native fish genera was lowest in the Willamette River upstream of Springfield (reaches 20-22, 27) and in the lower McKenzie River (reaches 3-5) and was highest in the Willamette River downstream of Skinner Butte (reaches 15-16) (Figure 39). The number of genera is similar to the number of species, except that sculpin species were combined into a sculpin group and dace species were combined into a dace group.



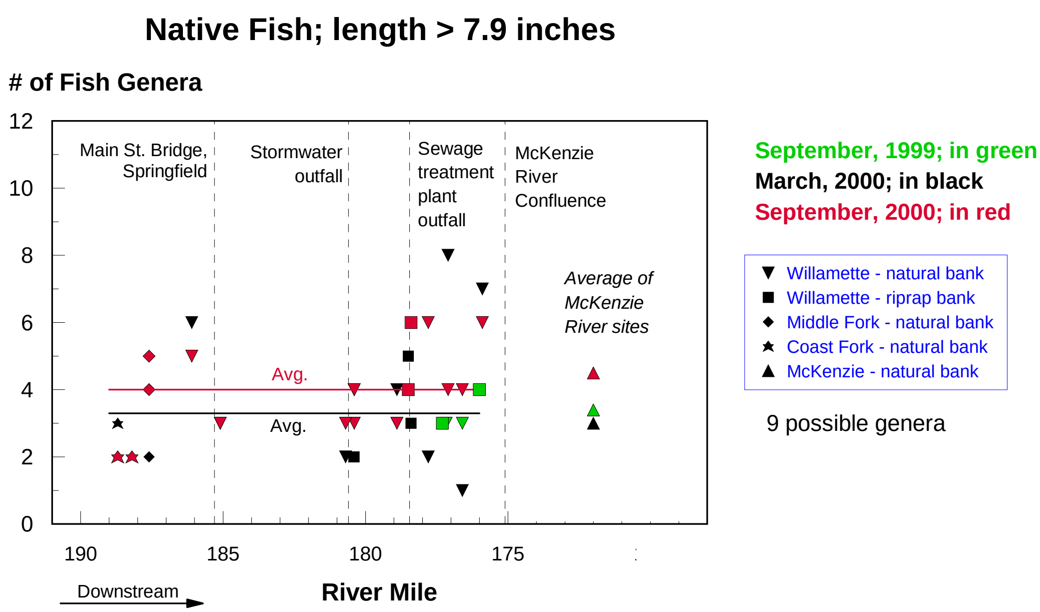


Figure 39. The number of fish genera for three sampling periods and two fish length classes. For the lower McKenzie River, 5 sites were sampled in September, 1999, 4 sites in March, 2000, and 2 sites in September, 2000.

There was no pattern in genus abundance for large fish (greater than 7.9 inches). The high diversity of small fish in the most urbanized portion of the Willamette River during March may be caused by the extra nutrients provided by stormwater and point discharges. These nutrients can increase primary productivity and result in a more diverse food base, thereby attracting a greater diversity of fishes. The greatest genus diversity was found at two sites nearest the wastewater treatment outfall.

In this study, the catch per unit effort is expressed as the number of fish caught per 100 feet of bank sampled. The catch per unit effort does not indicate the absolute size of the population of fish being sampled, but is merely an index of abundance. Hereafter, we refer to catch per unit effort as "relative abundance." Species of fish were assigned to one of four different groups. The group, salmonids, consisted of salmon, trout, and mountain whitefish. The group, scrapers, consisted of suckers and chiselmouth which obtain their food by scraping periphyton off rocks and other bottom substrate. All other native fish were considered other native and non-native fish were classified as introduced.

For all sites combined, the relative abundance of small fish declined from March to September, with nearly all of this decline due to fewer salmonids (Figure 40). Specifically, small mountain whitefish left the area after March in large numbers (Figure 41), presumably to seek out cooler water in the Middle Fork Willamette River or the McKenzie River. In addition, few small Chinook salmon remained by the end of the summer and probably migrated downstream at various times throughout the summer.

Large salmonids did not decline over the summer, but rather increased (Figure 40), due mostly to an increase in cutthroat trout. Some of these trout may be summer refugees from the warm Coast Fork Willamette River and Mohawk River.

The relative abundance of large scrapers increased from March to September. Most of the scrapers were largescale suckers. In early spring, when food supplies in the main channel are scarce, largescale suckers will congregate in alcoves and other off-channel areas (Andrus et al. 2000). Presumably, these areas have an early-season growth of periphyton on rocks and other surfaces and the low velocity in these areas help the scrapers avoid expending energy battling strong currents in the main channel.

The relative abundance of other native fish declined from March to September for small fish, largely due to a decline in redside shiners, but increased for large fish, a result of more pikeminnow (Figure 42). Redside shiner are heavily predated upon by large fish, great blue heron, and other animals and so their decline over the summer is not surprising. Yet, the reasons for seasonal increase in the relative abundance of large pikeminnow is unknown.

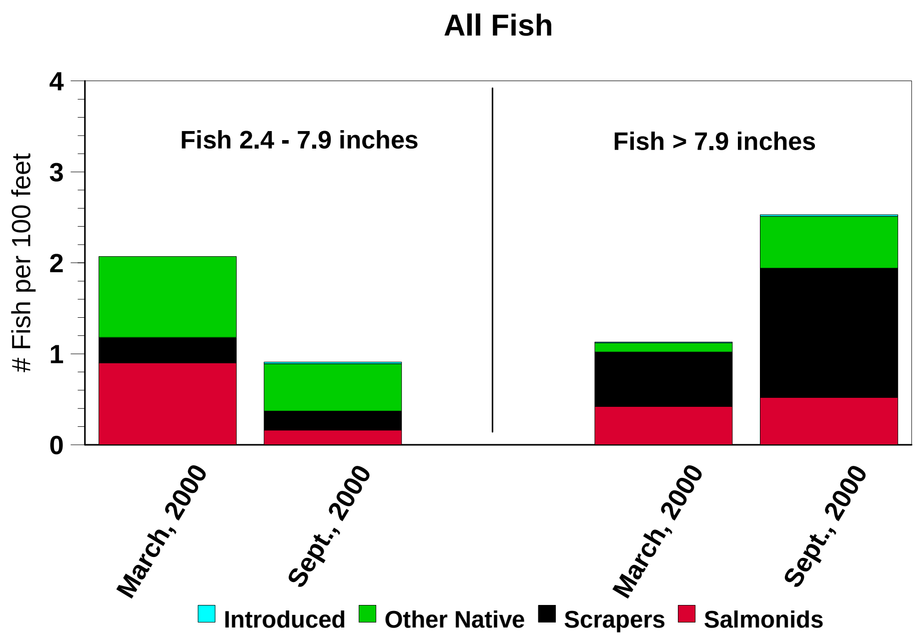


Figure 40. Relative abundance of fish, by group, sampled along the edges of the Middle Fork Willamette River (2 sites), Coast Fork Willamette River (2 sites), and the Willamette River downstream to the McKenzie River confluence (12 sites) (Andrus 2000).

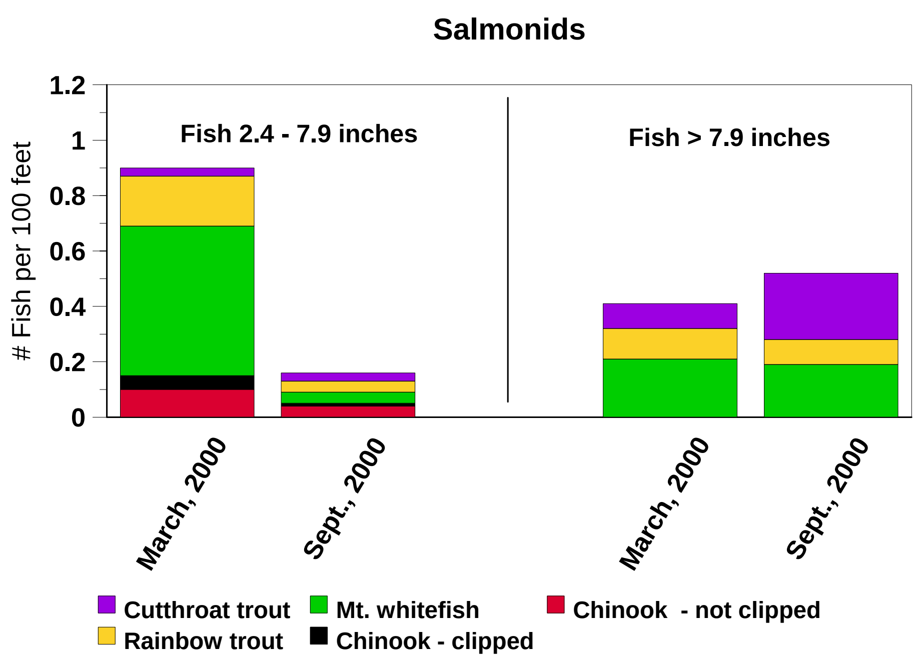
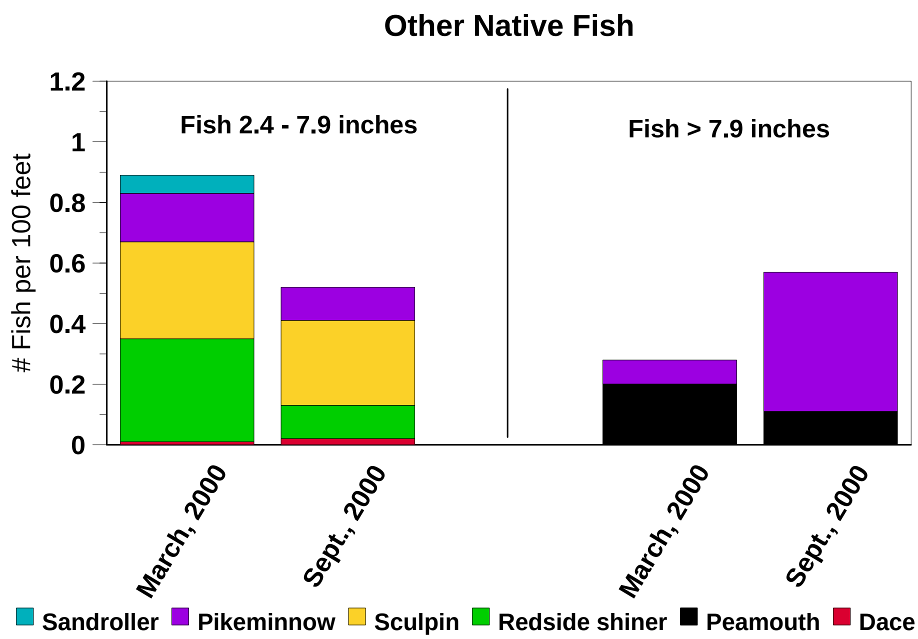


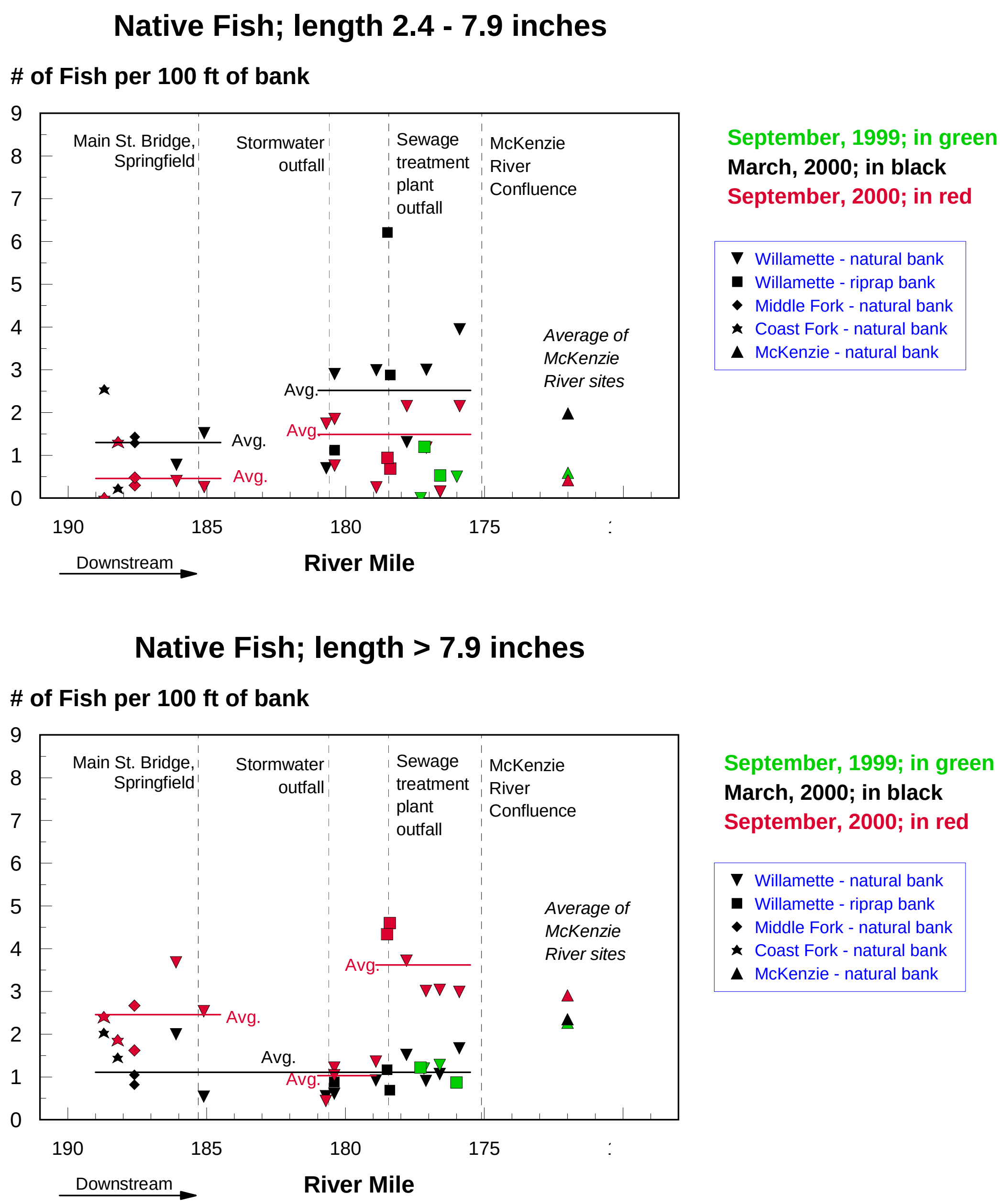
Figure 41. Relative abundance of salmonids, by species, sampled along the edges of the Middle Fork Willamette River (2 sites), Coast Fork Willamette River (2 sites), and the Willamette River downstream to the McKenzie River confluence (12 sites) (Andrus 2000).



<u>Figure 42</u>. Relative abundance of other native fishes, by species, sampled along the edges of the Middle Fork Willamette River (2 sites), Coast Fork Willamette River (2 sites), and the Willamette River downstream to the McKenzie River confluence (12 sites) (Andrus 2000).

Introduced fish were rarely caught in the main channel of these rivers during either sampling periods. The species that were caught included largemouth bass, smallmouth bass, and common carp.

Longitudinal variations in the relative abundance of native fish in the Willamette River throughout the study area differed between seasons and between the two fish size classes. The relative abundance of small native fish in the Willamette River varied considerably among sites but, in general, was less upstream of Springfield than downstream (Figure 43). The relative abundance of small native fish in the McKenzie River was also low. Small fish were more abundant in March than in September at almost every site. In contrast, large native fish were more abundant in September than in March. This difference was most pronounced in the Willamette River downstream of the wastewater treatment plant. Large fish in this section may benefit from nutrients released from the wastewater treatment plant effluent and a river bottom dominated more by cobbles and less by bedrock and fine material.



<u>Figure 43</u>. Longitudinal differences in the relative abundance of all native fish for the main channel Willamette River and McKenzie River during March and September (Andrus 2000, Andrus et al. 2000). McKenzie River values are shown as an average of 4 sites in March and 5 sites in September.

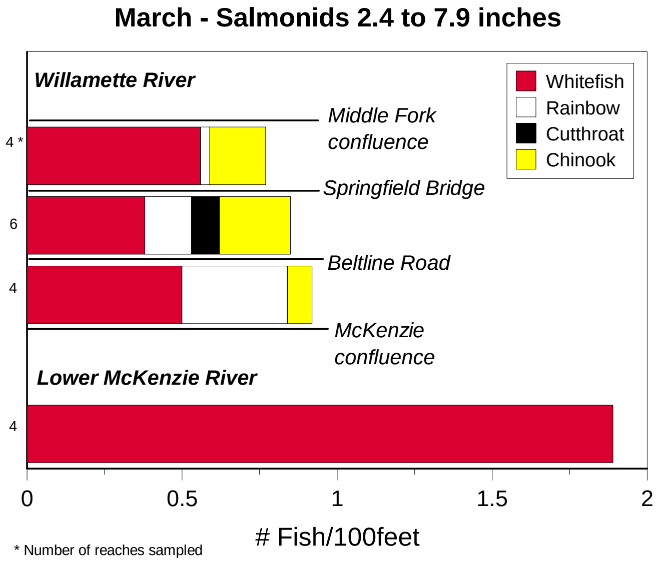
Salmonids

The relative abundance of small salmonids increased in a downstream direction for the Willamette River in March, boosted by an increase in rainbow trout for sites closest to the McKenzie River confluence (Figure 44). Portions of the McKenzie River and its tributaries are known for their high native rainbow trout populations.

Surprisingly, all small salmonids caught during March within the main channel of the lower McKenzie River, where banks were natural material or riprap were mountain whitefish. Some small salmonids were caught within alcoves and along main channel sections with rock barbs. Rock barbs are made of large angular rocks placed at a right angle to the bank (sticking out 20 to 30 feet from the bank). This creates a large pool of slow water immediately downstream of the barb that allows fish to withstand downstream movement yet puts the fish close to fast water in order for them to initiate feeding forays. Small mountain whitefish were nearly absent during the September sampling and probably moved upstream to cooler water.

The section of the Willamette River between the Springfield Bridge and Beltline Road had the fewest large salmonids during March and September, mostly due to a scarcity of mountain whitefish (Figure 45).   Mountain whitefish feed on small aquatic insects that favor loose gravel substrates in relatively shallow water. This section of the Willamette River once had extensive gravel deposits, but they were mined from the river in the 1940s and 1950s and the channel was deepened and narrowed when the west bank was developed. This has probably reduced the abundance of aquatic insects and, consequently, has created less favorable habitat for large mountain whitefish.

The relative abundance of large rainbow trout in March was not appreciably greater in the McKenzie River than in the Willamette River probably because they spawn mainly in March and many may have temporarily moved upstream in the McKenzie River to spawning grounds. In September, both large rainbow trout and cutthroat trout were more numerous in the lower McKenzie River than elsewhere. In fact, the values shown in Figure 45 for the McKenzie River are probably understated because the electrofishing boat brought far more trout to the surface of the water than the netter could gather.



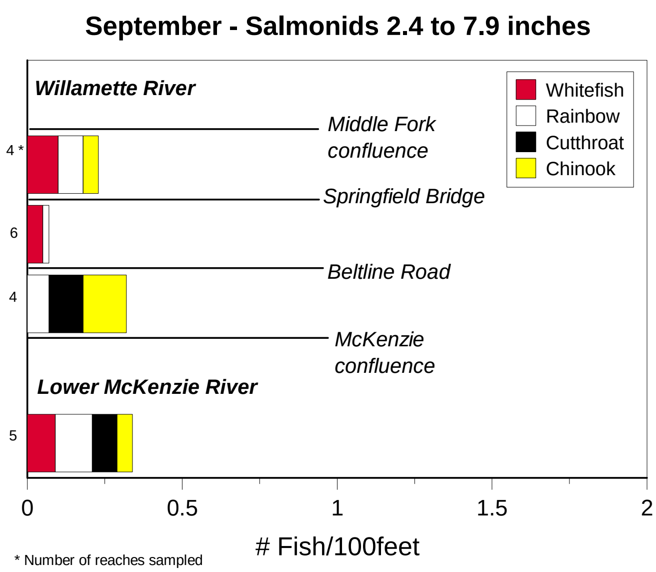
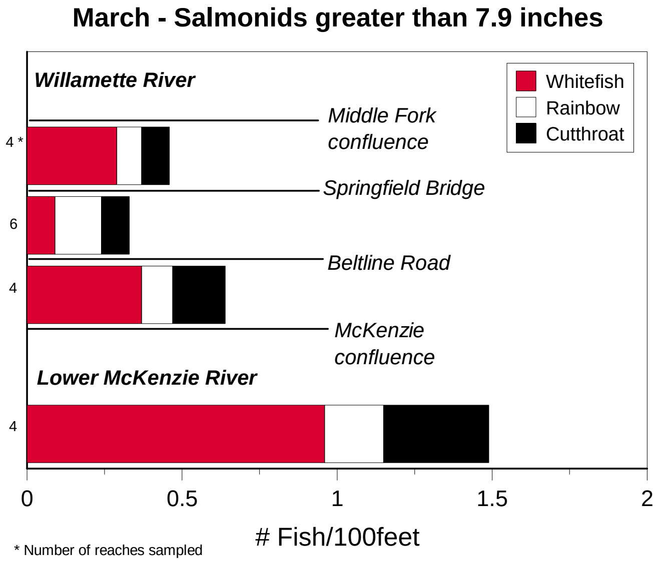


Figure 44. Longitudinal differences in the relative abundance of small salmonids for the main channel Willamette River and McKenzie River during March and September (Andrus 2000, Andrus et al. 2000).



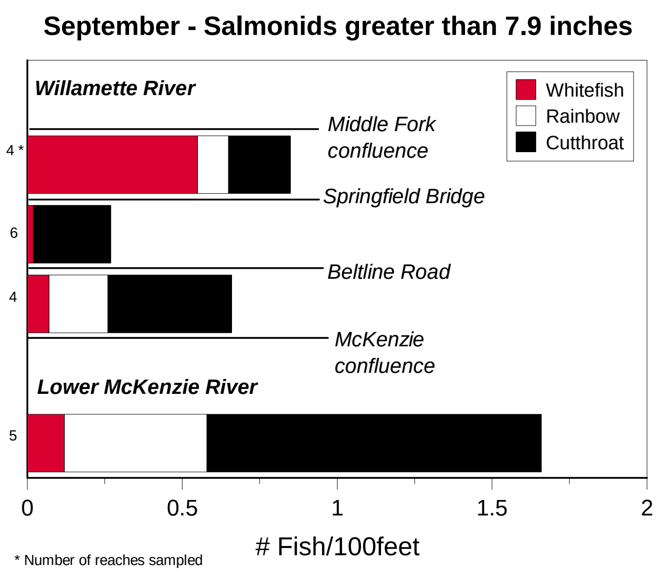


Figure 45. Longitudinal differences in the relative abundance of large salmonids for the main channel Willamette River and McKenzie River during March and September (Andrus 2000, Andrus et al. 2000).

Juvenile Chinook salmon were scarce in the main channel of the Willamette River and McKenzie River, with captures at only 2 sites in September, 2000, and 8 sites in March, 2000 (Figure 46). In March, values were highest at sites near the wastewater treatment plant outfall at the Beltline Road Bridge.

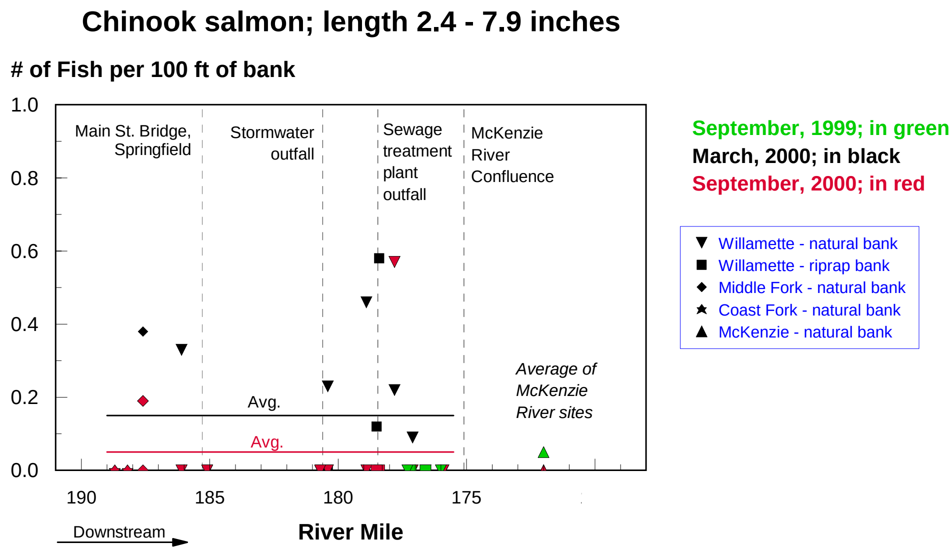


Figure 46. Longitudinal differences in the relative abundance of small Chinook salmon for the main channel Willamette River and McKenzie River during March and September (Andrus 2000, Andrus et al. 2000).

Few juvenile Chinook salmon caught in the McKenzie River had a clipped adipose fin, while 35% of Willamette River Chinook had a clipped fin in March (Table 23). This means that at least one-third of Willamette River juvenile Chinook are of hatchery origin, but the real proportion, while unknown, is probably much higher. The hatchery Chinook juveniles in the McKenzie River seem to be a much smaller proportion of all Chinook juveniles (Table 23), but the sampling periods were not coincident with the months that hatchery fish are released. Upon release, juvenile Chinook salmon raised in hatcheries quickly move downstream to the Columbia River (Snelling et al. 1993).

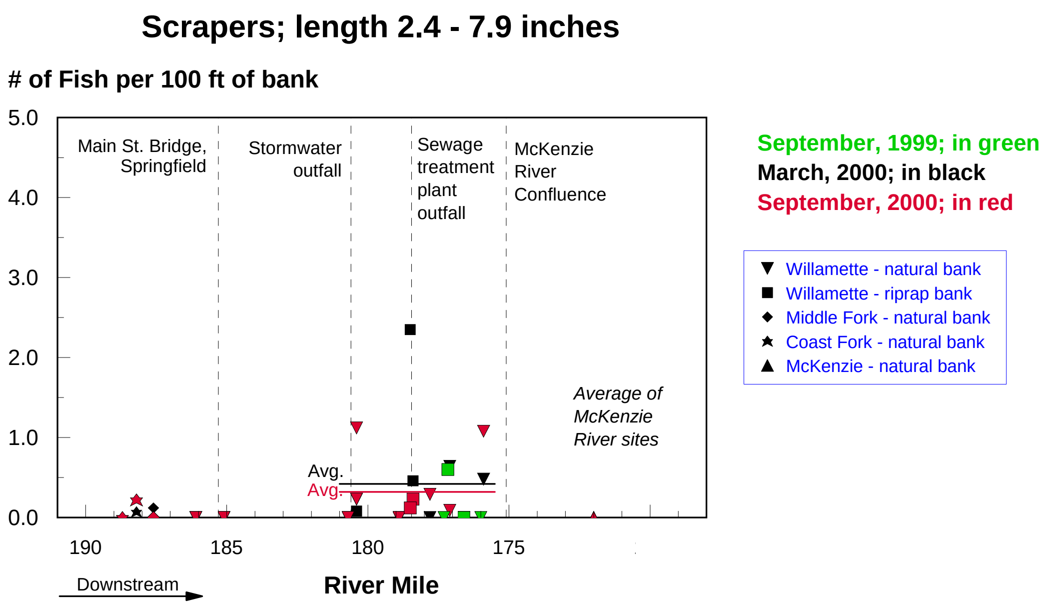
Table 23. Percentage of juvenile Chinook salmon with a clipped adipose fin during March and September sampling for the Willamette River and McKenzie River (Andrus 2000, Andrus et al. 2000).

	Willamette River	McKenzie River
March	35%	3%
September	18%	0%

Observations and informal sampling of juvenile Chinook salmon has taken place at other locations in the study area. Seining in the lower McKenzie River by the Oregon Department of Fish and Wildlife Research office and the Springfield office indicate that young Chinook juveniles can be seasonally found within pockets along the edges of the McKenzie River where conditions are conducive to seining. Seining is successful only in areas with a finer substrate, low velocity water, a water depth of less than about 6 feet, and where the river bottom is free of wood and other obstacles that would snag a net. Consequently, seining can yield little information about fish in other habitat types. The McKenzie River, like all study area waters, is too turbid to observe fish by snorkeling. Results from seining in early spring through mid-summer suggest that young-of-the year Chinook move through the lower McKenzie River in spring with few Chinook born the previous year still present (Kirk Schroeder, ODFW Research, personal communication).

Scrapers

Small scrapers (largescale sucker, mountain sucker, and chiselmouth) were relatively uncommon throughout the main channel of the Willamette River and McKenzie River, except for certain sites between the Springfield Bridge and the McKenzie River confluence (Figure 47). In contrast, large scrapers were common with the highest densities near the wastewater treatment plant in September. Their numbers decreased with increasing distance downstream from the outfall. Large scrapers were relatively low upstream of the outfall. The wastewater treatment plant releases nutrients that probably fuel an abundant periphyton community that attracts the scrapers. This enhanced periphyton community is probably missing in March when sunlight is scarce and the water is deeper and more turbid.



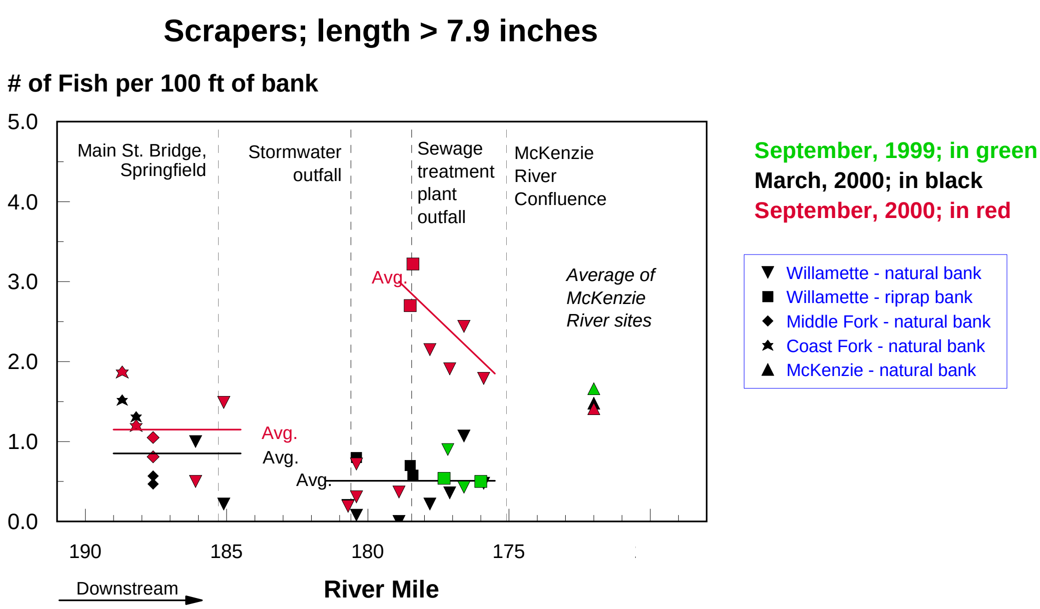


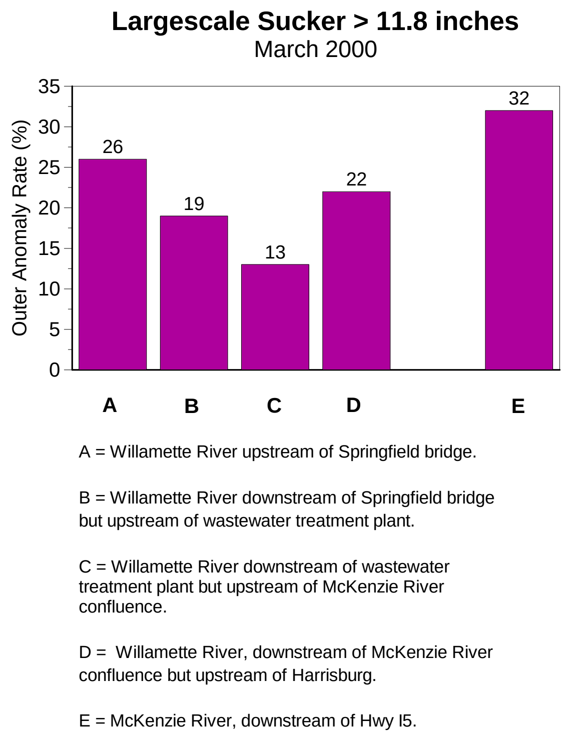
Figure 47. Longitudinal differences in the relative abundance of scrapers for the main channel Willamette River and McKenzie River during March and September (Andrus 2000, Andrus et al. 2000).

Much has been made of deformities of fish occupying the Willamette River from the Wilsonville pool and downstream to the Columbia River. Here, skeletal deformity rates among native juvenile minnows are high and outer anomalies among other fish, especially introduced species, are reported to be high. Outer anomalies include lesions, parasites and infection of fins and skin, blind eyes, and injury. The reasons for the deformities are still being explored, but may include a combination of high levels of industrial pollutants and naturally-occurring warm water.

Outer anomalies in the upper Willamette River basin are rare for most fish. In an evaluation of fish in the Willamette River and lower McKenzie River, less than 1% of fish 2.4 to 7.9 inches had outer anomalies, while fish over 12 inches (excluding largescale sucker) had an outer anomaly rate of 5% (Andrus et al. 2000). Salmonids were relatively free of anomalies, with cutthroat trout having none.

In contrast, outer anomalies among largescale sucker greater than 12 inches long were common in March, especially in sections of the river least expected to have water quality problems (Figure 48). Water temperature is not expected to be a factor in disease susceptibility during March since the temperatures of all rivers in the study area are low. September outer anomaly rates were somewhat higher than those in March.

Outer anomaly rates decreased from 26% in the section upstream of the Springfield Bridge to 13% downstream of the wastewater treatment plant. Rates were highest in the McKenzie River at 32%. The abundance of food available to largescale suckers in early spring may be negatively correlated to anomaly rates. Extra food in the portion of the Willamette River flowing through Eugene may be a result of extra nutrients provided by stormwater and treated wastewater effluent. A well-fed fish may be more capable than an ill-fed fish to ward off disease.



<u>Figure 48</u>. Outer anomaly rates among largescale sucker greater than 12 inches long in March for sections of the Willamette River and McKenzie River.

Fish community variation among water and bank types

Data compiled from the Willamette / McKenzie confluence study (Andrus et al. 2000), the City of Eugene study (Andrus 2000), and a study downstream of the McKenzie River confluence (Andrus, unpublished data) provide the opportunity to compare fish assemblages among water types and for different bank types along the main channel. Included are sites for gravel pits, alcoves, and the main channel. Main channel sites had either natural banks, riprapped banks, or riprapped banks with rock barbs. The gravel pit ponds were connected to the river only during high flows. Table 24 provides a summary of the number of sites sampled for each type for both March and September sampling.

The relative abundance of small native fish in March was considerably higher at sites with rock barbs along the main channel than at any other type of site (Figure 49). Yet, by September, most of these small fish were gone and these sites became the domain of large trout. The diet of large trout can include small fish. Native fish within <u>alcoves</u> for the Willamette River generally increased with increasing distance downstream of the Springfield Bridge, while the relative abundance of native fish in the <u>main channel</u> decreased. The lower McKenzie River had more native fish at main channel sites than at alcove sites during March. The reverse was true for Willamette River sites; alcoves had more fish than main channel sites. McKenzie River alcoves were deeper than Willamette River alcoves and lacked aquatic plants and other cover features and so they may have been less desired by small fish. Gravel pits had the lowest relative abundance of native fish in March.

Table 24. Number of sampling sites by season, water type, and section for boat electrofishing in March, 2000, and September, 1999.

Sampling	Water Type	Number of Sites Sampled					
		McKenzie R.	Willamette R. upstream of confluence		Willamette R. downstream of confluence		Total
	Section	**1**	**2**	**3**	**4**	**5**	
March 2000	Alcove	4	-	3	6	7	20
	Main channel						
	Natural bank	4	5	10	4	7	30
	Riprap bank	1	-	5	-	1	7
	Riprap bank w/ barbs	2	-	-	-	-	2
	Gravel pit pond	-	-	2	-	-	2
	Total	11	5	20	10	15	61
Sept. 1999	Alcove	4	-	1	3	-	8
	Main channel						
	Natural bank	5	-	3	2	-	10
	Riprap bank	2	-	4	-	-	6
	Riprap bank w/ barbs	2	-	-	-	-	2
	Gravel pit pond	-	-	2	-	-	2
	Total	13	-	10	5	-	28

Reaches: 1 = McKenzie River
2 = Upstream of Springfield Bridge
3 = Springfield Bridge to McKenzie Confluence
4 = McKenzie Confluence to Harrisburg
5 = Harrisburg to Corvallis

In September, alcoves were dominated by small native fish while main channel reaches were dominated by large fish. Native fish in gravel pit ponds decreased to very low numbers by September.

Main channel sites with riprap had about the same number of native fish as main channel sites with natural banks, although some riprap sites (those with the fastest water) had very few fish.

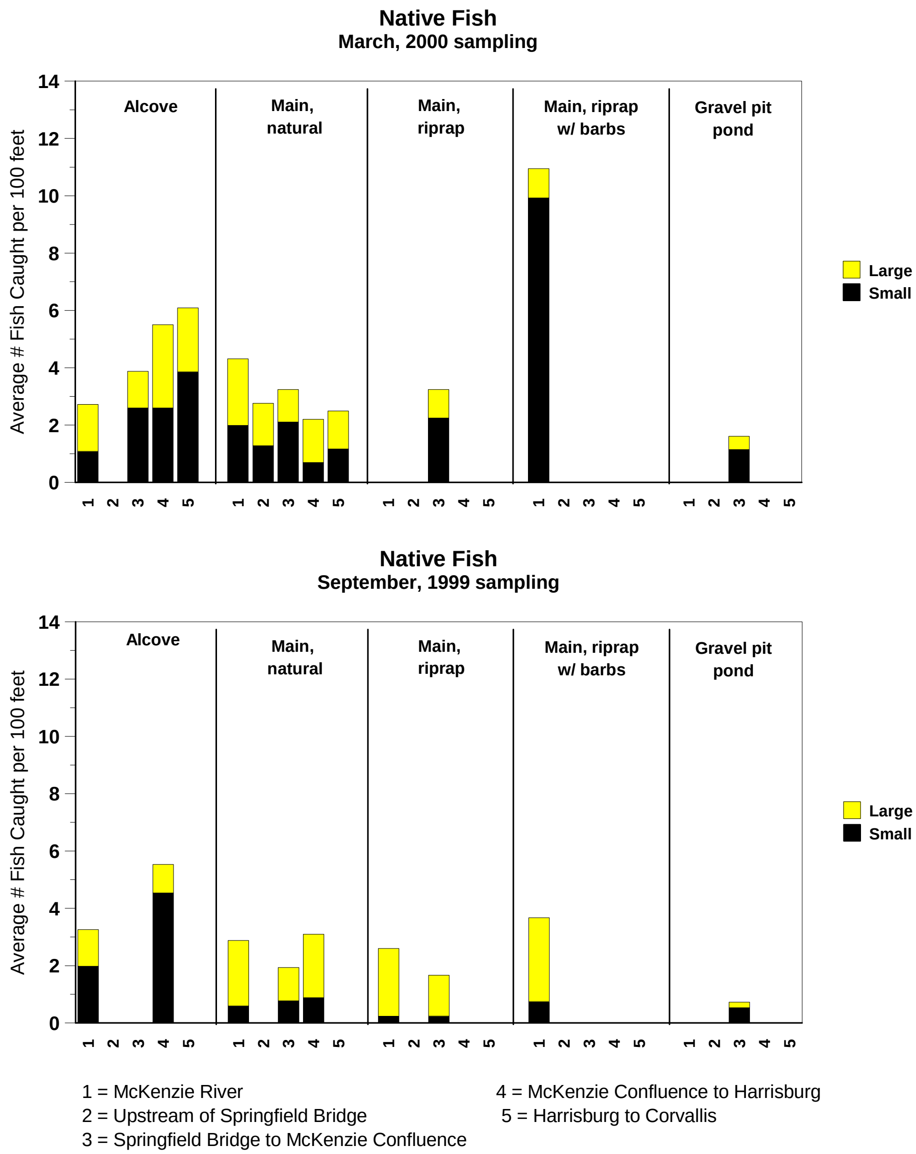
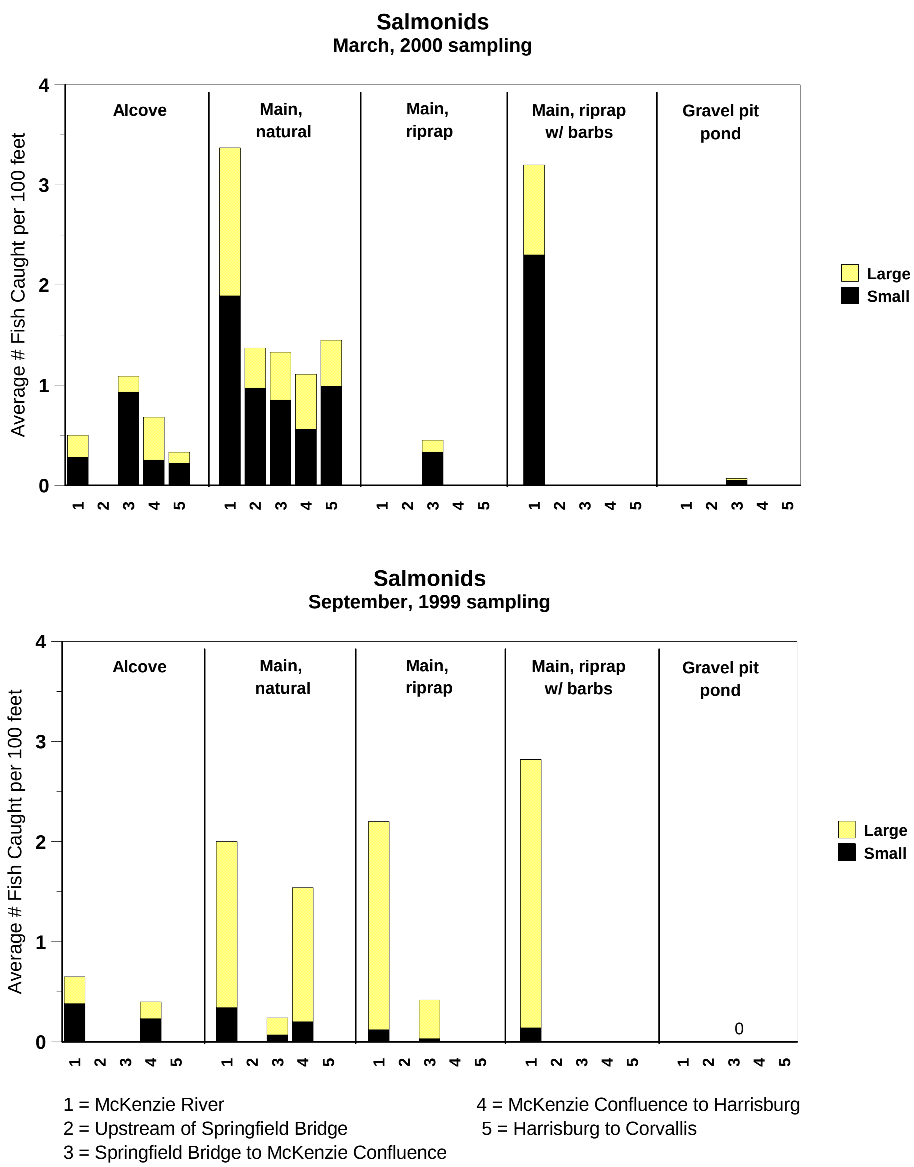


Figure 49. Summary of the relative abundance of all native fish by water type and bank type for various sections of the Willamette River and McKenzie River for September, 1999 and March, 2000. "Main" means the main channel of the river. Sections with no values for a specific water type indicates that no sampling took place.

The relative abundance of salmonids in March was greatest in the McKenzie River at main channel sites with natural banks or with rock barbs (Figure 50). Sites with natural banks were dominated by mountain whitefish while rock barb sites were dominated by juvenile Chinook salmon and trout. By September, the juvenile Chinook salmon and most other small fish were gone from the rock barb sites and very large rainbow trout occupied these slackwater areas instead. Presumably, the rainbow trout benefit from the proximity of low velocity water for resting and high velocity water for feeding.

Alcove sites had fewer salmonids than did main channel sites in March, except for main channel sites with riprap. Gravel pit ponds had only a few salmonids in March which then died by September. A single Chinook salmon was caught at one of the gravel pit ponds in March, suggesting they are not trapped within inundated gravel pits in large numbers. Both gravel pit ponds were much warmer than the main channel of the Willamette River during the summer.

Main channel sites during September had a high abundance of large salmonids in the McKenzie River and Willamette River downstream of the McKenzie River confluence, but few in the Willamette River immediately upstream of the McKenzie River confluence.



<u>Figure 50</u>. Summary of the relative abundance of salmonids by water type and bank type for various sections of the Willamette River and McKenzie River for September, 1999 and March, 2000. "Main" refers to the main channel of the river. Sections with no values for a specific water type indicates that no sampling took place.

Introduced fish were absent from all main channel sites and present in only low densities within alcoves (Figure 51). Most introduced fish were small, consisting largely of bluegill and largemouth bass. In contrast, the relative abundance of small introduced fish in gravel pit ponds was high for both March and September. Few intermediate-sized largemouth bass were caught; most were either less than 4 inches long or greater than 12 inches long. Since the gravel pits have no surface connection with main channel during the summer, native predatory fish, such as northern pikeminnow, cannot feed on the small exotic fish. Alcoves, even those with warm water during the summer, are readily entered by northern pikeminnow (usually at night) and feed on introduced fish, thereby keeping them at low densities.

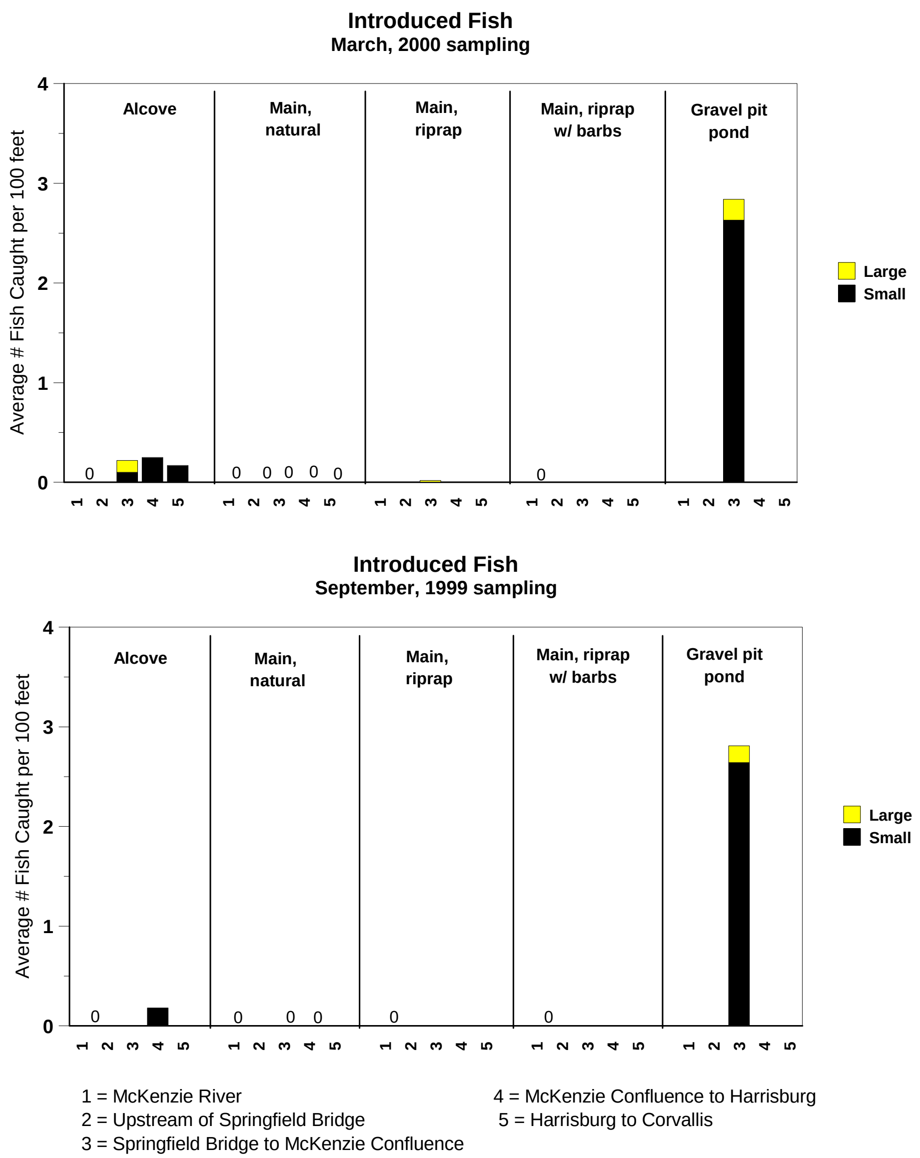


Figure 51. Summary of the relative abundance of introduced fish by water type and bank type for various sections of the Willamette River and McKenzie River for September, 1999 and March, 2000. "Main" refers to the main channel of the river. Sections with no values for a specific water type indicates that no sampling took place.

4.1.3 Barriers to fish movement

Only two small streams in the study area have been surveyed for culverts and other barriers that would block upstream fish movement. A survey by the Oregon Department of Fish and Wildlife and Salmon-Trout Enhancement Program (STEP) volunteers in April, 2001 indicated that none of the 10 city culverts in Spring Creek had characteristics associated with the blockage of fish.

Similarly, 12 out of 13 culverts surveyed in Flat Creek seemed to pass fish. They found that a culvert at Irving Road had been dammed and screened to create a pond about ¼ mile in length as part of a housing development. This dam is a barrier to fish. When we checked this site in April, 2002, the dam was still present.

A number of piped sections of stream throughout urban portions of the study area probably keep fish from entering upstream portions of small basins. For example, Russell Creek in southeast Eugene is piped underground at the community college, thereby isolating the upstream portion of the watershed. Similarly, many tributaries of upper Amazon Creek are also piped underground at their lower ends. An unnamed tributary to the Middle Fork Willamette River (flows into reach 26 from the north) traverses through wooded property owned by a wood products mill and appears to be blocked by a perched culvert that flows underneath Jasper Road.

Fern Ridge Dam and several downstream irrigation diversion dams prevent fish from moving upstream from the Willamette River and spawning in the upper Long Tom River watershed. Removing these barriers to allow upstream movement of cutthroat trout and other fishes has been designated as lower priority for the Corps of Engineers and the irrigation district. Use of the lower portion of the Long Tom system by juvenile salmon originating from the McKenzie River and Middle Fork Willamette River for rearing and refugia during non-summer months is currently thought to occur (Jeff Ziller, ODFW, personal communication).

Determining whether or not fish have upstream access throughout a stream is time-consuming and can be done only by walking the length of stream (usually during higher water in early spring). This is difficult in an urban setting due to the many landowners and dogs that need to be appeased.

4.1.4 Potential interactions between hatchery and native trout

Rainbow trout raised at the Leaburg hatchery on the McKenzie River are transferred to MECT study area rivers and the Alton Baker Canal / Patterson Slough from February to July. These trout are a different variety than the native “redside” rainbow trout. Their pallid color, slight build, clipped adipose fin, and tendency to school make their appearance and behavior different than native rainbow trout. The hatchery rainbow trout are of a stock that does not normally breed or even survive the winter in the MECT area. During sampling of the rivers in the study area in March and September, only one hatchery rainbow trout was caught that had survived the winter, and it was heavily diseased (Andrus 2000).

About 62,000 hatchery rainbow trout greater than 8 inches long were placed in waters within or near the study area during 2002 (Table 25). Of those, over 18,000 were placed in the Alton Baker Canoe Canal. The bulk of the hatchery rainbow trout were put into the McKenzie River upstream of Hayden Bridge. Hatchery rainbow trout tend to school when released into a river. This, along with their aggressive behavior when feeding, will often result in local displacement of wild fish. Fortunately, they do not seem to wander far from where they are placed. The presence of these non-reproducing and easily-caught hatchery fish takes some pressure off the native trout and provides fishermen meat for the frying pan. Nevertheless, there is probably some incidental catch of larger juvenile Chinook salmon by allowing bait fishing for hatchery trout in places such as the Alton Baker Canoe Canal. Although not confirmed by sampling, Alton Baker Canoe Canal has an unscreened diversion from the Willamette River. Juvenile Chinook are likely shuttled into the Alton Baker Canoe Canal in a manner that is similar to the juvenile Chinook salmon that are diverted from the McKenzie River into Cedar Creek in large numbers.

Interactions between juvenile Chinook salmon released from hatcheries and naturally-reared salmon are probably minor since hatchery fish commonly migrate downstream within a few weeks after they are released (Snelling et al. 1993).

Table 25. Number of hatchery rainbow trout (8 inches and longer) introduced into waters within and near the MECT study area during 2002. Most placed trout are 8 to 10 inches long, with about 4% averaging 12 inches.

Month	Alton Baker Canoe Canal	Lower McKenzie River	Lower Middle Fork Willamette River	Lower Coast Fork Willamette River
February	3,000			
March	3,900			
April	3,900	8,000	1,500	1,500
May	3,900	6,000	1,500	1,200
June	3,900	12,000	4,350	
July		6,000	1,150	
Total	18,600	32,000	8,500	2,700
Grand total = 61,800				

4.1.5 Fish harvest and regulations

The harvest of fish and the level of enforcement of fishing regulations can greatly influence the salmonid population of a river. Within the study area, fishing regulations and their enforcement vary widely (Table 26). Trout fishing in the lower McKenzie River is catch and release for wild trout and only artificial flies and lures are allowed. The other rivers have a 5 fish per day limit and fishing with bait is allowed from April to October. For all waters, steelhead and spring Chinook without a clipped adipose fin must be released.

Table 26. Fishing regulations for water bodies within the MECT study area for 2002.

Water body	Gear	Trout limit
Alton Baker canoe canal	Bait allowed	5/day (year-round)
McKenzie; mouth to Hayden Bridge (reaches 3-9)	Artificial flies and lures only	5/day (year-round)
McKenzie; upstream of Hayden Bridge (reaches 10-14)	Bait allowed (April to December)	5/day for hatchery rainbow trout (April to December); otherwise catch and release
Willamette upstream of McKenzie	Bait allowed	5/day (April to October); otherwise catch and release
Middle Fork Willamette	Bait allowed (April to October)	5/day (April to October); otherwise catch and release
Coast Fork Willamette	Bait allowed (April to October)	5/day (April to October); otherwise catch and release
Long Tom tributaries upstream of Fern Ridge Reservoir	Bait allowed (April to October)	5/day (April to October); otherwise catch and release
Other streams in study area	Artificial flies and lures only	Catch and release
Regulations applying to all waters: No angling for bull trout. Steelhead and Chinook salmon without a clipped adipose fin must be released. No limits on warm water game fish; angling for warm water fish restricted to artificial flies and lures in streams and rivers.		

Funds for State Police and Department of Fish and Wildlife to enforce fishing regulations has decreased in recent years and so salmonid populations may suffer increased levels of poaching in the future. Self-policing by flyfishers and local guides has helped control illegal fishing to some extent.

4.1.6 Conclusions, recommendations, information gaps for fish

Fish populations in study area rivers are relatively healthy due to an abundance of cool water from the McKenzie River and Middle Fork Willamette River, the presence of good physical habitat in many reaches, and the lack of water pollution capable of affecting fish. Major factors that have caused three species to be federally listed as Threatened or Endangered are not directly tied to land use practices in the study area. The future of wild Chinook salmon is threatened mainly by the practice of mixing hatchery fish with the few remaining wild fish. The future of Oregon chub is threatened mostly by invasion of introduced fish into backwater areas and ponds. And, the future of bull trout, probably always an infrequent visitor to lower reaches of study area rivers, is tied to management of spawning and rearing habitat in the upper river basins, as well as, controlling poaching of adults.

Streams in the study area are more affected than rivers by land use practices. Stormwater inputs, an excavated channel, and lack of shading limits the Amazon Creek summer fish community to tolerant species such as dace and redside shiners. The seasonal use of urban streams by trout and juvenile Chinook salmon is largely unknown, but they are probably present at least in the lower portions of streams during the winter. Blockages due to piping of streams probably limit their distribution in some basins such as Russell Creek and Amazon Creek. Artificial water features, such as the Alton Baker canoe canal and the Springfield Mill Race receive water (and fish) from the river and thereby provide habitat to native fish, at least during non-summer months.

The surges in peak discharge and poor quality water due to stormwater have the potential to severely degrade fish habitat in tributaries. Yet, except for certain streams draining into the Long Tom River basin (and also Spring Creek and the East Santa Clara waterway), serious stormwater problems have yet to materialize in the remainder of the study area, either because the stormwater is immediately diluted by river water (Cedar Creek for example) or development has not yet extended far into the basin (Pudding Creek, Russell Creek, and Willow Creek for example). Seasonal fish use occurs in some waterways specifically designed to convey stormwater, such as the Q Street Floodway, but the species and abundance of these fish is unknown.

Portions of the McKenzie River within the study area have exceptional habitat and water quality for Chinook salmon and other native fishes. Reaches 7 and 10 through 14 retain much of their pre-reservoir geometry that favor salmonids. Reach 13 currently lacks some of the channel complexity of neighboring reaches, but it could be restored to its pre-reservoir condition. Reach 24 on the Middle Fork Willamette River and reaches immediately downstream and upstream of the McKenzie River are also exceptional.

It is unclear why salmonid populations in the Willamette River upstream of the McKenzie River confluence and in the Middle Fork Willamette River are less abundant than in the McKenzie River. Water quality declines of the Willamette River as it flows through the urban area is probably not the cause since the relative abundance of salmonids is no greater upstream of the urban area. Differences between the McKenzie River and the upper Willamette River might be due to upstream reservoirs, river substrate, innate channel geometry, and fishing pressure. The upper Willamette River is more affected by peak flow decreases caused by dams, has fewer gravel deposits along its edges and bottom (a function of peak flow decreases and past in-channel gravel mining), and less restrictive fishing regulations.

Information is lacking on juvenile Chinook use of non-river waters within in the study area. Studies of tributaries elsewhere in the Willamette basin indicate that they search out the lower reaches of tributaries during the winter in search of refuge from fast water and to capitalize on terrestrial food sources. Surveys would need to be conducted during the winter or early spring, a time when sampling methods are least effective. Backpack electrofishing is difficult due to the large volume of water present, traps are time-consuming since they need to be visited daily to release fish, and seine nets often get snagged in small streams. Furthermore, the National Marine Fisheries Service has made it extremely difficult to obtain permits for sampling Chinook salmon. Permits applications often need to be submitted a year before the sampling occurs and the permits often come back with severe restrictions on what kind of sampling can occur.

Information is also lacking on the fate of juvenile Chinook salmon within certain waters throughout the year. For example, it is unknown whether or not the juvenile salmon that get shuttled into the Alton Baker Canoe Canal at its Willamette River inlet are surviving bass predation and angling pressure during spring and summer. If sampling indicates that juvenile salmon do not survive in the canal, then perhaps the inlet should be screened to keep them out. Other waters where summer survival of juvenile Chinook is in question include the Springfield Mill Race, Delta Ponds (Debrick Slough), and the near-river gravel pits that get inundated during the winter.

Recent discoveries of two small populations of Oregon chub within and near the study area suggest that other populations could also exist. Information is needed on where other populations are located prior to development or stormwater disposal in areas with preferred habitat. Priority areas to search are off-channel areas in reaches 10 to 14 of the McKenzie River, Oxley and Berkshire Sloughs, and off-channel areas in reaches 24 to 26 of the Middle Fork Willamette River. Paul Scheerer at the Corvallis office of Oregon Department of Fish and Wildlife is responsible for Oregon chub surveys and restoration efforts and is already searching for Oregon chub in some of these areas.

Efforts to protect and restore habitat for juvenile Chinook and other native fishes would logically focus on the lower McKenzie River and Willamette River reaches immediately upstream and downstream of the McKenzie River. It is there that the best remaining habitat and the greatest potential to restore their habitat exists. Nevertheless, there is also a legal responsibility, under the Endangered Species Act, to not engage in activities that result in the “take” of an endangered species, wherever they may occur. The take of an endangered species also includes the destruction of its habitat. Consequently, the use of juvenile Chinook salmon of lower portions of tributary streams and off-channel areas, even if it turns out that use is only seasonal and does not involve many fish, becomes an important issue in the local decision of stream management.

Finally, efforts to protect or improve habitat conditions for listed fish should also include a consideration of the entire fish community. There are other native fish species in the Willamette basin populations in decline (three-spine stickleback and sandroller are examples) and may be federally listed in the future. Attention to specific habitat needs of all native fish today can result in a more effective long-term response to protecting and improving fish habitat than focusing exclusively on species already listed.

Recommendations:

1. Two populations of Oregon chub have been recently located within and adjacent to the study area. More may still exist. Proposed development near sites that are favorable to Oregon chub survival (backwater areas with cold water which helps exclude bass) should be sampled prior to any activities in order to protect the last remaining populations of this endangered species.

2. Although there is a legal responsibility to protect habitat for the threatened spring Chinook salmon wherever it occurs, it’s the rivers and not the streams which provide the best and most extensive habitat for juvenile rearing. Protection and restoration efforts should, therefore, focus on the rivers and especially the McKenzie River.

3. Restoration of Chinook salmon habitat in rivers is costly because it involves rearranging the channel to make preferred habitat features. Natural processes that once did this for free have been truncated by reservoirs and other human activities. Because of the high cost of creating these features, money spent on protecting existing high quality habitat is more cost-effective than restoring lost habitat.

4. Restoration of habitat for Chinook salmon and other salmonids should be directed at mimicking important habitat features that are now scarce. For example, several large logs with rootwads that are secured together at their bases with cable replicate log jams that once provided the nooks and crannies for fish to hide from predators and feed effectively in the current.

Information gaps:

1. Juvenile Chinook use of waterways other than the rivers and Cedar Creek is largely unknown for the study area. Current Chinook use of the Alton Baker Canoe Canal, Delta ponds, and the lower ends of Pudding Creek, Spring Creek, East Santa Clara Waterway, and Springfield Mill Race is suspected but cannot be confirmed. Fish sampling of these streams would best be done in March or April during low-flow conditions. Fish sampling should be accompanied by a survey of obstacles to upstream fish passage.

2. The fate of juvenile Chinook salmon that are shuttled into the Alton Baker Canoe Channel at an unscreened inlet is unknown. Information is needed on whether they try to stay in the channel into the summer season and survive bass predation and how many are inadvertently caught during the intensive fishing for hatchery rainbow trout.

4.2 Western Pond Turtle

The western pond turtle is the only native turtle in the upper Willamette River basin and it is declining rapidly mostly because of its failure to successfully reproduce (Holland 1994). Turtles seen within ponds, rivers, and streams are mostly old adults (15 to 30 years old) with few young turtles. Eggs and young turtles are often eaten by exotic animals such as opossum, dogs, bullfrog, and largemouth bass. Native species that consume eggs and young turtles include raccoons, foxes, and coyotes. A lack of top predators (mountain lion and wolf) has lead to a relatively high population of raccoons and coyotes in the Willamette River basin.

Bare areas are important to turtles since they will nest successfully only where vegetation is sparse and low-lying (Holte 1998). The eggs in their shallow nests require full sunlight and warming of the soil to develop. Yet, bare substrate along Willamette River basin waterways is now rare since aggressive exotic plants have been introduced and peak flows have been dampened by upstream reservoirs. Reed canarygrass, blackberry, and Scotch broom now aggressively occupy many water boundaries. Without floods capable of scouring vegetation and causing periodic shifts in the river boundaries, few bare areas are being created. Sites ideally suited for nesting have a cap of clay that hardens when dry and keeps the nest from caving in and are above the normal high water mark (eggs are deposited in June, young turtles stay in the nests over the winter, and emerge in the spring) (Holte 1998).

For lack of areas without dense vegetation, turtles will often use nearby plowed fields and active gravel roads, often with disastrous results (Bill Castillo, ODFW, Springfield, personal communication). Nesting is more successful where nests are near water since young turtles have a poor sense of direction once they emerge from the nest and are especially vulnerable to predation until they find water (Holte 1998). High islands within rivers offer some of the best conditions for minimizing predation and providing the young turtles immediate access to water. However, some terrestrial predators such as raccoons do swim.

Adult pond turtles often bask in the sun to regulate their temperature. Logs at the fringe or within the water are often chosen by the turtles for basking since they also offer some protection from terrestrial predators. Artificial ponds, such as gravel pits, often lack these logs.

Western pond turtles are relatively common in the MECT study area compared to other portions of the Willamette Valley. Sightings of pond turtles in the MECT area have been compiled and mapped by Eric Wold with the City of Eugene and include main rivers, gravel pit ponds, other excavated ponds, and streams. Pond turtles are particularly common in abandoned gravel pit ponds. Areas of highest pond turtle density in the MECT study area include: lower Amazon Creek (including the West Eugene wetlands), gravel pit and natural ponds near the McKenzie River confluence, within Delta Ponds (old gravel pits and sloughs), areas of slow moving water near the Middle Fork and Coast Fork Willamette River confluence (old gravel mining area), and along the south bank of the McKenzie River and its associated off-channel areas in the flood plain upstream of Springfield. Both juvenile and adult turtles have been observed in a small excavated pond near the Willamette River in the Santa Clara area.

The MECT study area has an unusual density of water features (rivers, streams, old gravel pits, natural ponds), thereby allowing local populations of turtles to interbreed and re-populate areas where turtles have died off. In addition, the bare substrate common to gravel extraction areas allows for some successful nesting. Furthermore, the urban setting of the MECT study area probably means there are fewer foxes and coyotes and, therefore, less predation on turtle nests. Gravel pit operations are usually closed to public access so this probably also reduces predation of nests by dogs and shooting of adult turtles by humans.

Activities to improve nesting success and to reduce predation on young turtles have been modest in the MECT area. Until this year, the Oregon Department of Fish and Wildlife in Springfield operated a “Head Start” program for western pond turtles where eggs were removed from nests, incubated indoors, and the young raised in tanks. Once the turtles were of a certain size, they were placed back into ponds and streams. This program was successful at supplementing younger age classes of turtles but has been discontinued due to budget cuts. Reproductive success at nest sites near Fern Ridge Reservoir was greatly improved by constructing wire cages around nests within 24 hours after egg deposition (Bill Castillo, ODFW, Springfield, personal communication). These efforts required a considerable amount of time since the turtle nesting season extends for several months and the nests are hard to find. At least one person is exploring the use of trained hunting dogs to sniff out turtle nests (Dave Vesley, Pacific Wildlife Research, Corvallis, personal communication).

4.2.1 Conclusions, recommendations, and information gaps for turtles

The study area is well-suited for western pond turtles. Waters capable of supporting turtles are numerous and interconnected. Pond turtles are still relatively numerous throughout the study area, though few young turtles are now seen. Turtles seem tolerant of a range of water quality conditions, ranging from the McKenzie River to lower Amazon Creek. Their most serious threat seems to be a lack of suitable nesting areas and predation upon their nests and young.

Successful nesting in the field will probably require that areas of bare substrate be maintained near high quality rearing habitat. This is challenging since exotic vegetation quickly invades bare areas and the riverside areas. Invading vegetation usually grows high and dense, thereby preventing the sun from warming the nest site and providing cover for predators. The Confluence Group (a combination of gravel extraction companies operating near the McKenzie River confluence, environmental groups, the McKenzie Watershed Council, and state and federal agencies) have initiated projects to improve pond turtle nesting and basking habitat along the Willamette River . Monitoring of turtle nesting success will be a part of this project. Data from sites where pond turtles are already reproducing successfully in the study area would be important for better understanding how to improve reproductive success. Abandoned gravel mining areas and natural sloughs provide some of the best opportunities for improving conditions for turtles.

Recommendations:

1. Efforts to restore wetlands, ponds, and their aquatic biota should include measures to provide

safe nesting areas for turtles. Safe sites include islands surrounded by deep water which helps repel predators and non-vegetated areas that allow the sun to warm the soil around nests.

2. Enlisting volunteers to help with the tracking and fencing of turtle nests can greatly improve turtle nesting success.

Information gaps:

1. Not much is known about the site conditions that are allowing turtles to nest successfully in the study area. A comparison of sites that have young turtles with those that have only old turtles may reveal which conditions are critical in this part of the Willamette Valley.

4.3 Macroinvertebrates

Benthic insects, worms, snails, mollusks, and other aquatic invertebrates, hereafter referred to as macroinvertebrates, represent a community of organisms that spend at least part of their life cycle within the substrate or water column of study area waterways. Macroinvertebrates are important participants in nutrient cycling processes that supply aquatic environments with organic material and other aquatic and terrestrial vertebrates with food. Macroinvertebrates occupy almost every available aquatic niche ranging from within and on almost all substrate types, to free floating in the water column, to skimming along the surface water-air interface. They exhibit a wide range of feeding and reproductive strategies.

The community of macroinvertebrates for a particular water body, when adequately understood, can provide information on the aquatic ecological system. Consequently, macroinvertebrate communities can be useful for assessing and monitoring changes to aquatic habitat, whether the change be related to natural or human disturbances. Via their varied life history patterns, sensitivity to microhabitat change, range of trophic roles, community resilience, and integration of relatively location-specific conditions into their community structure, macroinvertebrates offer a unique way to evaluate the habitat status of streams (Walsh 1996, Hawkins et. al. 1982, Kondratieff et. al. 1984, Pearson 1984, Towns 1981).

The examination of macroinvertebrate communities allows one to assess response to chemical (e.g., bacteria, heavy metals, and dissolved oxygen), physical (e.g., stream temperature, flow, and substrate) and habitat condition change (e.g., riparian/aquatic plant communities, and shade) (Kondratieff et. al. 1984). However, because macroinvertebrate community response varies widely according to the local setting, trying to determine a clear community response can be quite difficult. Both macroinvertebrate populations and the sampling of them are subject to high variability (McElravey et. al. 1989, Resh and Rosenberg 1989, Resh 1979, Cummins 1962, Needham and Usinger 1956). Sources of variability include:

- Life cycle and emergence patterns that can shift with changes in habitat (Newbold et. al. 1994, Towns 1985)
- Microhabitat preferences (including substrate, flow, and food availability) (Downes et. al. 1993, Reice 1980)

- Drift response (Richards and Minshall 1988, Hall et. al. 1980)
- Response to disturbance (Richards and Minshall 1992, Reice 1985, Pearson 1984)
- Recovery patterns after disturbance (Tikkanen 1994, Williams 1976, Waters 1964)

Sampling variability can be reduced by attention to sample collection techniques (Brussock and Brown 1991, Cummins 1962). For example, for monitoring stream conditions over time, macroinvertebrate samples should be collected:

- at the same sampling point
- from similar microhabitats (flow, substrate, light conditions) among sample sites
- at the same time of year each sample season
- using the same equipment and techniques each year (net mesh, sample area)

Macroinvertebrate information has been collected at a number of locations in study area streams and rivers (Table 27, Map 12). The collection objectives, methodologies, and consistencies differ in many respects among studies. Detailed descriptions of these projects, their methodologies, and their conclusions are available in Appendix B.

Table 27. Macroinvertebrate sampling studies that have been conducted in the MECT study area.

Water Body	Sampling Agent	Date	No. of stations	Quantifiable data	Site map reference*
Amazon Creek	ABA, Inc.	April 1999	3	Yes	1 – 3
	Anderson, T., W.R. Tinniswood and P. Jepson	December 1996, April 1997	4	No	4 – 7
	City of Eugene	April 2001	8	Yes	57-64
	Rachel Carson Natural Resource School	1999-2002	4	No	NA
Willow Creek	City of Eugene and Woodward-Clyde	1995	8	Yes	20 – 27
	Cary Kerst	1995-2002	NA	No	28, 30-32, 35
	Rachel Carson Natural Resource School	1999-2002	2	No	NA
A-3 Channel	DEQ	May 1996	3	No	38 – 40
Spring Creek	ABA	April 1999	1	Yes	41
West Eugene Wetlands	Steve Gordon and Cary Kerst		NA	No	NA
Cedar Creek	McKenzie Watershed Council	Fall 1998, Fall 1999	2	Yes	42
McKenzie River	McKenzie Watershed Council		2	Yes	44 – 45
Willamette River	City of Eugene	Fall/Spring 1994-2001	8-11	Yes	46 – 56

*Site map reference numbers correspond with sample site numbers on Map 12.

4.3.1 Evaluation of Sites and Methods

Overall, the basin-wide macroinvertebrate sampling effort, though uncoordinated, is fairly impressive. Some of the strengths of the available information are:

- Consistent use of a single lab to pick and identify samples and organize data
- Sampling over time at fairly similar sites
- Sampling at consistent seasonal times each year
- Involvement of local high schools and watershed councils in data collection efforts to help keep costs low

There are also weaknesses, however. Attention to sampling design planning and development was not as consistent among the study area macroinvertebrate efforts as it was to sample collection and interpretation. Though some projects demonstrate thorough planning and understanding of sampling design and macroinvertebrate sampling variability, others can improve. For example, sampling within Cedar Creek has not been collected consistently each year from the same locations. Data has been collected for three years at three separate, single-sample locations. This results in a database where year-to-year variability at a site cannot be distinguished well from site-to-site variability. If funding limits the ability to sample many sites every year for a period of time, sampling many sites in a single year and then doing this every few years yields better information than sampling single, different sites each year.

Though qualitative surveys, such as those performed by the Department of Environmental Quality on the A-3 Channel and C. Kerst and S. Gordon on Willow Creek and elsewhere, are less expensive than quantitative surveys, their results cannot be combined with quantitative surveys. Qualitative surveys may serve some specialized information need by a group, but they rarely add much to the general understanding of an area. Simple, non-systematic overviews of collected adults can be valuable as long as educated and interested volunteers consistently apply themselves to a particular region, much like bird watchers have done at times.

One of the greatest strengths of the MECT study area macroinvertebrate data is the consistent use of one or two third-party, professional laboratory firms that apply rigorous criteria to their sorting, identifying, and counting methods. All samples analyzed using ABA, Inc.'s standard sampling methodology were characterized by applying a multimetric bioassessment for Pacific Northwest *montane* streams. Except for the highest reaches on Amazon Creek, none of the sample sites in the study area correspond well to the montane index. ABA, Inc. is close to finishing development on a multimetric bioassessment for Pacific Northwest urban streams (personal communication, R. Wisseman). A more region-specific index may help tease out the complex interactions within macroinvertebrate communities between unique habitats and the broader environment.

Macroinvertebrates in Willamette Valley streams and rivers are best sampled in the spring or early fall. Fall sampling tends to be favored in larger systems because populations have had a chance to develop without significant flow disturbance. In addition, when sampling objectives are designed to attempt to determine response to particularly point source pollution, increased spring flows may have a dilution effect, thereby reducing the likelihood of monitoring a macroinvertebrate response. Fall sampling should be considered in these and similar cases. However, because many smaller streams are dry in early fall, small system sampling may be more successful in the spring. In summer-dry systems, such as Willow Creek, spring sampling should be earlier. Because, emergence begins much earlier (e.g., in Willow Creek, 48% of 2,652 Ephemeroptera, Plecoptera, and Trichoptera collected in emergence traps emerged before April 1), early March is a more appropriate time. In perennial systems, spring sample timing should aim for April to remain consistent with previous sampling efforts in the MECT area. By this time, macroinvertebrate communities have recovered from disturbance caused by winter high flows, but have not yet experienced significant adult emergence (i.e., natural drop in population numbers).

For a single monitoring project, good sample sites are those with homogeneity, adequate flow, and no large changes in substrate during the season (e.g., from bare riffle to aquatic macrophyte growth). Because study area rivers are influenced by reservoir flow regulation, sampling sites on river channels will experience aberrant flow regimes when compared to natural flow conditions. Consistent sampling at a specific site may become difficult as riffles are unseasonally inundated. Sampled communities may exhibit abnormal characteristics as they respond to atypical changes in habitat conditions. Having backup sample sites for different flow conditions, recording flow levels at local USGS gauging stations at time of sampling, and sampling over time may help account for this source of variability.

4.3.3 Macroinvertebrate community overview

The following data synthesis was conducted to provide an overview of the aquatic macroinvertebrate community in the study area. In this multi-project macroinvertebrate data analysis, sampling sites that were fairly close to each other were grouped to discourage the tendency to search for effects based on a project's original objectives (which are not part of this data grouping objective) and to equalize longitudinal differences between sample points as much as possible (i.e., not to over-weight data differences among closely grouped sample sites compared to long unsampled reaches).

Because of the general overall emphasis of each study area project on generating the best data possible from the site samples (i.e., use of a professional laboratory for sample analysis), most of the data from different sample sites and projects could be grouped together to observe study area spatial and temporal variability. Despite this strength, however, grouping data from different studies for the purpose of evaluating cause and effects is strongly discouraged. Those sorts of conclusions can only be drawn using a focused, objectives-based sampling design.

In order to compare results of the various macroinvertebrate samples, we constructed the following indices from the raw data:

- Hilsenhoff Biotic Index (HBI). This index provides a picture of the macroinvertebrate communities' tolerance to pollution within their habitat. A low level indicates a generally intolerant community (more sensitive to environmental stressors) while a higher value indicates a more tolerant community (less sensitive to environmental stressors).

- Brillouin H. This is a diversity index that measures the abundance (number) and richness (distribution of organisms among taxa) of a sample. Higher numbers reflect increasing diversity within the total sample population and, therefore, varied habitat and food sources able to support a more diverse community.

- EPT:Chironomidae. This ratio is a measure of the relative abundance of typically more sensitive Ephemeroptera (mayflies) , Plecoptera (stoneflies), and Trichoptera (caddis) genera with the typically less sensitive Chironomidae (true flies) populations. The closer this index is to 1, the more balanced the populations. Such a result, along with a coinciding substantial representation of the EPT genera, is one indication of positive biotic conditions within the sample area. Numbers greater than 1 indicate healthy habitat and decreasing numbers indicate proportionate increases in the tolerant Chironomidae family, or less favorable conditions.

- %Shredder. The shredder functional feeding group gathers its food from material that falls into the stream system from outside sources. They are typically associated with higher, headwater streams that are covered by a relatively complete riparian canopy that provides their food sources. Because of this headwater association, shredders are typically intolerant taxa. However, even in excellent conditions, one would not expect to find them in large amounts in a more open stream lower in the valley.

- %Collector-filterer. The collector-filterer functional feeding group is, as a whole, more tolerant of pollution and disturbance. Collector-filterers weave silk nets to filter suspended particles from the water. Increases in the percentage of collector-filterers could indicate increases in available food due to upstream disturbance or increased suspension of organics within the water column that favor this functional feeding group over others.

- *%Oligochaeta*. Oligochaetes, or aquatic worms, are a highly tolerant taxa that, though normally present in small numbers in most aquatic systems, become one of the few taxa to thrive under polluted conditions. Though not the only highly tolerant taxa, increases in percentages of Oligochaetes are fairly clear indicators of increasing pollution levels.

Study area setting

In general, little habitat data was collected with the aquatic insect samples. Some projects did record that samples had been collected in a riffle or run environment. However, other projects identified the sample site as simply “riffle/run” and others did not identify the site other than by geographical location. Therefore, determining habitat quality, similarities, or differences among the sample sites or grouping sample sites by habitat types in the figures below to further account for sample variability was not possible.

Observationally, however, it is clear that a wide range of macroinvertebrate habitat conditions are potentially present within the study area. Within the smaller non-river waterways, the south end of the study area contains forested/valley headwater systems, such as upper Amazon Creek and Willow Creek, that are undergoing development. Between these two headwater systems, food sources, gradient, substrate, and flow conditions vary dramatically from a macroinvertebrate microhabitat perspective. Proceeding northward, small stream systems are affected by urbanization including excavation, channel straightening, stormwater pipe outlets, removal of riparian vegetation, and bank and substrate hardening. These modifications have the potential to dramatically affect macroinvertebrate habitat by altering food and energy sources and channel hydrology and hydraulics. There is also natural variation; streambeds in the basalt geology are usually rich in gravel while streams in the Missoula flood deposit geology are lined mostly by fine material.

Heavily-impacted urban waterways that were sampled included lower Amazon Creek and Spring Creek. Cedar Creek flows along the north side of Springfield and is likely influenced by McKenzie River hyporheic flow, riparian vegetation, and channel movement. For these reasons, it exhibits unique attributes including mixing of small stream/large river and more rural/urban pollution influences.

In the river systems of the Middle Fork, Coast Fork, Willamette, and McKenzie Rivers, macroinvertebrate habitat conditions are highly variable. Microhabitats in terms of flow conditions and substrates can range from backwater depositional areas to rapid shallow flow over smooth substrates within one cross-sectional area of a river. Consistent attention to sample location type is critical to obtain comparative data. Samples that have been collected on the Willamette River since 1994 have all been collected from “classic” riffle environments (including the most downstream site, #46) with the exception of the two sample sites below Beltline. No riffles were present in this area to sample (Kerst, personal communication). However, these collection sites are critical to the testing of the project hypothesis and, therefore, are defensible. A balance of ideal sample location characteristics and project objectives is always necessary. Accurate and thorough recording of differences and basis for decisions made can account for these situations.

Longitudinal change

Longitudinal change in taxa and functional feeding groups as related to habitat change is a commonly accepted macroinvertebrate community structure theory (Statzner & Higler 1986, Vannote et. al. 1980, Towns 1979). The assumption is that as micro- and macro-habitats and dominant food sources change in a downstream direction, the macroinvertebrate populations will reflect this by changing as well. The shredder functional feeding group, for example, will be a larger percentage of the population in smaller streams with dense surrounding vegetation but a smaller percentage in larger systems with less terrestrial organic inputs and greater flows. The collector-filterer functional feeding group, on the other hand, will be less represented in smaller streams which are nutrient poor and more abundant in larger streams where more material is transported within the water column.

Indeed, this phenomenon is reflected in the pooled MECT macroinvertebrate data (Figure 50), showing a pattern of greater abundance of the shredder feeding group in the headwater systems and less representation in the larger rivers. The clearest example of this relationship is on the Willow Creek system. The Willow Creek data was collected in 1996 for the specific purpose of serving as baseline data prior to basin development (Woodward-Clyde, 1996). Though the stream is dry in the summer, data from Willow Creek offers probably the most “pristine” macroinvertebrate populations of all available data. Shredder populations on Amazon Creek are fairly low, despite heavy riparian vegetation. Sedimentation, altered hydrology from stormwater inputs, and increased hydraulic forces caused by channelization, three conditions that would discourage shredder populations and favor more collector-type functional feeding groups, already affect the Amazon Creek system by this point in the basin. Vegetation inputs also shift on Amazon Creek from predominantly leaf litter detritus to grass and blackberry leaves soon after Dillard Road. Anderson et. al. (1997) observed in their report on Amazon Creek a general lack of intolerant shredders such as stoneflies (which are commonly associated with leaf litter mats) and the dominance of more tolerant shredders such as chironomids in reaches that were dominated by overhanging exotic vegetation species (e.g., reed canary grass and blackberry) (for more discussion on this report, see Appendix B).

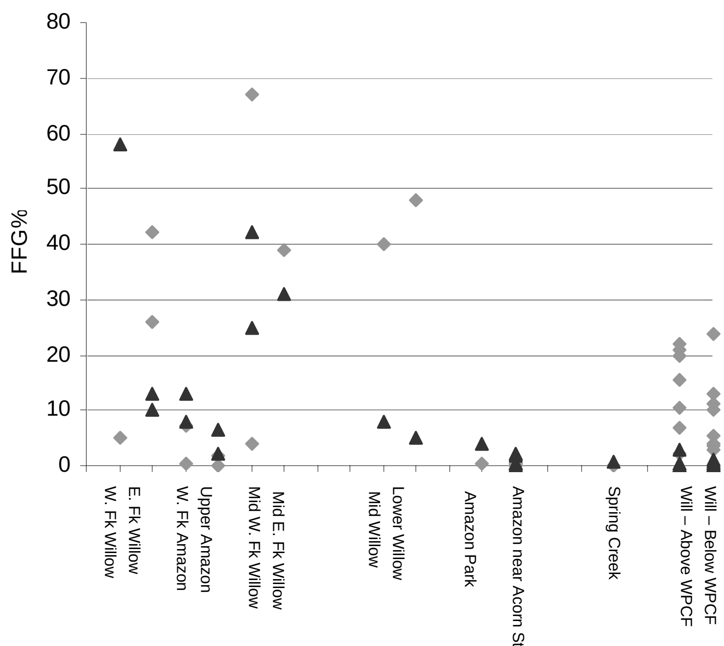


Figure 52. Spring % shredder (▲) and % collector-filterer (◆) functional feeding groups (FFG) from headwaters of Amazon (Willow Creek) to the Willamette River below the wastewater treatment plant. 1994-1999 data.

Collector-filterer populations do not exhibit as clear a response to longitudinal change. This could be expected because collector-filterers feed on a broader range of food types than shredders and, as a group, are not clearly tied to the presence or absence of a particular food source. In addition, many of the small streams in the study area are influenced by pollution and other abiotic factors which may already be loading the water column with nutrients. Kondratieff et. al. (1984) observed that stations stressed by urbanization were dominated by collector-gatherers and filterers to the virtual exclusion of scrapers. Some of the stations high up in the study area may already be stressed enough to exhibit these shifts. In the case of some of the more urban-influenced study area waterways such as Amazon Park and Spring Creek, the longitudinal change model fails to hold as collector-filterers are eliminated from the sampled populations (Figure 52).

The clearest possible traditional example of a shift to collector-filterer feeding groups is not observable longitudinally. The Willamette River data points show that above and below the Eugene-Springfield Water Pollution Control Facility (WPCF), collector-filterers are consistently more abundant than the shredder populations over time (from 1994 to 1999). The collector-filterer populations sampled in the spring are the less abundant of the spring/fall collector-filterer cohorts. Figure 53 shows that fall populations of collector-filterers consistently make up a larger portion of the population on the Willamette River.

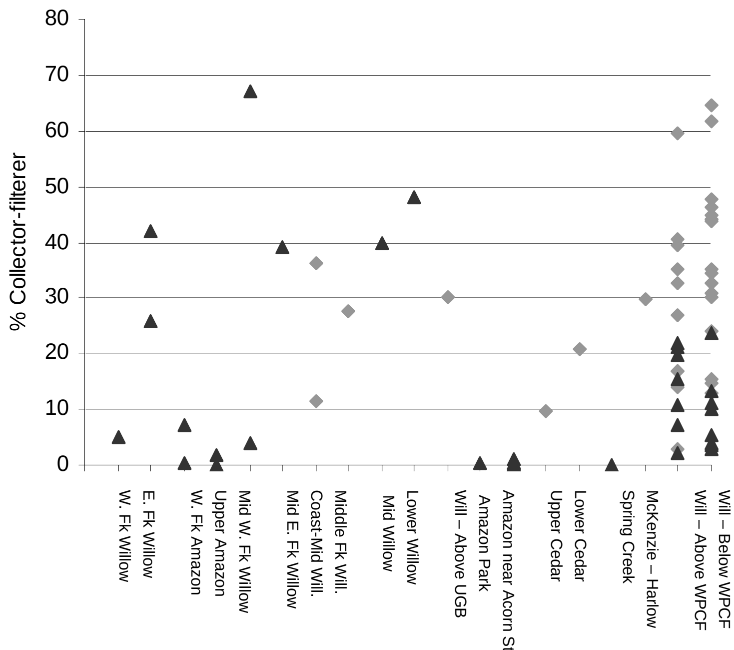


Figure 53. Percent collector-filterer populations in the MECT study area from headwater to lower river reaches for spring (▲) and fall (◇). 1994-1999 sample data.

In Figure 52 and 53, both shredders and collector-filterers exhibit depressed populations in the middle reaches of Amazon Creek and in Spring Creek. These reaches are heavily affected by urbanization including stormwater inputs, pollution sources, reduced riparian vegetation, and increased sedimentation. There is a notable difference in collector-filterer population percentages between the Lower Willow Creek site and the Amazon Creek Acorn Bridge site. Little less than a mile separates these two sampling sites. However, the Willow Creek functional feeding group community is almost 50% comprised of collector-filterers while the Amazon Creek site's community is 0.2% collector-filterer. Continued sampling over time, additional selection of sampling points related specifically to this hypothesis, and the same sampling methodology would need to be applied to determine what factors were causing this difference in populations between the two nearby systems.

Seasonal change

Macroinvertebrate sampling efforts within the study area occurs in both the spring and fall. Both seasons are acceptable periods for sampling macroinvertebrates. Understanding the natural variability of a community is important in being able to sort out possible disturbance effects (McElravey et. al. 1989, Cummins 1962). Seasonal community responses are part of the natural variability that occurs outside the effects of anthropogenic disturbance. Whiting and Clifford (1983) observed that macroinvertebrate diversity was lower in urban streams in the spring because large numbers of tubificids [aquatic worms] were present. Though their large numbers were likely enhanced by organic enrichment, the surge in numbers could also be part of natural life history. To determine whether seasonal sampling differences might contribute to variability within the study area macroinvertebrate community information, Figure 54 displays the Brillouin H index from headwater to rivers. Willow Creek is not included because Brillouin H was not calculated for that project. However, because sampling in the fall is not an option for this system, its absence is not critical.

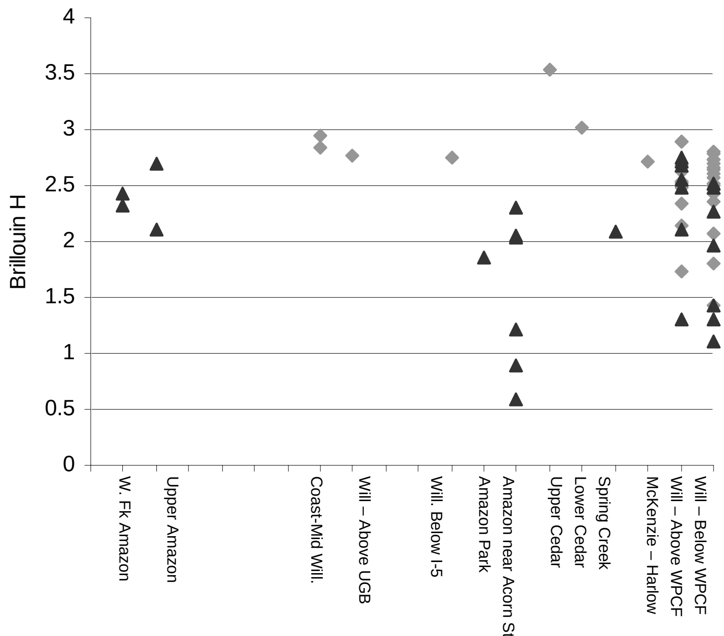


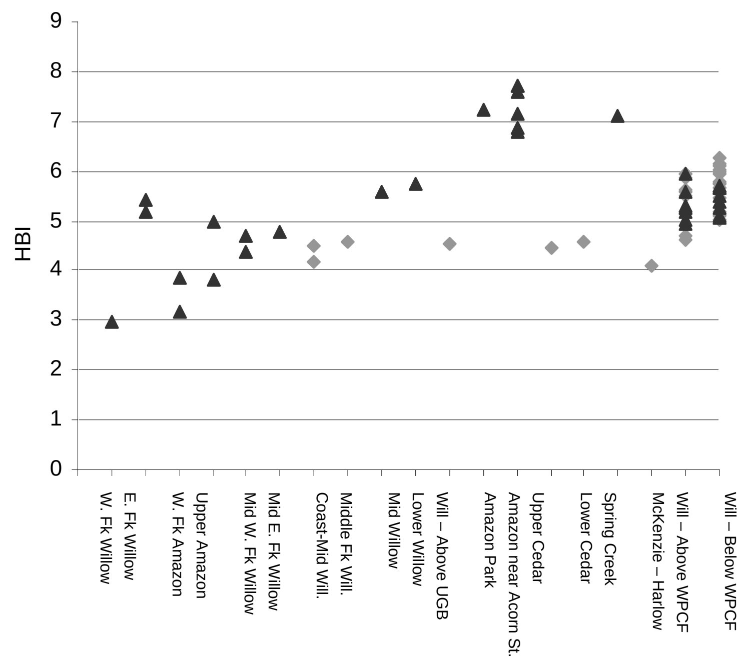
Figure 54. Brillouin H for spring (▲) and fall (◆) samples taken throughout the MECT study area from 1994-1999.

In general, there does not appear to be an observable difference in sample diversity between spring and fall. This is further supported by the overlap in the Willamette River samples. This data set was the only one currently available that had both spring and fall samples taken at the same sample sites. Either a spring or a fall sample, and in one year (1995) both spring and fall, have been taken since 1994. The low fall Brillouin H metrics for the mid-Amazon sites are a result of local poor habitat conditions rather than season of sampling. The highest point is well within the range exhibited by other sites. The Long Tom Watershed Council and the City of Eugene sampled this site in fall 2001 and spring 2002. With current funding, they will continue sampling in both fall and spring through spring 2003. Data for the later sampling dates were unavailable at this time. The planned sampling regime will allow analysts to observe potential differences between fall and spring sampling within this degraded system.

Though unrelated to sampling season, of particular note in terms of diversity is the upper Cedar Creek site, located near Cedar Flats Road. Though outside the study area boundary, the site was included because of the importance of Cedar Creek in terms of its potential response to Springfield's influences, its proximity to the McKenzie, and the lack of sampling data on the creek as a whole. Cedar Creek is a unique stream system closely tied to the McKenzie River because a water diversion provides river water to that portion of the stream downstream of the highway. It is noteworthy in Figure 54, that a single year and point's sample produced the macroinvertebrate community with the highest recorded diversity near the study area. Exploring the variability around this diversity value through increased spatial (more points) and temporal (more years) sampling would provide more information on Cedar Creek's habitat potential and current quality.

Healthy and degraded systems

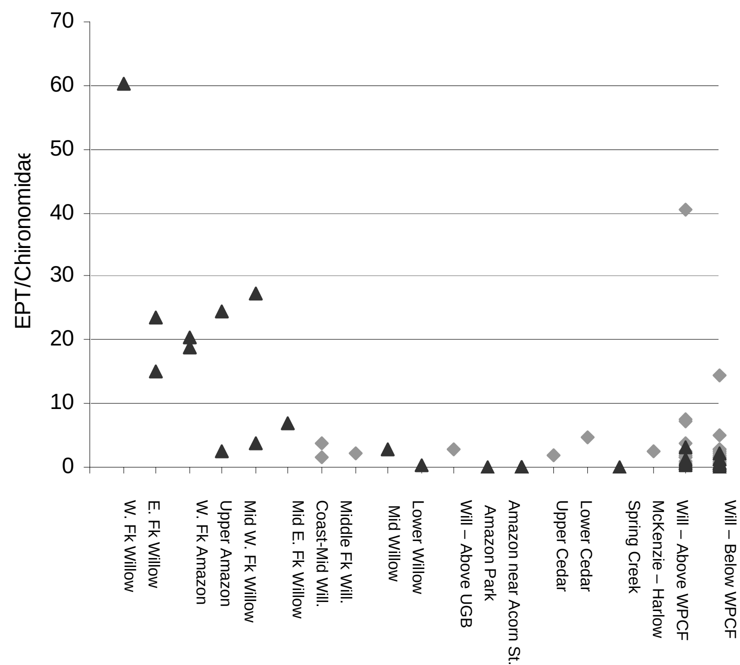
Each study, even those with only a single data point, within the study area has asked a specific question about a site's condition. Those questions can only be approached with project specific data. However, because many of the projects implemented in the basin collected, identified, and counted macroinvertebrate samples using similar methods, a gross overview of study area hotspots for healthy and poor macroinvertebrate communities can be generated. These spots should be viewed as only a coarse guide to areas where aquatic conditions may be fairly healthy or are clearly poorer than general basin macroinvertebrate community levels. They cannot be interpreted from a cause and effect perspective. The factors which create the observed conditions are unknown until monitored. To examine trends of general macroinvertebrate community condition, three indices were chosen: the Hilsenhoff Biotic Index (HBI), EPT:Chironomidae ratio, and %Oligochaetes.



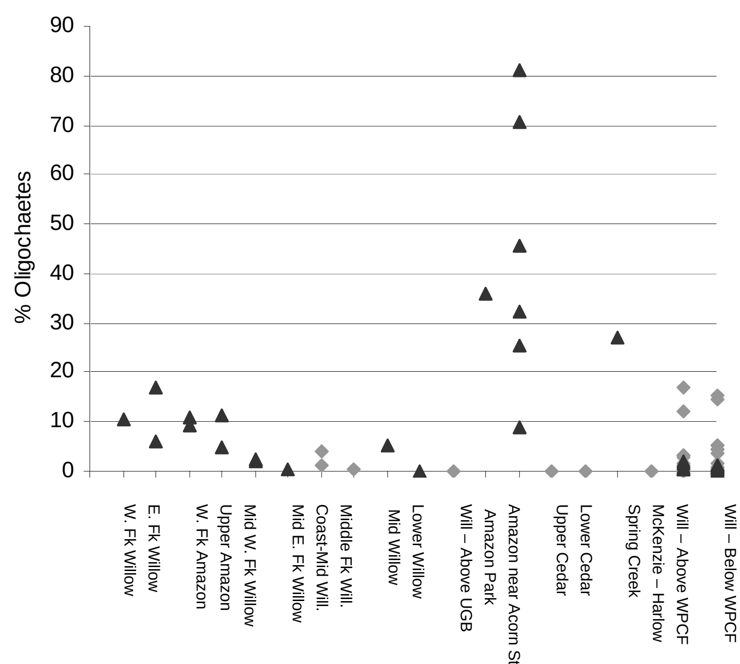
<u>Figure 55</u>. Change in HBI from high in the basin to lower river reaches for both spring (▲) and fall (◆) sampling seasons. 1994-1999 sample data.

In general, HBI remains fairly consistent through the MECT study area (Figure 55). Higher values of HBI indicate increasing response to organic pollutants within the system through changes in macroinvertebrate community structure. Some higher order reaches have slightly lower HBI values than average. Because there is little to no reference data for stream reaches in the upper Willamette Valley, it is uncertain whether the HBI values observed in Willow Creek are high, average, or low for these higher-order, smaller systems. The highest HBI values were observed for the middle reaches of Amazon Creek and Spring Creek. The McKenzie sample point shows fairly low HBI values for the sample area and the Cedar Creek sample sites are also fairly low.

Higher in the study area, in the smaller streams, the members of the Ephemeroptera, Plecoptera, and Trichoptera orders are far more abundant than the Chironomidae (Figure 56). Quickly, however, these ratios fall and through most of the urbanized areas, the ratio is fairly low. At some sample points, particularly in the middle reaches of Amazon Creek and at Spring Creek, no EPT cohorts were recorded and the ratio is zero. Ratios rise again inconsistently in the Willamette River. The fall sampled outlier for the Willamette River sampling points above the Eugene-Springfield Water Pollution Control Facility was caused by a sample that collected 525 EPT taxa and 13 Chironomidae. Over 200 Glossosoma caddis flies were collected alone (Kerst, personal communication, April 2002). Glossosoma are periphyton scrapers that do not tolerate sedimentation or large aquatic plants (Walsh 1996).



<u>Figure 56</u>. EPT:Chironomidae ratio for the spring (▲) and fall (◆) samples in the MECT Study area. 1994-1999 sample data.



<u>Figure 57</u>. %Oligochaetes for spring (▲) and fall (◆) samples in the MECT study area. 1994-1999 sample data.

Oligochaetes or aquatic worms are highly tolerant aquatic invertebrates. They are common to most aquatic systems. However, they are one of the few tolerant taxa to thrive under severely degraded conditions. Their presence in the basin community is observed across all sampling sites (Figure 57). If we exclude the middle reaches of Amazon Creek and Spring Creek, the proportion of sampled populations range from 0-17%. The middle reaches of Amazon Creek and Spring Creek, however, contain far greater percentages of Oligochaetes and reach as high as 82%.

In general, using the three indices of macroinvertebrate community health, the sample sites that exhibit relatively healthy community conditions are those at the upper headwaters of Willow and Amazon Creeks, Cedar Creek, and the McKenzie River. Sampled reaches on the Willamette River exhibit average to healthy macroinvertebrate populations for the study area. The middle reaches of Amazon Creek and Spring Creek are clearly more influenced by pollutants than the other sample sites. Because these measures are relative, however, the "healthy" site should be monitored if necessary to determine community response to urban influences. One cannot assume these sites will remain in their current relative condition. In particular, Cedar Creek, which currently exhibits consistently positive community metrics for the study area, should be monitored more extensively. The potential for pollution exists and the examined sample population was small in both time (one year) and space (two sites).

Willamette River focus

Data have been collected on the Willamette River since 1994 at the same sampling sites around the Eugene-Springfield Water Pollution Control Facility. In 1999, three new sampling sites were added to explore macroinvertebrate community condition above the Eugene-Springfield Urban Growth Boundary (UGB) and to compare these observed conditions to those monitored around the WPCF (for more detail on this project, see Appendix D). The WPCF-Willamette macroinvertebrate monitoring project provides the strongest data set in the study area because of its temporal and spatial consistency. Examined within the context of the overall study area as conducted above, the Willamette River sample sites exhibit a degree of variability probably found within many of the study area's populations monitored between years, seasons, and closely situated sample sites. However, because of sample site proximity to the WPCF and the recent sampling design expansion to address possible within-UGB/outside-UGB community differences, it is worthwhile to briefly examine the sites using the HBI pollution tolerance index and the Brillouin H diversity index.

To reduce between year and between season variability, only samples taken in 1999 and 2000 were used. Both years sampled in the fall. The two years were used because data for above the UGB and below I-5 were only available for 1999 and data for the Coast and Middle Forks were only available for 2000.

Figure 58 shows that HBI values on the Coast and Middle Forks, above the UGB, and below I-5 are relatively low, indicating a macroinvertebrate community with a greater sensitivity to pollution.

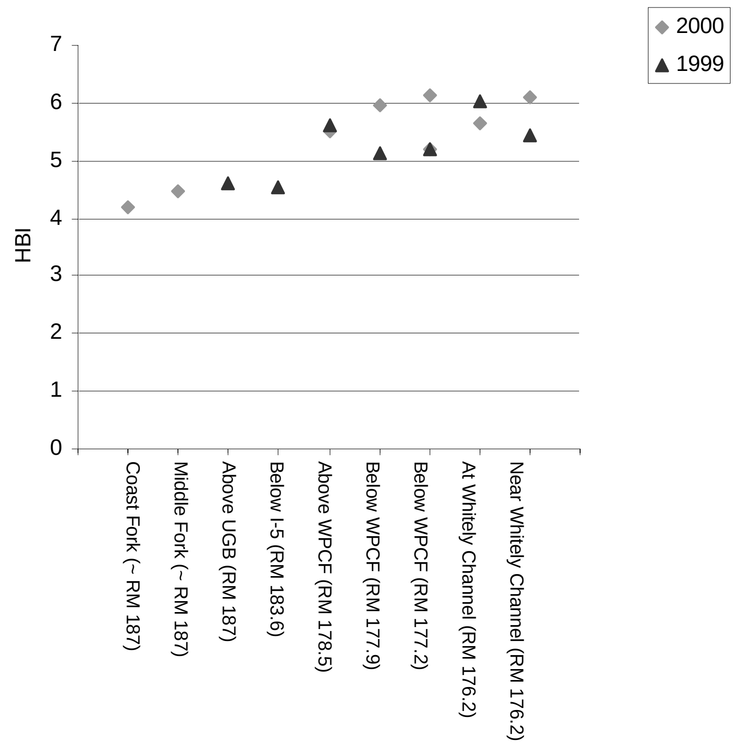


Figure 58. HBI for fall 1999 (▲) and fall 2000 (◆) samples on the Willamette Rivers within the MECT study area from the Coast and Middle Forks and above the urban growth boundary (UGB) to below the Eugene-Springfield Water Pollution Control Facility (WPCF).

Within the UGB around the WPCF, HBI values rise and, though there is variability between years, both years' samples indicate the presence of a macroinvertebrate community that tolerates more pollution than the insects above the UGB.

Community diversity, as described by the Brillouin H index, decreases slightly from above the UGB to below the UGB (Figure 59). The difference is not large though, especially when compared to the change between years at the same sample sites. Brillouin H values range from 2.36 to 2.95 among the Willamette River sample sites. In contrast, Brillouin H values for the entire study area ranged from 0.6 to 3.6. Variability between years at a few of the sample points was almost as great as the range between stations.

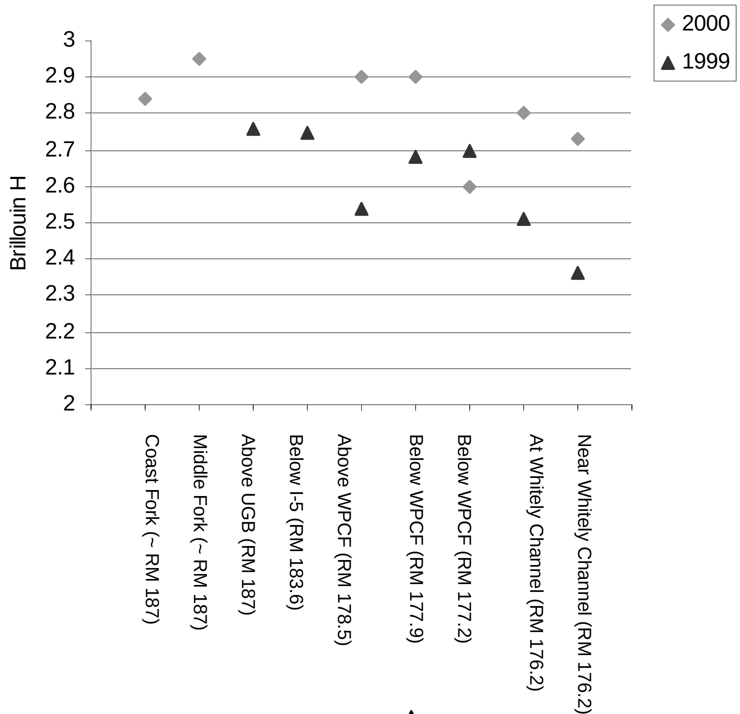


Figure 59. Brillouin H for fall 1999 (▲) and fall 2000 (◆) samples on the Willamette Rivers within the MECT study area from the Coast and Middle Forks and above the urban growth boundary (UGB) to below the Eugene-Springfield Water Pollution Control Facility (WPCF).

It should be noted as well that the EPT:Chironomidae ratio for these sample sites and years on the Willamette River showed no difference between macroinvertebrate communities above the UGB and those around the WPCF. The highest ratio value, which indicates a proportionately greater abundance of Ephemeroptera, Plecoptera, and Trichoptera populations compared to Chironomidae, was found in 1999 at the sample station near the entrance of Whitely Channel below the WPCF, the farthest downstream site.

4.3.4 Conclusions, recommendations, and information gaps on macroinvertebrates

In general, data collected throughout the study area indicate that the diversity and sensitivity to pollution of the study area's macroinvertebrate community appears relatively consistent. An exception is the macroinvertebrate community sampled in the middle reaches of Amazon Creek, which appear to be more tolerant of degraded water and less diverse. Macroinvertebrate communities in other study area waterways with conditions similar to these stretches of Amazon Creek may be expected to be as affected.

Excluding the urbanized reaches of Amazon Creek, the macroinvertebrate communities in study area non-river waterways do not differ greatly from those found in study area rivers. Though some smaller waterways, such as Cedar Creek and Willow Creek, contain more diverse and less pollution tolerant communities, in general, this consistency between systems is probably indicative of a moderately healthy river macroinvertebrate community and a possibly less-healthy non-river waterway macroinvertebrate community. However, reference data sets or bioassessment indices are not currently available for Willamette Valley streams and rivers. Therefore, it is impossible to accurately define the health status of the macroinvertebrate community within the study area.

Recommendations:

1. For new projects yet to be implemented, use macroinvertebrate monitoring to assess physical habitat improvement. Suggestions include monitoring:

- Planned restoration site for at least two seasons prior to installation, throughout installation, and then after installation
- At the same time of the year
- Within similar habitats (riffle/run, e.g.)
- With the same intensity each time

2. Measure and record physical habitat conditions at sampling site since observed community structure changes can easily be misattributed without an understanding of background abiotic factors. This will help better account for background variability or conditions that affect the local macroinvertebrate community. Variables of interest would be:

- Substrate size and composition and channel form
- Shade and bank vegetation (understory and overstory)
- Flow conditions

Many studies have demonstrated that substrate has a significant effect on observed macroinvertebrate communities (Reice 1980, Cummins 1962). Macroinvertebrate communities within riffles and pools can be quite different. Year-to-year variability can be more apparent in riffle habitats than in pool habitats. To attempt to account for these differences, record substrate and channel form at the sample site and sample consistently from the same substrate and within the same channel form (Brussock and Brown 1991, McElravey et. al. 1989). Hawkins et. al. (1982) observed that canopy type was a greater influence than substrate character on total macroinvertebrate abundance and functional feeding group representation. When attempting to determine effects of a disturbance other than canopy disturbance, select sample sites with similar canopy structure to reduce variability. McElravey et. al. (1989) also found that communities in years with peak discharges on a third order stream showed reductions in macroinvertebrate densities and increases in relative proportions of Chironomidae. Without knowledge of basic flow conditions, understanding this potential source of community response is much more difficult and ripe for error.

3. Continue to use ABA, Inc. or other similar services whenever possible. Encourage new project managers to do the same. Consistent analysis of samples allows for the comparison of data throughout the basin. In the data sets ABA, Inc. currently interprets for study area projects, they use a montane macroinvertebrate index that does not account for unique habitat conditions found in valley stream environments. ABA, Inc. will be releasing a new metric system sometime in 2002 that will improve upon the current set of metrics used to evaluate data. It will include allowance for more than one functional feeding group assignment, greater inclusion of response to local habitat changes (tolerance of temperature increases, substrate, etc.), and three separate indices for montane, mid-order, and riverine environments (R. Wisseman, personal

communication). In order to more accurately interpret the quality and health of a macroinvertebrate community, project managers should request that new valley floor waterway or river data sets being sent to ABA, Inc. be analyzed using this new bioassessment metric.

4. Except for monitoring to assess restoration efforts, discontinue general macroinvertebrate monitoring efforts on Amazon Creek. This stormwater flow channel continues to be affected by past management decisions and is constricted from any major change by the current urban setting. The aquatic macroinvertebrate communities along the stretches that flow through Eugene appear to be a long way from the point where community recovery would be observable. Negative cumulative effects from upstream polluted reaches will most likely be the primary inhibitors of monitoring any sort of significant change for the near future. Monitoring efforts and monies may be better applied elsewhere. One significant exception to this is the ongoing effort surrounding the Amazon Creek widening project near Acorn Park. The design, planning, and long-term focus of this project serve as an example of objective-based macroinvertebrate monitoring. If long-term monitoring is to continue on Amazon Creek, attempt to establish a reference site further up into the headwater area. Macroinvertebrate community dynamics are likely affected by the time the streams reach Martin Street. Natural springs abound up near Owl Road and could serve as spring and fall sampling sites.

5. Conduct further and intensified monitoring on Cedar Creek. Though this waterway currently exhibits fairly healthy community diversity, it stands to experience increasing effects from Springfield development. As a system, Cedar Creek also appears to be significantly connected to the McKenzie River. Along with other water quality parameters, there is the clear possibility that the two systems share macroinvertebrate communities through groundwater flow, intergravel communities, and aerial dispersal. Macroinvertebrate monitoring on Cedar Creek is recommended by the EWEB Stormwater and Urban Water Monitoring Plan to continue to support its objectives (EWEB 2001). A thorough review of the current macroinvertebrate monitoring plan design based on the objectives of various participating organizations is recommended to determine if questions will be answered in the plan's current format.

6. Attempt to coordinate with the USFS Blue River District and other larger basin stakeholders to help determine reservoir and flow regulation effects on macroinvertebrates. Expanding out to include samples collected within the larger "true" watersheds will greatly assist in understanding the current habitat condition of the study area and possible changes occurring within it.

Information needs:

1. Little is known about the macroinvertebrate communities in small Willamette Valley perennial streams that are undisturbed by development. Macroinvertebrate sampling of the undeveloped Pudding Creek would provide this information.

5. Synthesis

The rivers of the study area, though altered since European settlement, still yield relatively clean water and provide high quality habitat for fish, pond turtles, and macroinvertebrates. Urban water pollutants are either shuttled away from the study area via the Long Tom drainage or are diluted by river flows that are supplemented by upstream reservoir releases during the summer and fall. The rivers have low concentrations of bacteria, heavy metals, and nutrients. Reservoir releases of water in the McKenzie River and Middle Fork Willamette River during the summer increase river depth and help keep the water cool.

Amazon Creek, the most urbanized stream in the study area, suffers from high concentrations of heavy metals, nutrients, and bacteria. Along with an excavated channel, increased peak flows, warm water, and piped tributaries, it is habitat to only the hardiest of native fish. Willow Creek, Amazon Creek's relatively undeveloped tributary, still provides a glimpse of the natural condition of foothill and valley bottom streams. Meanwhile, the City of Eugene has learned from a case study on lower Amazon Creek that created wetlands can indeed reduce stormwater pollutants in a stream.

Most stormwater from Springfield flows directly into Cedar Creek, the McKenzie River, Willamette River, or the Middle Fork Willamette River; all are home to spring Chinook salmon and other salmonids.

The study area is served by a joint wastewater treatment plant that yields relatively benign effluent. Fish and macroinvertebrate sampling upstream and downstream of its inlet indicate no disruption of these communities, except perhaps an increase in their density due to the nutrients in the effluent. Other point sources of pollution in the study area seem minor in their influence on the Willamette River.

The three federally listed species of fish that use the study area (Chinook salmon, Oregon chub, and bull trout) owe much of their troubled status to factors outside of the study area boundaries. Yet, the Endangered Species Act does not readily discriminate between major and minor causes of decline and all activities receive scrutiny. Local degradation of Chinook salmon habitat, much of which occurred decades ago, is associated with crowding the rivers with development and refusing to let their channels wander back and forth across the flood plain. Much of the Willamette River upstream of Beltline Road has been reduced to an unwavering simple channel. Evidence that it was once a complex channel studded with gravel bars on each bank is found only in old aerial photographs. Decades of gravel mining at the mouth of the Coast Fork Willamette River and the mouth of the McKenzie River have transformed contorted mazes of side channels into single paths.

Reversing this trend of simplifying river channels and, instead, allowing them more room to wander are limited. Most obvious, a community could choose not to further develop in the flood plains. Common sense might dictate that no building should occur where the river is going to someday flood. Yet, the intensive development of the McKenzie River flood plain upstream of the study area indicates that common sense is not an effective deterrent. A survey of riverfront homes along the lower 53 miles of the McKenzie River in 2001 indicated that 62% were likely to be flooded by a 50-year runoff event. For over one-third of riverfront homes, the distance to water's edge was less than 100 feet (Alsea Geospatial et al. 2001). Land purchases and conservation easements are another option for preventing development next to rivers. In some cases, removing dikes, opening up old side channels, or connecting shallow gravel mines to the river can increase space for the river to meander and create habitat for fish. However, these activities are expensive.

Given the choice to either protect or restore habitat in rivers, the protection option probably provides the most benefit per dollar spent. And it involves no state or federal permits. The study area includes a number of river reaches with exceptional fish habitat that are currently vulnerable to development. McKenzie reaches upstream of the Interstate 5 would be top priority for protection as is the Willamette River reach immediately downstream of the McKenzie River confluence. Reach 24 of the Middle Fork Willamette River is also undeveloped and contains high quality fish habitat.

Where riprap currently exists along a river, the addition of rock barbs perpendicular to the flow can create micro-habitat that is attractive to juvenile Chinook in the spring and large trout in the summer. The barbs probably mimic a natural feature that was once common to these river channels – large trees with rootwads. Most of the vegetation bordering the rivers is young and too small to be effective in the channel as fish habitat. However, these hardwood riparian stands are common (occupying nearly 60% of all river banks) and fast-growing. If left in place they soon will get large. Tree planting, a time-honored tradition for raising community awareness of environmental issues, should be reserved for riparian areas overrun by aggressive exotic vegetation. As many have found out the hard way, long-term control of exotic vegetation is by far the most challenging part of tree planting.

Oregon chub were not known to exist in the study area prior to the discovery of a small population in small side channels along the McKenzie River in 2001. Other populations probably exist. Similarly, little is known about juvenile Chinook salmon use of the lower portions of streams and off-channel areas of rivers during the winter and spring because these waters have not been surveyed.

The following is a summary list of recommendations and information gaps from the previous sections:

5.1 Recommendations

1. Efforts to protect segments of the river from development would benefit fish most if focused on reaches that currently have high quality physical habitat. High quality reaches include 7, 10-12, and 14 on the McKenzie River and the two reaches of the Willamette River immediately upstream and downstream of the McKenzie River confluence.

2. Efforts to restore segments of the river would benefit fish most if focused on reaches that have the largest difference between historic and current physical habitat quality and have no serious barriers to restoration, such as adjacent deep gravel pit mines or buildings. Such reaches

include 12 and 13 on the McKenzie River and 22 and 24 of the Middle Fork Willamette River.

3. Large wood is scarce in study area rivers. The supply of large wood is limited by reservoirs and it is being removed from rivers as quickly as it enters. Increasing large wood abundance could be accomplished by encouraging the Corps of Engineers to truck wood trapped at reservoirs and put in the river downstream of the dam and by passing local ordinances that prohibits the removal of wood from rivers.

4. Riprap along river banks degrades fish habitat. About 17% of study area river banks are already riprapped. Local ordinances, along with firm enforcement, can be used to limit further expansion of riprap.

5. Peak flows are the sculptors of river channels and much fish habitat is lost when peak flows are muted by upstream reservoirs. While development along rivers prevents a return to historic peak flow regimes, some increase in peak flow magnitude and frequency is possible without flooding downstream landowners. In order to accomplish this, close coordination with the Corps of Engineers and Lane County would be needed.

6. Although tree planting is a common restoration activity, few opportunities exist for planting along study area rivers without first investing in extensive weed and brush control. These efforts need to extend beyond the time of planting in order to avoid tree mortality.

7. Riparian stands along rivers are young compared to historic conditions. Young trees provide rivers with fewer pieces of large wood than do older stands. Trees along rivers are commonly cut for improving views to the river, increasing open areas around houses, or for firewood. Local ordinances can be used to promote the growing of larger trees near rivers, especially native conifer trees.

8. In order to increase the age diversity of overstory species, allow young hardwood stands to mature. This will increase the likelihood of improving riparian function in terms of shade, large woody debris inputs, and wildlife habitat.

9. Because native grass, shrub, and tree species are naturally adapted to habitats within the study area, they require less effort to establish and maintain and provide habitat benefits to wildlife species that are adapted to using them for food and shelter. Therefore, focus on using native plants in revegetation efforts and, as much as possible, on management strategies that mimic historic habitat conditions that supported these plants through flooding.

10. Because an important concern is to offer as much potential habitat to salmonids as possible, focus monitoring, naturalization of flow regimes, and water quality clean-up efforts on channels which currently have the greatest potential to provide salmonid habitat. These are typically unexcavated channels that are closest to the larger rivers. These include, in order of importance:

- Cedar Creek
- Pudding Creek
- Maple Island and Keizer Slough

- Patterson Slough
- Jasper Road, Oxley, and Berkshire Slough

If restoration monies become available, certain channels within the study area would appear to respond more quickly and with greater habitat results than others. Channels that may be suitable for restoration efforts include:
- Springfield Mill Race
- Lower reaches of Willow Creek

11. Natural and constructed ponds that might be suitable for Chinook rearing and the habitat needs of other native fish will be those that are adjacent to the larger rivers or that are closely connected with non-river channels with beneficial habitat conditions. These ponds exist near or are associated with sloughs, including Patterson Slough, Keizer Slough, and Oxley Slough.

12. Peak flow increases due to urbanization cause fish to be displaced in the high-velocity water. Such peak flow increases can be tempered by including well-designed retention basins during initial development and by widening previously-channelized stream channels through excavation.

13. 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.

14. Small streams warm quickly even when flowing through short reaches of channel that has 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.

15. 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.

16. 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.

17. 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.

18. Two populations of Oregon chub have been recently located within and adjacent to the study area. More may still exist. Sites that are favorable to Oregon chub survival (backwater areas with cold water, which helps exclude bass) should be sampled prior to any adjacent development activities in order to protect the last remaining populations of this endangered species.

19. Although there is a legal responsibility to protect habitat for the threatened spring Chinook salmon wherever it occurs, its the rivers and not the streams which provide the best and most extensive habitat for juvenile rearing. Protection and restoration efforts should, therefore, focus on the rivers and especially the McKenzie River.

20. Restoration of Chinook salmon habitat in rivers is costly because it involves rearranging the channel to make preferred habitat features. Natural processes that once did this for free have been truncated by reservoirs and other human activities. Because of the high cost of creating these features, money spent on protecting existing high quality habitat is more cost-effective than restoring lost habitat.

21. Restoration of habitat for Chinook salmon and other salmonids should be directed at mimicking important habitat features that are now scarce. For example, several large logs with rootwads that are secured together at their bases with cable replicate log jams that once provided the nooks and crannies for fish to hide from predators and feed effectively in the current.

22. Efforts to restore wetlands, ponds, and their aquatic biota should include measures to provide safe nesting areas for turtles. Safe sites include islands surrounded by deep water which helps repel predators and non-vegetated areas that allow the sun to warm the soil around nests.

23. Enlisting volunteers to help with the tracking and fencing of turtle nests can greatly improve turtle nesting success.

24. For new projects yet to be implemented, use macroinvertebrate monitoring to assess physical habitat improvement. Suggestions include monitoring:

- Planned restoration site for at least two seasons prior to installation, throughout installation, and then after installation.
- At the same time of the year
- Within similar habitats (riffle/run, e.g.)
- With the same intensity each time

25. Measure and record physical habitat conditions at each sampling site since observed community structure changes can easily be misattributed without an understanding of background abiotic factors,. This will help better account for background variability or conditions that affect the local macroinvertebrate community. Variables of interest would be:

- Substrate size and composition and channel form
- Shade and bank vegetation (understory and overstory)
- Flow conditions

26. Continue to use ABA, Inc. or other similar services whenever possible. Encourage new project managers to do the same. Consistent analysis of samples allows for the comparison of

data throughout the basin. In order to more accurately interpret the quality and healthy of a macroinvertebrate community, project managers should request that new valley floor waterway or river data sets being sent to ABA, Inc. be analyzed using this new bioassessment metric.

27. Except for monitoring to assess restoration efforts, discontinue general macroinvertebrate monitoring efforts on Amazon Creek. This stormwater flow channel continues to be affected by past management decisions and is constricted from any major change by the current urban setting. The aquatic macroinvertebrate communities along the stretches that flow through Eugene appear to be a long way from the point where community recovery would be observable. Monitoring efforts and monies may be better applied elsewhere.

5.2 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.

7. Juvenile Chinook use of waterways other than the rivers and Cedar Creek is largely unknown for the study area. Current Chinook use of the Alton Baker Canoe Canal, Delta ponds, and the lower ends of Pudding Creek, Spring Creek, East Santa Clara Waterway, and Springfield Mill Race is suspected but cannot be confirmed. Fish sampling of these streams would best be done in March or April during low-flow conditions. Fish sampling should be accompanied by a survey of obstacles to upstream fish passage.

8. The fate of juvenile Chinook salmon that are shuttled into the Alton Baker Canoe Channel at an unscreened inlet is unknown. Information is needed on whether they try to stay in the channel into the summer season and survive bass predation and how many are inadvertently caught during the intensive fishing for hatchery rainbow trout.

9. Not much is known about the site conditions that are allowing turtles to nest successfully in the study area. A comparison of sites that have young turtles with those that have only old turtles may reveal which conditions are critical in this part of the Willamette Valley.

10. Little is known about the macroinvertebrate communities in small Willamette Valley perrential streams that are undisturbed by development. Macroinvertebrate sampling of the undeveloped Pudding Creek would provide this information.

5.3 Ongoing or planned opportunities for habitat protection or restoration

The study area includes a number of ongoing and planned activities for protection and restoration of aquatic habitat. The following provides a summary of the major efforts.

5.3.1 Springfield Mill Race

Water is diverted from the Middle Fork Willamette River into the Springfield Mill Race and the flow is conveyed through a 3-mile-long excavated waterway that follows an old abandoned channel of the river. Flow enters a 30-acre mill pond and then is conveyed downstream through an excavated half-mile-long outlet and enters the Willamette River (Otak 1997). The Mill Race receives stormwater from the southern boundary of Springfield and part of the Mill Race flow is diverted for irrigation of pasture and watering of livestock. The mill pond is no longer used for storing logs.

The Mill Race inlet is simply an open channel that is excavated to the grade of the river. It is located at what is now a depositional area along the river so it annually becomes plugged with gravel and cobble and has to be removed (Klingeman and McDougal 1997). Hardly any flow entered the channel when we observed the site in May, 2002, a time of normal spring flow. Water within the Mill Race and pond warms in a downstream direction and suspended algae makes the water turbid in the pond. The upper Mill Race is bordered by hardwoods and other natural vegetation, but lower reaches are bordered mostly by exotic vegetation. The Mill Race has no functional fish ladder at its downstream that can allow fish to move upstream from the Willamette River, so fish enter only from the inlet on the Middle Fork Willamette River.

The City of Springfield has developed a plan to improve conditions for fish, wildlife, and aesthetic enjoyment by humans of the Mill Race. The plan includes:

- Re-locating the Mill Race inlet upstream to the Clearwater Park boat ramp, a location which would not cause the inlet to readily plug with gravel during the winter.

- Convert areas of exotic vegetation to native plants, especially along the Mill Race so as to improve shading over time.

- Drain the pond, increase the gradient of the mill pond bottom, and confine flow within a created channel that would be beneficial to native fish. Shallow wetland ponds would also be created in the bottom of the drained mill pond. Trees planted along the channel and wetlands would eventually provide shade and moderate water temperature.

- Replace the existing fish ladder with a lower and more effective ladder.

The City of Springfield is currently searching out funding sources for this project.

5.3.2 Willamette River / McKenzie River confluence

The Confluence Group first met in 1999 to resolve a basic problem: how to minimize future flood damage to gravel extraction operations near the confluence of the McKenzie and Willamette Rivers, while enhancing and protecting fish and wildlife habitat. And not just for the short-term, but for many decades in the future. The group consists of representative from local gravel companies, other landowners, the McKenzie Watershed Council, the McKenzie River Flyfishermen, and the various state and federal agencies with responsibilities in the area.

The gravel companies financed a study to model flooding hazard in the area and funding was obtained from the Oregon Watershed Enhancement Board for a study of fish and wildlife, and for designing and constructing some initial restoration projects. The studies revealed where gravel companies were most vulnerable to flooding and the biological study pointed towards where high-value habitat still existed and provided direction about where restoration opportunities existed (Andrus et al. 2000).

Near-term fixes to the confluence area that are being discussed (and now acted upon) include unplugging and constructing side channels and alcoves, designing dikes and riprap to be fish-friendly, connecting some gravel pits to the river, improving nesting and basking habitat for pond turtles, and converting areas with exotic plants to long-lived native trees. Also, conservation easements for exceptional habitat are being explored. For the long-term, they are examining opportunities to widen the active width of the river by proper siting of new gravel operations and integrating shallow gravel pits with the river once sites are mined.

5.3.3 Springfield Park downstream of Hayden Bridge

Weyerhaeuser Company donated a parcel of land along the McKenzie River to the City of Springfield (in reach 10) for purposes of a park. The parcel coincides with an area of high quality habitat for both fish and wildlife. Off-channel features, such as side channels and alcoves, are common and the land includes a small grove of cottonwood trees that are the largest in the study area (5 to 7 feet in diameter).

The land is undeveloped and the City of Springfield decided not to turn the area into a traditional park with mowed lawn, rest rooms, and roads. Instead, they have designed the park's future to emphasize its wild features and will simply build a few trails for access to viewing areas (Satre Associates 2001). The river will be allowed to spread across its flood plain during high water without encountering hard infrastructure. In the river geomorphology section of this report, we rated this reach as having the best remaining habitat for fish in the study area. Pond turtles are commonly seen in the area.

5.3.4 McKenzie River Trust

The McKenzie River Trust is a program operated by the Three Rivers Land Conservancy whose purpose is to preserve land with exceptionally high ecological values for the future. The Conservancy is a non-governmental organization that works with interested landowners to establish conservation easements, land leases, and land purchases in order to protect parcels of land from development. They are active in the McKenzie River basin and have secured conservation easements for land opposite the Springfield park (reach 10) and recently purchased a large parcel of land on the south side of the McKenzie River in reach 12. This reach was rated as having the fourth highest physical habitat index among all reaches in the study area. The McKenzie River is able to spread widely across its flood plain in this reach and includes a number of side channels and ponds supplemented by cool subsurface river flow. It also includes an extensive area of older hardwood forest.

5.3.5 Delta Ponds

Delta Ponds is a series of abandoned shallow gravel pits (74 acres in total) that are connected to the Willamette River at the downstream end via Debrick Slough. The land, once owned by Eugene Sand and Gravel, was sold at a low price to the City of Eugene in order to provide a place for people to fish. Previous to the sale, an upstream inlet to the Willamette River was maintained in order to provide cool and oxygen-rich water to the ponds. This connection was later neglected and the ponds have became stagnant (Russ Fetrow Engineering and Scientific Resources 1989) and fish populations have declined (John Altucker, Eugene Sand and Gravel, personal communication).

The ponds are currently home to pond turtles, river otters, and some other wildlife (Russ Fetrow Engineering and Scientific Resources 1989), although wildlife diversity is hampered by the dominance of exotic plant species growing within and alongside the ponds and the lack of connectivity between ponds on the east on the west sides of the highway. The Corps of Engineers will fund two-thirds of a project to improve conditions for fish and wildlife in the Delta Ponds and has been preparing a detailed plan over the last few years. The goal for fish is to provide a slow-velocity area during non-summer months to find refuge and feed. The City of Eugene will fund the other one-third of the project. Project costs are estimated to be $5 million.

The project plan is long overdue and the Corps has provided few details on certain specifics of the anticipated activities. However, in general, these activities will include:

- Re-establishing surface water connection among the various ponds and the river.
- Convert areas with exotic vegetation to natural vegetation.

The Corps of Engineers has not indicated how they will deal with the heavy metals that contaminate sediments in portions of upper Debrick Slough and possibly the Delta Ponds.

5.3.6 West Eugene wetlands plan

The West Eugene wetlands plan was developed in response to expanding development along the western fringe of Eugene and the realization that extensive areas of wetlands, some with endangered and rare plant populations, were in the path. The plan was developed beginning in 1989 by citizens, city staff, local officials, and property owners and adopted in 1992. The plan integrates wetlands protection with development in west Eugene. A formal partnership was formed between the City of Eugene, Bureau of Land Management, the Nature Conservancy, Oregon Youth Conservation Corps, and the Corps of Engineers to manage the wetland program.

The plan provides for acquisition of wetlands and adjacent uplands for public and non-profit ownership and dictates zoning ordinances that protect wetlands and waterways. The plan increases certainty for developers by letting them know where wetlands will be protected and where fill and development is allowed. A wetland mitigation bank was established that allows developers to purchase credits in lieu of doing private mitigation. As of 1998, 2200 acres in west Eugene are now in public and non-profit ownership, with 1400 of those acres being wetlands and adjacent wetlands (Lane Council of Governments 1999).

5.3.7 Buford Park

The Friends of Buford Park and Mt. Pisgah have developed a plan to re-introduce channel complexity to a site along the Coast Fork Willamette River at Buford Park. The plan calls for reopening blocked side channels that dissect the 200-acre South Meadow area. A section of an old Corps of Engineers berm at the upstream end of side channels will be removed to allow flow to enter at higher water, road fills and their culverts will be removed from the side channels, and an excavated backwater area will be excavated at the downstream end of South Meadow. The goal is to allow the river to spread laterally during higher flows and allow fish to find refuge and seek out food.

Appendix A. Glossary of terms

Adipose fin – the small fin located near the tail on the backs of salmon, trout, and whitefish. This fin can be clipped off to identify a fish without impairing its ability to swim.

Alluvium - material transported and deposited by a stream or river, usually a coarse deposit composed of sand, gravel, or cobbles.

Alcove – similar to a side channel only it is not connected to the river at the upstream end during lower flows.

Anthropogenic – human-related.

Aquatic biota – organisms that live in the water.

Bank revetment – riprap or other artificial surface along a river intended to reduce bank regression.

Bedload - the sand- to boulder-sized sediment that moves downstream along the bottom of a stream or river, especially during high flows.

Benthic - pertaining to the bed of a body of water.

Bioavailable – a nutrient that is immediately available for uptake by aquatic organisms.

Braided channel - a channel that is comprised of many small channels that weave in and out.

Canopy cover – the layer of vegetation that overhangs a stream or river channel and obstructs the view to the sky.

Chironomids - any of the family (Chironomidae) of midges that lack piercing mouth parts.

Chord length – the straight line distance between the beginning and ending of a reach of stream or river.

Collectors - referring to a group of macroinvertebrates that filter fine particulate organic matter from the water.

Coleoptera - beetles

Diptera - true flies.

Ephemeroptera - mayflies

EPT ratio - the ratios of individuals in taxa from the Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies); a measure of diversity of species in aquatic systems.

Filterer - an organism that feeds by filtering organic matter or minute organisms from a current of water that passes through some part of its system.

Fire regime – the frequency and intensity of fire in an area.

Flood plain - the area next to a stream or river that is currently or has been covered by water during high flows.

Freshet – an antiquated term for a high flow event in a stream or river.

Functional feeding group (FFG) - a classification scheme that distinguishes insect taxa that perform different functions within aquatic ecosystems with respect to processing of nutritional resources (from Merritt and Cummins, 1984).

Gallery forest - a band of trees that grows exclusively along the river channel.

Genera – a taxonomic group of any rank (species, genus).

Geographic Information System (GIS) - a computer system designed for storage, manipulation, and presentation of geographical information such as topography, elevation and geology.

Geomorphology - land and submarine relief features of the earth’s surface.

Grazers - macroinvertebrates feeding on attached coarse particulate organic matter (algae, larger plants).

Groundwater flux – the volume of groundwater that enters a water body over a given amount of time.

Heavy metals – metals such as zinc, iron, copper, and lead.

Hydrology - pertaining to the circulation and distribution of water.

Hydric - pertains to soil conditions that are typically moist for much of the year.

Invasive exotic vegetation – introduced plants with vigorous growth that crowd out native plants.

Macroinvertebrates - animals without a backbone retained by a screen with interstices ranging from 1 millimeter to 0.425 millimeters.

Megaloptera – an order of aquatic insects that have wings with a folded anal area in the hind pair, and develop from predacious larvae.

Metric - a measurable biological attribute used to evaluate water quality impacts.

Montane river – a river bordered by forested slopes that flows through upland areas.

Odonata – dragonflies.

Oligochaetes - the order containing the earthworms and freshwater worms.

Outer anomalies – defects or disease on the outer surface of a fish, including lesions, disease, injury, parasites, and missing body parts.

Peak flow – the highest discharge that occurs in a stream or river; often used in context with a recurrence interval such as a 100-year peak flow. A 100-year peak flow would be the discharge that is equaled or exceeded every 100 years, on average.

Periphyton – the film of algae and associated organism that grow on the surfaces of river or stream substrate.

Plecoptera – stoneflies.

Predators - macroinvertebrates preying on other animals.

Primary productivity – the algae, bacteria, and zooplankton present in water.

Richness - a parameter describing macroinvertebrate characteristic from instream sampling, refers to total number of species present.

Riparian - the area near a water body that is characterized by wetter soils and vegetation communities that favor conditions near water.

Salmonid – the group of fishes that include salmon, trout, and whitefish.

Savannah - a landscape characterized by grasslands with scattered trees.

Scraper – a group of fish that feed by scraping periphyton off river or stream substrate.

Shredders - referring to a group of macroinvertebrates that live by feeding on coarse particulate organic matter (i.e., decomposing vascular plant tissue).

Side channel – a channel in a stream that is secondary in size to the main channel.

Sinuosity – the degree to which a stream or river wanders back and forth laterally.

Slough - an abandoned segment of the river that is still connected to the river but has little or no flow.

Stormwater - water that flows off impermeable man-made surfaces such as pavement or roofs.

Substrate – mineral or organic surfaces within a stream or river.

Succession – the change from one vegetative community type to another over time.

Taxa - a taxonomic group of any rank (species, genus).

Thalweg – the portion of a river channel that has the fastest flow.

TMDL – an abbreviation for Total Maximum Daily Load which is an evaluation initiated by the Oregon Department of Environmental Quality to determine relative degrees of pollutant loading originating from various sources in a watershed.

Transpiring – to give off oxygen.

Trichoptera – caddisflies.

Trophic – pertaining to nutrition or feeding.

Watershed – the area upstream of a point along a stream or river that encompasses the portions that contribute to downstream surface or subsurface water.

Water column – the entire depth of water in a pond, river, or stream.

Water hardness – A measure of the amount of calcium, magnesium and iron dissolved in the water. Usually given as milligrams per liter (mg/L).

Xeric – pertains to soil conditions that are dry, at least for a portion of the year.

Appendix B. Description of macroinvertebrate sampling studies

Amazon Creek

Because of Amazon Creek's high visibility, recreational use, and use for stormwater conveyance, its macroinvertebrates have been studied often. Consultants, state environmental quality agents, and students have explored its communities to varying degrees.

Aquatic Biology Associates, Inc., April 1999 (ABA, Inc. 1999)

ABA, Inc., under contract with City of Eugene, collected macroinvertebrate samples at two sites on the West Fork of Amazon Creek and one site on the upper mainstem. The sampling sites were established to monitor long-term trends in aquatic community condition as development in the surrounding basin intensifies and to conduct a baseline examination of the biotic community as it existed at the time. According to the City of Eugene, these sites have not been used for repeated monitoring.

The furthest upstream site on the West Fork (Map 12, Station 1) is located 400 meters above the Martin Street crossing. The second sampling site on the West Fork (Map 12, Station 2) is located approximately 250 meters downstream of the upstream site. The main fork Amazon Creek site (Map 12, Station 3) is located in the park approximately 150 meters below the confluence of West and East Forks.

Riffle/run habitats were sampled using a D-frame kick-net at five points at each sample site. Samples were compiled to represent one square meter of stream bottom. Sample counts and genera/species were analyzed using the Aquatic Biology Associates, Inc. multimetric bioassessment of Pacific Northwest montane streams. Researchers acknowledged the limitations of interpreting data using this index developed for higher-gradient, more forested streams. However, a multimetric biotic index for urban or valley bottom streams was not available.

Because of upstream disturbances due to development, the upper sampling point (Station 1) on the West Fork should not be interpreted as a reference site. Rapid suburbanization is occurring upstream of the sampling site within 1000 feet. Although the researchers observe that the site's habitat characteristics align it most closely with the montane river condition assumption of the multimetric bioassessment index, Site 1's macroinvertebrate community was only 44.4% of that expected from a montane site that has high habitat integrity and complexity. The researchers estimate that upper reach plateau sites, such as Site 1 in the Amazon basin, could achieve 60-70% on the index scale under undisturbed conditions.

Urban development also occurs between Station 1 and the second site on the West Fork (Station 2). Habitat complexity is severely limited at Station 2 by fine sediments despite a higher gradient and riparian cover. Interestingly, because the site exhibits characteristic montane forest habitat conditions (higher gradients, larger substrates, fewer macrophytes), tolerant macroinvertebrate taxa found lower in the basin do not thrive and because of the disturbances from surrounding land use practices, intolerant taxa characteristic of this habitat also are not found. As a result, Station 2 scored a low 46.8% when the expected rating would be between 70-80%.

The total bioassessment ranking for the site on mainstem Amazon Creek (Site 3) was 44.4% of that expected from a montane site with very high habitat integrity and complexity. Fine sediment and lack of habitat complexity are likely the dominant factors negatively affecting macroinvertebrates at this site as well.

Overall, researchers found these three Upper Amazon sampling sites to have poorer community structure than could be expected from similar undisturbed sites. The compounded effects of suburban development, including sedimentation and reduction of habitat complexity, likely played a dominant role in the observed communities.

Anderson, T., W.R. Tinniswood and P. Jepson, 1996-97 (Anderson et al. 1997)

Anderson and colleagues sampled four sites on the mainstem of Amazon Creek in the winter of 1996 and early spring of 1997. The two upstream sites (Map 12, Stations 4,5) were located upstream of the South Eugene High School and the two downstream sites (Map 12, Stations 6,7) were located by the Lane County Fairgrounds and through the commercial district by 11th Street. The four sites straddle the open concrete culvert portion of Amazon that runs through the city center.

The area sampled at each site was not reported. Samples were collected using a 500µ mesh dip net, preserved in the field, and taken to the lab for identification. Other than simple presence/absence information, macroinvertebrate population data were not summarized or reported and raw data were not available. No comparative statistics between sample sites are given. Given the energy invested in sampling, cleaning, sorting and identifying aquatic insects, creating comparative statistics from the data is well worth the additional effort in terms of how a project will both build upon itself in future years and contribute to basin-wide efforts. Population indices for this project and its sites could not be included in the basin-wide overview. Fortunately, this project is the exception among the majority of macroinvertebrate sampling efforts undertaken in the MECT Study area.

From the information that is available, Chironomidae (Diptera) families were the most diverse families present at all sampling sites. Plecoptera, Coleoptera, Megaloptera, and Ephemeroptera were only found at the most upstream site. No Hydropsyche were found at any of the sample sites. Predators were the most common functional feeding group at all sites in December but decreased as a percentage of the community in April (36% in Dec./18% in April). Scrapers (22% in Dec./37% in April) and collector-filterers (4% in Dec./0% in April) were minor components of the community at all sites.

One interesting observation from this report was the lack of intolerant shredders, such as stoneflies, and the dominance of more tolerant shredders, such as chironomids, in reaches that were dominated by overhanging exotic vegetation species (e.g., reed canary grass and Armenian blackberry). From a trophic perspective, the more tolerant shredder community may serve the same role in stream nutrient cycling. Without relative percentages of populations of stoneflies to chironomids or an analysis of the differences in fecal size and nutrient content, however, this conclusion can only be considered. It is potential differences in community structure and function such as these, between the more thoroughly examined montane systems and the less studied urban, low-land systems, that need to be explored to better understand urban stream systems.

The report mentions, but does not quantitatively explore, the direct effects of water quality on the macroinvertebrate communities. Their qualitative observations indicated that the downstream macroinvertebrate communities in Amazon Creek are altered by cumulative poor habitat, nutrient resource, and water quality conditions. Even in areas where local beneficial habitat was available (e.g., riffles with little embedded sediment), communities remained simple and dominated by tolerant taxa.

City of Eugene/Long Tom Watershed Council, April/Fall 2001

The Amazon Creek Widening Project between Acorn Street Bridge and Oak Patch was implemented during the summer of 2001. Prior to restoration actions to widen the channel, the City of Eugene and the Long Tom Watershed Council sampled macroinvertebrate populations in April, 2001, at six sites above, below and within the restoration reach (Map 12, Stations 57-64). Post-restoration installation sampling was conducted in Fall, 2001, by Judy Li, professor at Oregon State University, at the same sites. The before samples were taken to determine pre-restoration macroinvertebrate community structure. The post-restoration activity samples were taken to monitor immediate response to the disturbance of the restoration activity.

Samples were collected using a modified version of the sampling methodology established by Woodward-Clyde consultants for Willow Creek in 1995 and were sorted, identified and counted by Aquatic Biology Associates, Inc.

Community data collected prior to restoration work indicates a highly tolerant community consisting primarily of Chironomids, a few Odonata, aquatic worms, and other non-insect aquatic taxa. Very few less-tolerant taxa such as Ephemeroptera, Plecoptera, or Trichoptera were observed.

Bi-annual sample collection and analysis is funded through Spring, 2003. Spring, 2002, samples were collected this April (personal communication, C. Thieman).

Rachel Carson Natural Resource Program, Spring 1999-2002

High school students participating in the watershed resources learning program at the Rachel Carson Center for Natural Resources at Churchill High School have been sampling macroinvertebrates from four sites on Amazon creek since 1999. Sites are located near the West Amazon Parkway (called Headwaters), in Amazon Park, near Acorn Park and Oak St. (called Quaker St.), and near Fern Ridge (called Tailwaters). Every two weeks from January to May, a team of students samples at least one of the four sites. Students collect the insects with nets and sort and identify them in the field to the order level. After counting the insects, they assign them to different groups based on a DEQ-approved Pollution Tolerance Index developed by the Saturday Academy's Student Watershed Research Project.

Willow Creek

City of Eugene/Woodward-Clyde Consultants, 1996 (City of Eugene and Woodward-Clyde Consultants 1996)

Willow Creek presents an interesting and important macroinvertebrate habitat within the MECT Study area. Its summer-dry streams, wetlands, and beaver ponds require unique life history responses from its macroinvertebrate community that distinguishes this community from other macroinvertebrate communities in other MECT Study area habitats.

The City of Eugene and Woodward-Clyde initiated this project to establish the baseline status of the macroinvertebrate communities to use as a comparative measure for future responses to urbanization and/or restoration activities. The researchers established eight sample sites within the Willow Creek basin (Map 12, Stations 20-27). Five of the sites were riffle habitats and three were shallow run habitats. Sampling occurred in early March which, though earlier than other spring sampling efforts in the Study area, is an appropriate spring sampling period for the voltinism patterns of Willow Creek's insect community and its habitats.

Community metric responses, including taxon richness, HBI (Hilsenhoff Biotic Index), and various functional feeder group (FFG) or other genera, to family ratios were presented. The HBI results at each sampling site within Willow Creek indicate that, generally, communities at each sampling point became less sensitive/more tolerant of pollution in a downstream direction. The EPT:Chironomidae ratio, which describes the balance between more sensitive Ephemeroptera, Plecoptera, and Trichoptera populations with less sensitive Chironomidae populations, decreased in a downstream direction. The change in this index either was a sign that numbers of Ephemeroptera, Plecoptera, and Trichoptera were decreasing *or* that populations of Chironomids were increasing while the EPT cohort remained constant.

Cary Kerst, 1995-2000

Stemming from a personal interest in the natural history of summer dry streams, Mr. Kerst has collected, identified, and documented adult taxa found during spring, summer and fall in the Willow Creek basin on 5 sites (Map 12, Stations 28, 30-32, 35). In 1995, he installed emergence traps at Reynolds Drive, Rathbone Lane, and just above 18th street on the West Fork. The traps were checked every few days to a week from 3/28/95 until 11/26/95. In 1996, Mr. Kerst installed traps at Reynolds Drive, on the ridge above Simmons Farm (East Fork of the West Fork, since purchased by The Nature Conservancy), another lower site at this farm, Rathbone Lane, a site just across from Hynix Semiconductor, a site above 18th Street on the East Fork, and a pond on the East Fork. These traps were checked from 2/12/96 to 10/27/96. Since 1996, Mr. Kerst has primarily netted adults to add to the list during collecting trips. The most recent list is in Appendix C.

Communication should be encouraged among other naturalists in the basin who may be collecting aquatic insects, either as adults or nymphs/larvae, to foster the sharing of observations. General lists could be developed. Although this information is valuable from a presence/absence perspective only in terms of monitoring, knowing that the insects are present is important. More importantly, if the sampling efforts and information are used to offer educational opportunities and to increase basin awareness of aquatic insect communities and their role reflecting the effects of urban change, great human community value can be gained.

A3 Channel

HW Project, Department of Environmental Quality (DEQ 1997)

DEQ selected the A-3 Channel that extends off Amazon Creek to implement a program of education and management activities to reduce point source and non-point source stormwater pollution. The project was designed to test the effectiveness of "place based" activities in improving the biological condition of a channel. Biological samples were linked with water quality samples that tested positive for organics and metals.

Macroinvertebrates were sampled at three points along the A-3 Channel in late spring (Map 12, Stations 38-40). At each point, four-square foot samples were collected using a traveling kick sample of the optimum habitat. The sample was subsampled in the field and organisms were identified to the family level. At least 100 organisms were identified for each sample.

Family identifications were then evaluated using the ODEQ Level 1 Macroinvertebrate Assessment. Out of a possible 30 points, all three sample sites scored either a 6 or a 7, indicating a highly impaired stream. No Ephemeroptera, Plecoptera, or Trichoptera were collected at the three sites. The dominant taxa were members of the Oligochaete family, specifically *Tubifex* worms.

Spring Creek

Aquatic Biology Associates, Inc., April 1999 (ABA, Inc. 1999)

ABA, Inc., under the direction of the City of Eugene, collected macroinvertebrate samples at one site on Spring Creek near Awbrey Park (Map 12, Station 41). The sampling site was established to assist in monitoring long-term trends in the urban aquatic community condition as development in the surrounding area intensifies and to conduct a baseline examination of the biotic community as it existed at the time. The Spring Creek site was selected to offer a comparison with the Amazon Creek sites that are "higher" in the basin and not as affected by extensive residential and industrial development and stormwater drainage.

The bioassessment score for this sample site was 30.5%. Based on the multimetric bioassessment index for montane streams, this type of lowland stream, were it not limited by surrounding urban or agricultural disturbances, would be expected to score in the range of 50-70%. Tolerant, common taxa, such as Oligochaeta and snails, dominated this site. No intolerant or cold water taxa were found.

This portion of Spring Creek dries up in the late spring, summer, and between storm events in the fall. However, observed taxa were not similar to those typically associated with seasonal streams, such as those found in Willow Creek by Woodward-Clyde (1996). Poor habitat conditions created by high amounts of fine sediment, nutrient enrichment, and lack of habitat complexity appeared to prevent these taxa from colonizing the site.

Because Spring Creek has not been sampled since its first long-term trend monitoring effort, conclusions about its current condition and how the stream may be responding to development in the Santa Clara area cannot be determined. If the MECT determined that Spring Creek warranted prioritization for monitoring, this site, as well as at least a second (to compare within system variability), should be used.

West Eugene Wetlands

Steve Gordon and Cary Kerst

A qualitative checklist was developed from three years worth of taxanomic sampling of adult dragon and damselflies in the West Eugene Wetlands. The list also includes adult dragonflies observed at other locations in the Eugene-Springfield area including Amazon Creek, Alton Baker Park, and the Springfield Mill Race. The list is in Appendix D.

Cedar Creek

McKenzie River Watershed Council, 1998-99

As part of a four-year, basin-wide sampling rotation established in 1998, the McKenzie River Watershed Council collected macroinvertebrates at two sites on Cedar Creek (Map 12, Stations 42 and off the map). A riffle site lower on Cedar Creek (within the MECT Study area boundary) was sampled in Fall, 1998 and another riffle site higher on the creek, near Cedar Flats Road, outside the study area, was sampled in Fall, 1999.

The Council has completed three out of the four planned years. The Council uses volunteers to address three objectives. The objectives are:

- To provide baseline information about biological water quality by identifying macroinvertebrate assemblages throughout the watershed and using these as indicators,
- To track long-term trends in water quality, and
- To offer local volunteers experiential learning opportunities related to watershed health concepts.

Collected samples were sent to ABA, Inc. for identification and data analysis. The Council is waiting to conduct data interpretation and summaries until all four years of sampling have been completed. At that point, a comprehensive monitoring report will be written. After this four year sampling effort, the Council hopes to use the results to supplement future monitoring at the same sites to track trends in biological indicators of water quality. Because of its broader geographic focus outside the study area boundaries and its temporal inconsistency (caused by the rotation of sampling efforts), the single site on Cedar Creek offers, alone, a limited data set for the MECT planners. However, by incorporating the larger project results and findings when they are published, the Council project offers considerable information to MECT planners in understanding macroinvertebrate community characteristics of the larger watershed that surrounds the study area.

McKenzie River

McKenzie River Watershed Council, 1998-2002

The McKenzie River Watershed Council established a four-year sampling rotation basin-wide in 1998. They have completed three out of the four years. The sampling sites within the study include one at Armitage Park, which was sampled in 2001, and a site at Harlow Camp, which was sampled in 2000 (Map 12, Stations 44-45). These will be the only samples taken at each of the sites. The Council uses volunteers to address three objectives. The objectives are:

- To provide baseline information about biological water quality by identifying macroinvertebrate assemblages throughout the watershed and using these as indicators,
- To track long-term trends in water quality, and
- To offer local volunteers experiential learning opportunities related to watershed health concepts.

Collected samples have been, and will continue to be, sent to ABA, Inc. for identification and data analysis. The Council is waiting to conduct data interpretation and summaries until all four years of sampling have been completed. At that point, a comprehensive monitoring report will be written. After this four year sampling effort, the Council hopes to use the results to supplement future monitoring at the same sites to track trends in biological indicators of water quality. Because of its broader geographic focus outside the study area boundaries and its temporal inconsistency (caused by the rotation of sampling efforts), these two sites offer, alone, a limited data set for the MECT planners. However, by incorporating the larger project results and findings when they are published, the Council project offers considerable information to MECT planners in understanding macroinvertebrate community characteristics of the larger watershed that surrounds the study area.

Willamette River

City of Eugene, 1994 – present (Kerst 2000, Kerst 1995)

Cary Kerst, environmental scientist for the City of Eugene, initiated a project in 1994 to monitor aquatic macroinvertebrate communities on the Willamette River above and below the wastewater treatment plant outfall. This long-term monitoring project constitutes some of the best macroinvertebrate data in the MECT Study area. Starting in 1994, samples were collected at 4 sites above the wastewater treatment plant outfall (between Beltline Bridge and Owosso Bridge) and 4 sites below the outfall (Map 12, Stations 46-54). Each sample covered a 0.25 m^2 area and was collected with a 250µ mesh net. In 1996, sampling methodology was adjusted to reflect ODEQ sampling criteria. Mr. Kerst began composite sampling created by combining 4-0.18 m^2

samples versus analyzing each single 0.25m^2 samples. For almost any habitat type, but particularly a large river system such as the Willamette with multiple diverse microhabitats within a single sample reach, composite sampling is an effective methodology. It increases the thoroughness of the sampling effort in terms of not only numbers but also diversity and richness. Mr. Kerst validated this assumption by collecting comparison samples between ODEQ and the initial sampling protocol. Population numbers are generally higher and more robust in the ODEQ samples.

In 1999, two additional sample sites were added in response to observations of little difference between sampling stations and yet general overall community changes within the urban area. The new stations are designed to assess possible overall urban effects. One is located near the confluence of the Middle and Coast forks of the Willamette River and the other is just downstream of the I-5 Bridge (Map 12, 55,56). Samples are taken in alternating years in spring (April) and fall (October). 1994 and 1995 samples were analyzed by Taxon Environmental Monitoring Service (Corvallis, OR). Samples since 1996 have been analyzed by Aquatic Biology Associates, Inc.

In the 1995 report, Mr. Kerst reported no clear changes in macroinvertebrate community structure below the wastewater treatment plant outfall. Populations below the outfall did exhibit lower community diversity, higher numbers of pollution tolerant taxa, and a shift toward the collector-filterer functional feeding group. However, Mr. Kerst noted that these changes could be a result of a combination of a number of environmental stressors including the treatment plant outfall, the local gravel mining operations, Beltline Road, heavy recreational use and drainage from Delta Ponds. Determining point specific pollution sources in an area extremely affected by nonpoint pollution is very difficult.

In the 2000 report, Mr. Kerst continued to explore the potential effects of the wastewater treatment outfall and added two sample sites to introduce the objective of measuring overall urban effect on Willamette River macroinvertebrate communities. Again, no measurable effect of the wastewater treatment plant outfall was observed. However, by adding two stations upstream of most direct urbanization effects to the river, Mr. Kerst was able to detect overall decreases in diversity, population density, and scraper functional feeding group representation and overall increases in collector-filterer functional feeding group representation and pollution tolerance.

Appendix C. Aquatic insects of the Willow Creek Basin

From Cary Kerst, Eugene Public Works, Wastewater Division

ODONATA

Latin Name	English Name
Aeshna californica Calvert, 1895[1]	California Darner
Aeshna umbrosa Walker, 1908[1]	Shadow Darner
Anax junius Drury, 1770	Common Green Darner
Erythemis collocata (Hagen, 1861)[5]	Western Pondhawk
Lestes congener Hagen, 1861[5]	Spotted Spreadwing
Libellula forensis Hagen, 1861[1]	Eight-Spotted Skimmer
Libellula lydia Drury, 1773[1]	Common Whitetail
Libellula quadrimaculata Linnaeus, 1758[5]	Four-Spotted Skimmer
Pachydiplax longipennis (Burmeister, 1839)[1]	Blue Dasher
Sympetrum costiferum (Hagen, 1861)[5]	Saffron-Winged Meadowhawk
Sympetrum illotum (Hagen, 1861)[1]	Cardinal Meadowhawk
Sympetrum madidum (Hagen, 1861)[1]	Red-Veined Meadowhawk
Sympetrum occidentale Bartener, 1915[1]	Western Meadowhawk
Sympetrum pallipes (Hagen, 1874)[1]	Striped Meadowhawk
Sympetrum vicinum (Hagen, 1861)[5]	Yellow-Legged Meadowhawk

1 -Identifications verified by: Dr. S. W. Dunkel
Collin County Community College
Plano, Texas

5 -Identifications verified by: Steve Valley
Albany, Oregon

EPHEMEROPTERA

Ameletus andersoni Zloty[3]
Baetis bicaudatus Dodds (?)[2]
Baetis tricaudatus Dodds, 1923 [2]

Caenis latipennis Banks[2]
Callibaetis pictus (Eaton)[2]
Callibaetie ferrugineus hageni Eaton, 1885 [2]
Procloeon venosum (Traver) (?)[2]
Paraleptophlebia debilis (Walker)[2]
Paraleptophlebia gregalis[2]
Siphlonurus occidentalis Eaton[2]

2 -Identifications verified by: Dr. W. L. Peters
Jan Peters
Center for Studies in Entomology
Florida A & M University

3 -Identification verified by: Dr. Jacek Zloty
Department of Biology
University of Calgary

PLECOPTERA

Capnia (new species)[6]
Isoperla fusca Needham & Smith[4]
Malenka perplexa (Frison)[4]
Ostrocerca dimicki (Frison)[4]
Ostrocerca foersteri[4]
Podmosta obscura (Frison)[4]
Sweltsa adamantea Surdick[4]

4 -Identifications verified by: Dr. B. C. Kondratieff
Department of Entomology
Colorado State University

6 -Currently being described by: Dr. Riley Nelson
University of Utah

TRICHOPTERA[7]

Lepidostoma cinereum (Banks) 1899
Clostoeca disjuncta (Banks) 1914
Grammotaulius bettenii Hill-Griffin 1912
Hesperophylax alaskensis (Banks) 1908
Limnephilus concolor Banks 1899
Limnephilus flavastellus Banks 1918
Limnephilus occidentalis Banks 1908
Limnephilus sitchensis (Kolenati) 1859
Pseudostenophylax edwardsi (Banks) 1920

Dolophilodes sisko (Ross) 1956
Ptilostomis ocellifera (Walker) 1852
Polycentropus crassicornis (Walker) 1852*
Rhyacophila grandis Banks 1911

7- Identifications verified by: Dave Ruiter
*Only record west of Montana as of 9/2000

MEGALOPTERA

Sialis rotunda

November 3, 2000

Appendix D. Odonata Checklist

Odonata Checklist
For the West Eugene Wetlands and Other Areas
33 total species, 28 West Eugene Wetlands species
(Cary Kerst, Steve Gordon, August 7, 2000)

WEST EUGENE WETLANDS SPECIES

Dragonflies, Suborder *Anisoptera*

Darner Family (*Aeshnidae)*

- ❑ California Darner, *Aeshna californica*
- ❑ Blue-eyed Darner, *A. multicolor*
- ❑ Paddle-tailed Darner, *A. palmata*
- ❑ Shadow Darner, *A. umbrosa*
- ❑ Common Green Darner, *Anax junius*

Skimmer Family (aka Common Skimmers) (*Libellulidae)*

- ❑ Western Pondhawk, *Erythemis collocata*
- ❑ Eight-spotted Skimmer, *Libellula forensis*
- ❑ Widow Skimmer, *L. luctuosa*
- ❑ Common Whitetail, *L. lydia*
- ❑ Twelve-spotted Skimmer, *L. pulchella*
- ❑ Four-spotted Skimmer, *L. quadrimaculata*
- ❑ Flame Skimmer, *L. saturata*
- ❑ Blue Dasher, *Pachydiplax longipennis*
- ❑ Variegated Meadowhawk, *Sympetrum corruptum*
- ❑ Saffron-winged Meadowhawk, *S. costiferum*
- ❑ Cardinal Meadowhawk, *S. illotum*
- ❑ Red-veined Meadowhawk, *S. madidum*
- ❑ Western Meadowhawk, *S. occidentale*
- ❑ Striped Meadowhawk, *S. pallipes*
- ❑ Yellow-legged Meadowhawk, *S. vicinum*
- ❑ Black Saddlebags, *Tramea lacerata*

Damselflies, Suborder *Zygoptera*

Spreadwing Family (Lestidae)

- ❑ California Spreadwing, *Archilestes californica*
- ❑ Spotted Spreadwing, *Lestes congener*
- ❑ Common Spreadwing, *L. disjunctus*

- Emerald Spreadwing, *L. dryas*

Pond Damsel Family (Coenagrionidae)

- Tule Bluet, *Enallagma carunculatum*
- Pacific Forktail, *Ischnura cervula*
- Western Forktail, *I. perparva*

SPECIES FOUND ELSEWHERE IN THE REGION:

Dragonflies

Spiketail Family, (*Cordulegasteridae*)

- Pacific Spiketail, *Cordulegaster dorsalis* (Upper Amazon Creek, Eugene, 1999 benthic study)

Cruiser Family, (*Macromiidae)*

- Western River Cruiser, *Macromia magnifica;* (7-8-00 Northview Blvd, Eugene, SCG*)*

Clubtail Family, (*Gomphidae)*

- Pacific Clubtail, G*omphus kurilis;* (7-9-00, Alton Baker Park, Eugene, SCG)
- Grappletail, *Octogomphus specularis*; (7-28-00, Frank Kinney Park, Amazon Creek, Bruce Newhouse, photographed).

Damselflies

Broad-winged Damselflies, (*Calopterygidae)*

- River Jewelwing, *Calopteryx aequabilis;* (7-7-00, Springfield Millrace, Springfield, SCG; 7-7-00, Alton Baker Canoe Canal, Eugene, CK).

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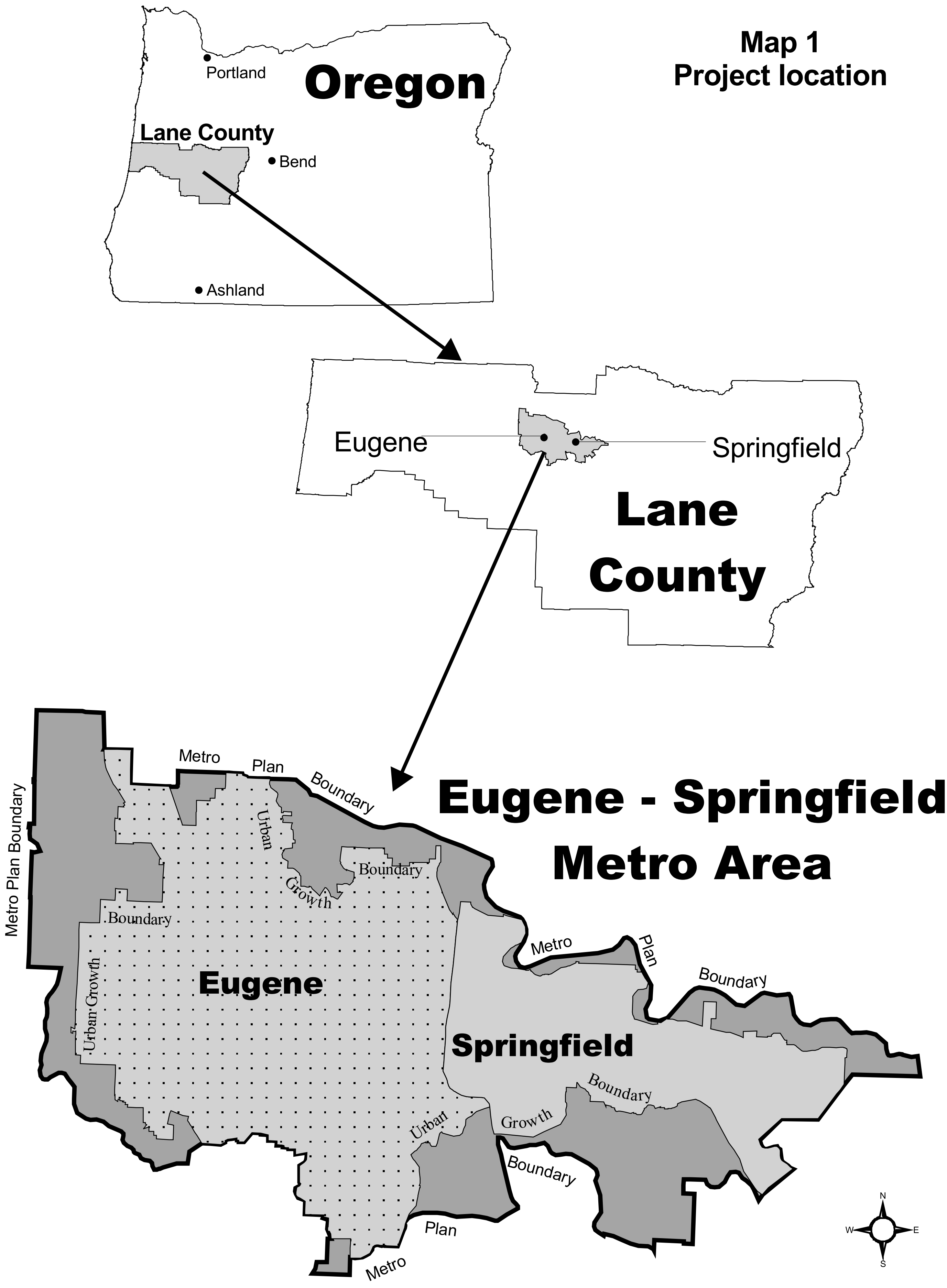
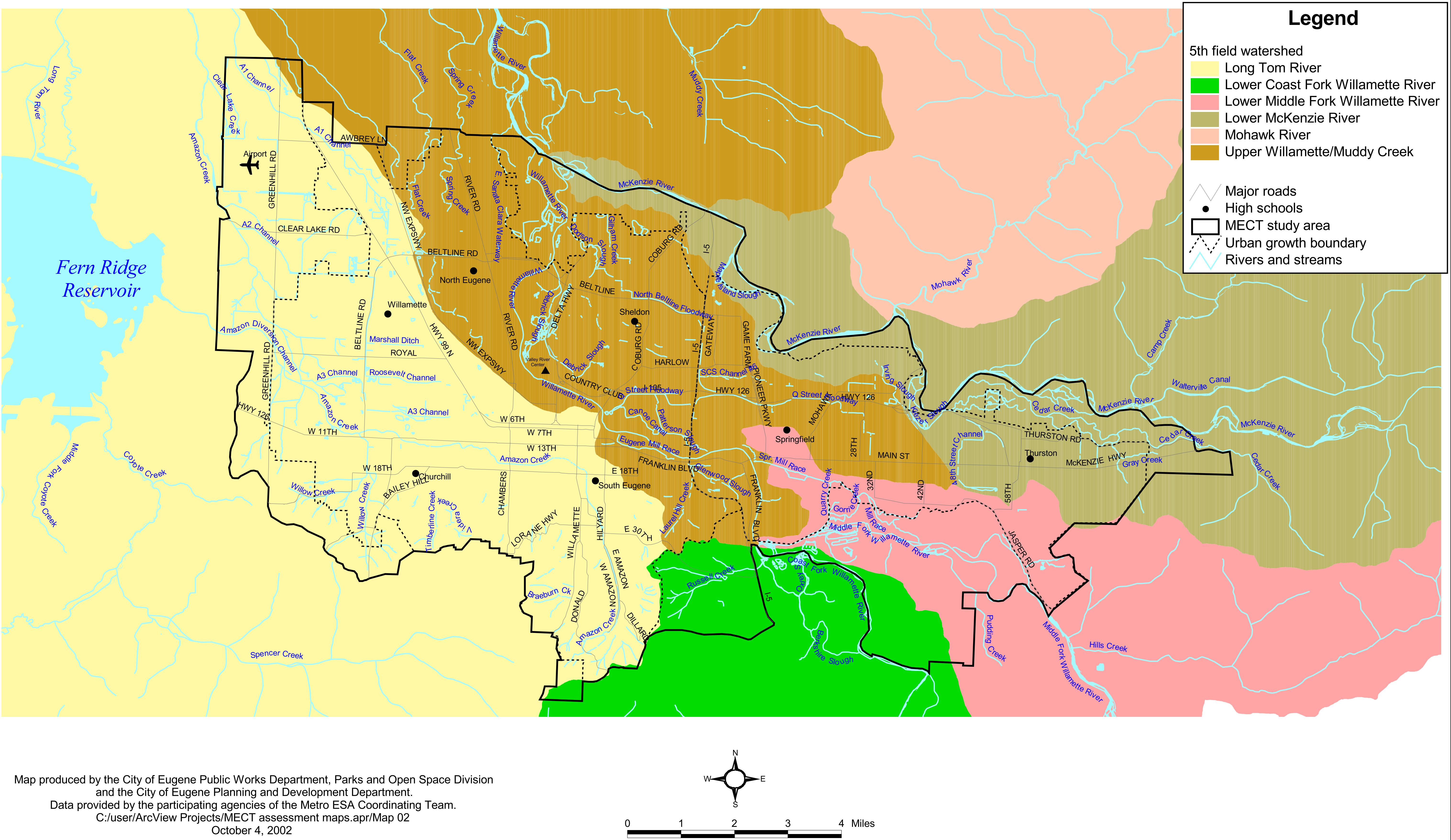
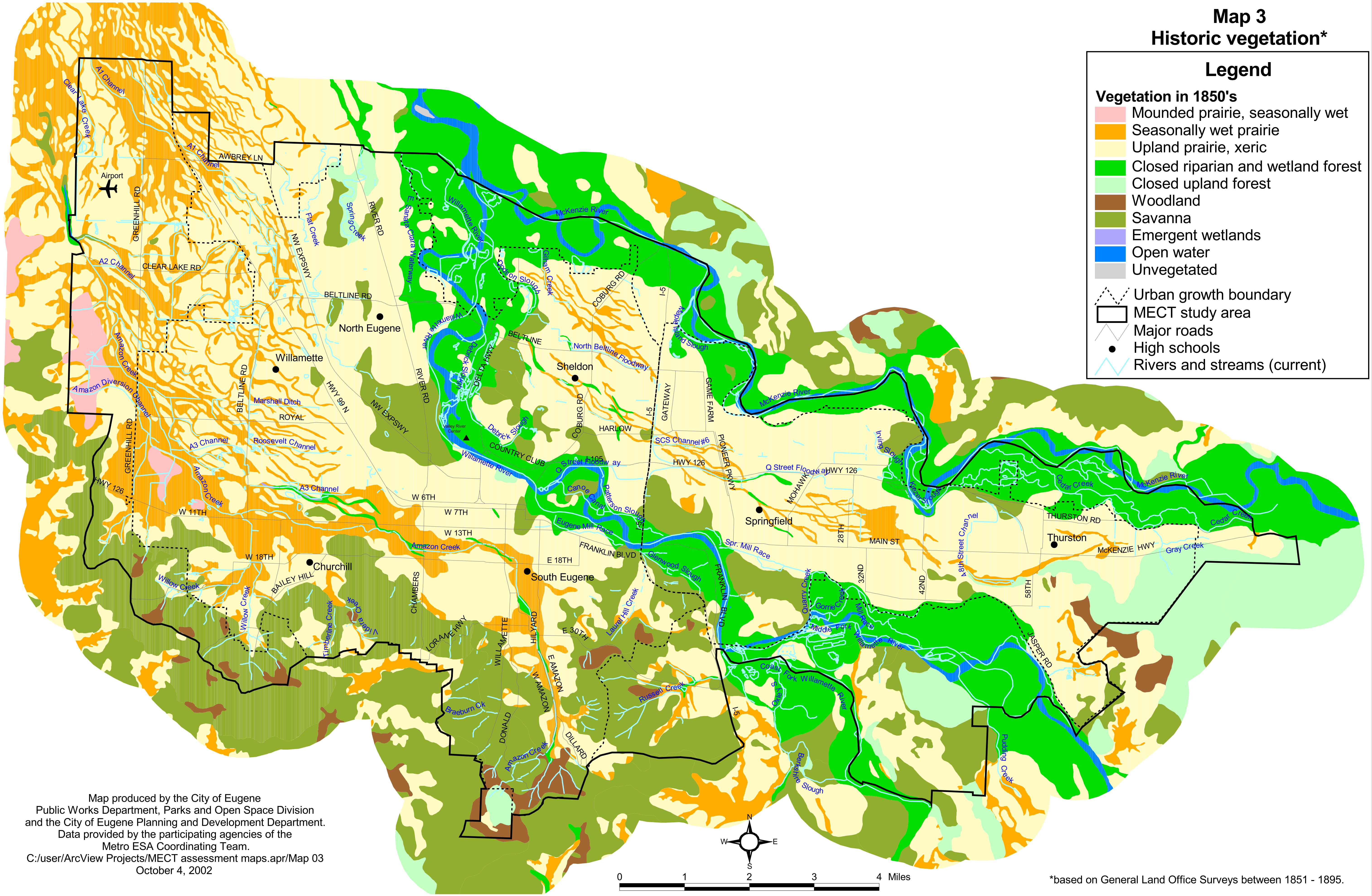

Map 1
Project location
Oregon
Portland
Lane County
Bend
Ashland
Eugene
Springfield
Lane County
Eugene - Springfield Metro Area
Metro Plan Boundary
Urban Growth Boundary
Eugene
Springfield
N
S
E
W

Map 2
Fifth field watersheds



Map produced by the City of Eugene Public Works Department, Parks and Open Space Division
and the City of Eugene Planning and Development Department.
Data provided by the participating agencies of the Metro ESA Coordinating Team.
C:/user/ArcView Projects/MECT assessment maps.apr/Map 02
October 4, 2002

Map 3
Historic vegetation*



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and the City of Eugene Planning and Development Department.
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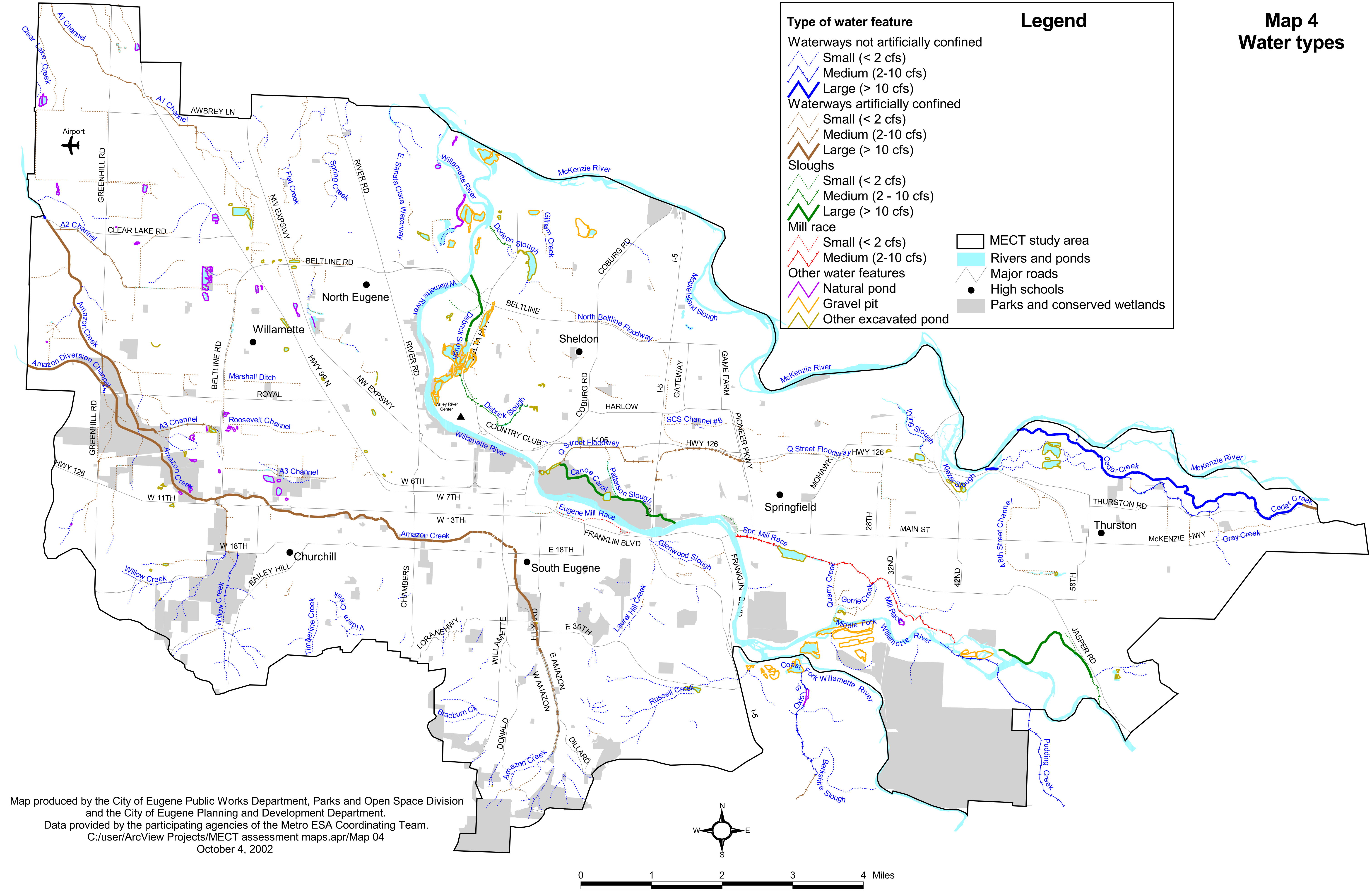
Metro ESA Coordinating Team.
C:/user/ArcView Projects/MECT assessment maps.apr/Map 03
October 4, 2002

*based on General Land Office Surveys between 1851 - 1895.

Map 4
Water types



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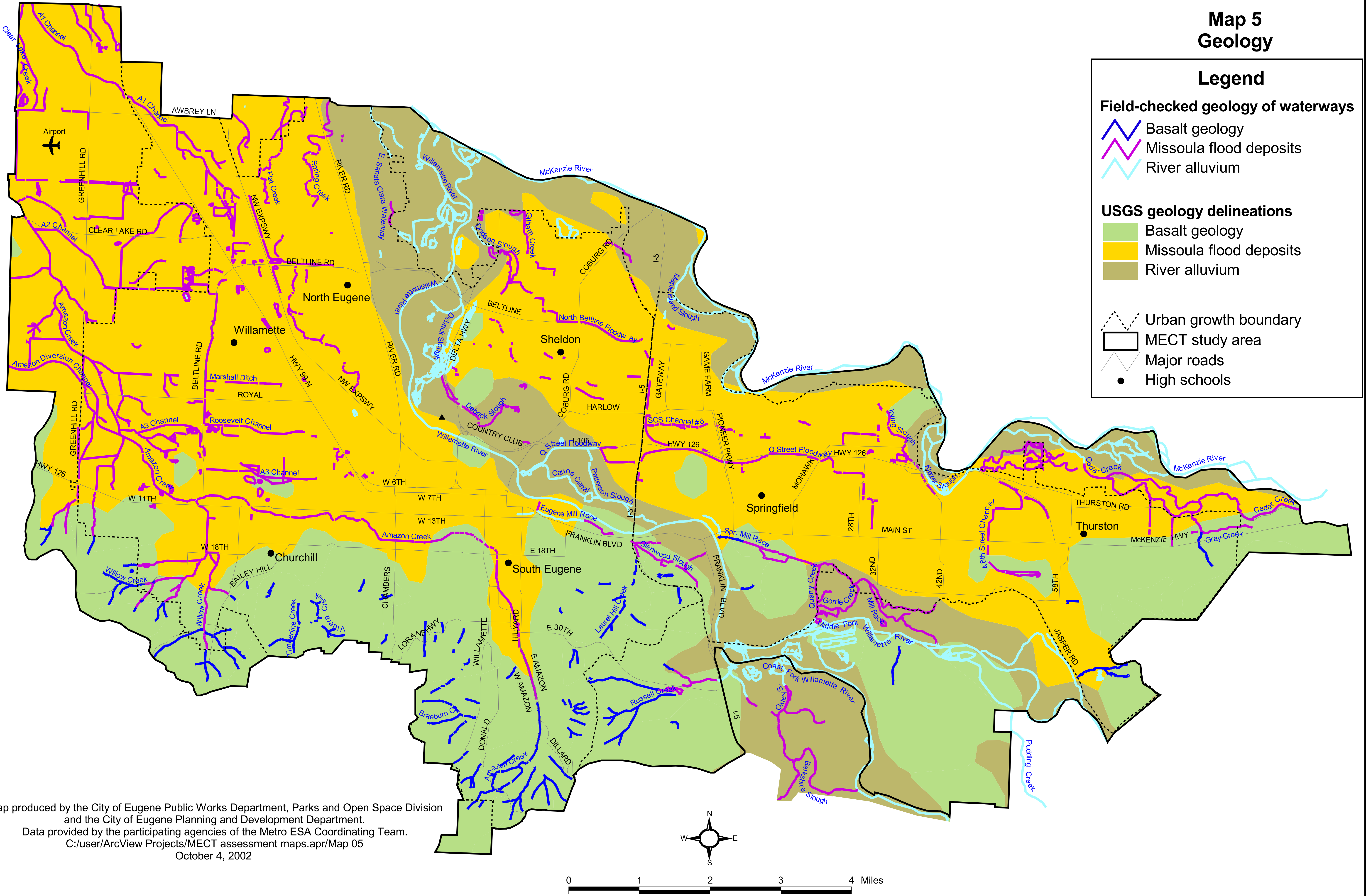
Data provided by the participating agencies of the Metro ESA Coordinating Team.
C:/user/ArcView Projects/MECT assessment maps.apr/Map 04
October 4, 2002

Map 5
Geology



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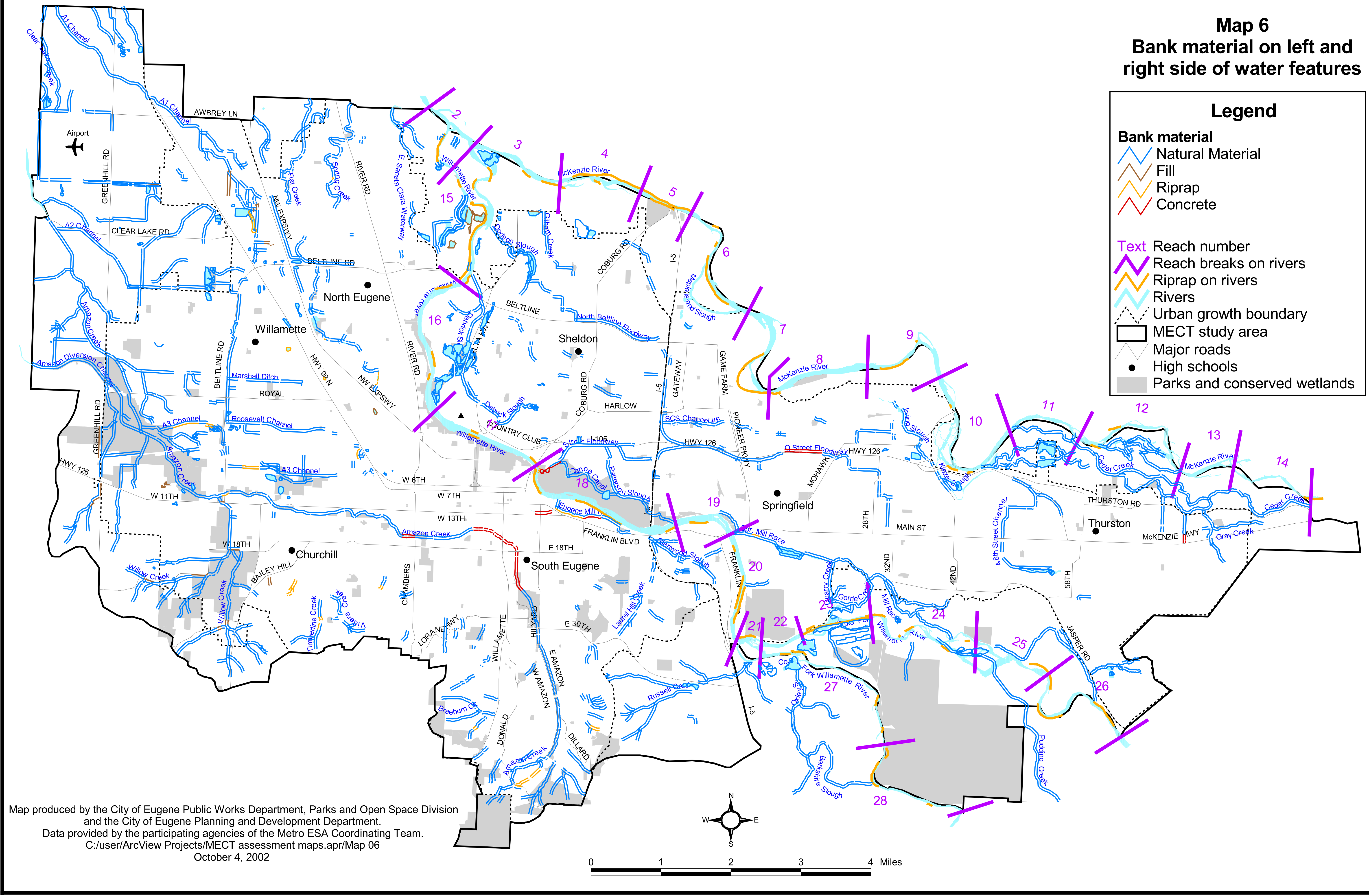
and the City of Eugene Planning and Development Department.
Data provided by the participating agencies of the Metro ESA Coordinating Team.
C:/user/ArcView Projects/MECT assessment maps.apr/Map 05
October 4, 2002

Map 6
Bank material on left and right side of water features



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Data provided by the participating agencies of the Metro ESA Coordinating Team.
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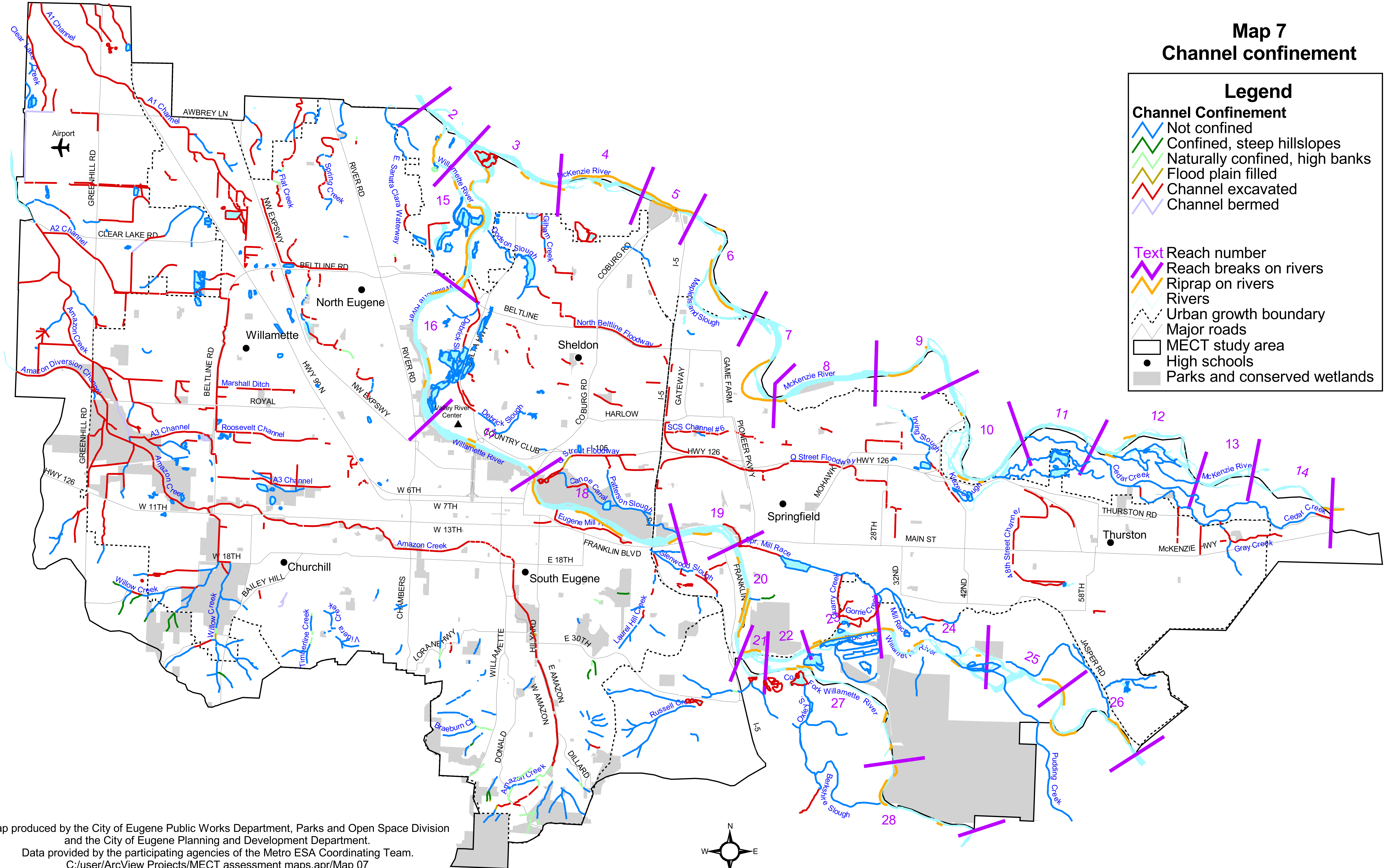
October 4, 2002

Map 7
Channel confinement



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Data provided by the participating agencies of the Metro ESA Coordinating Team.
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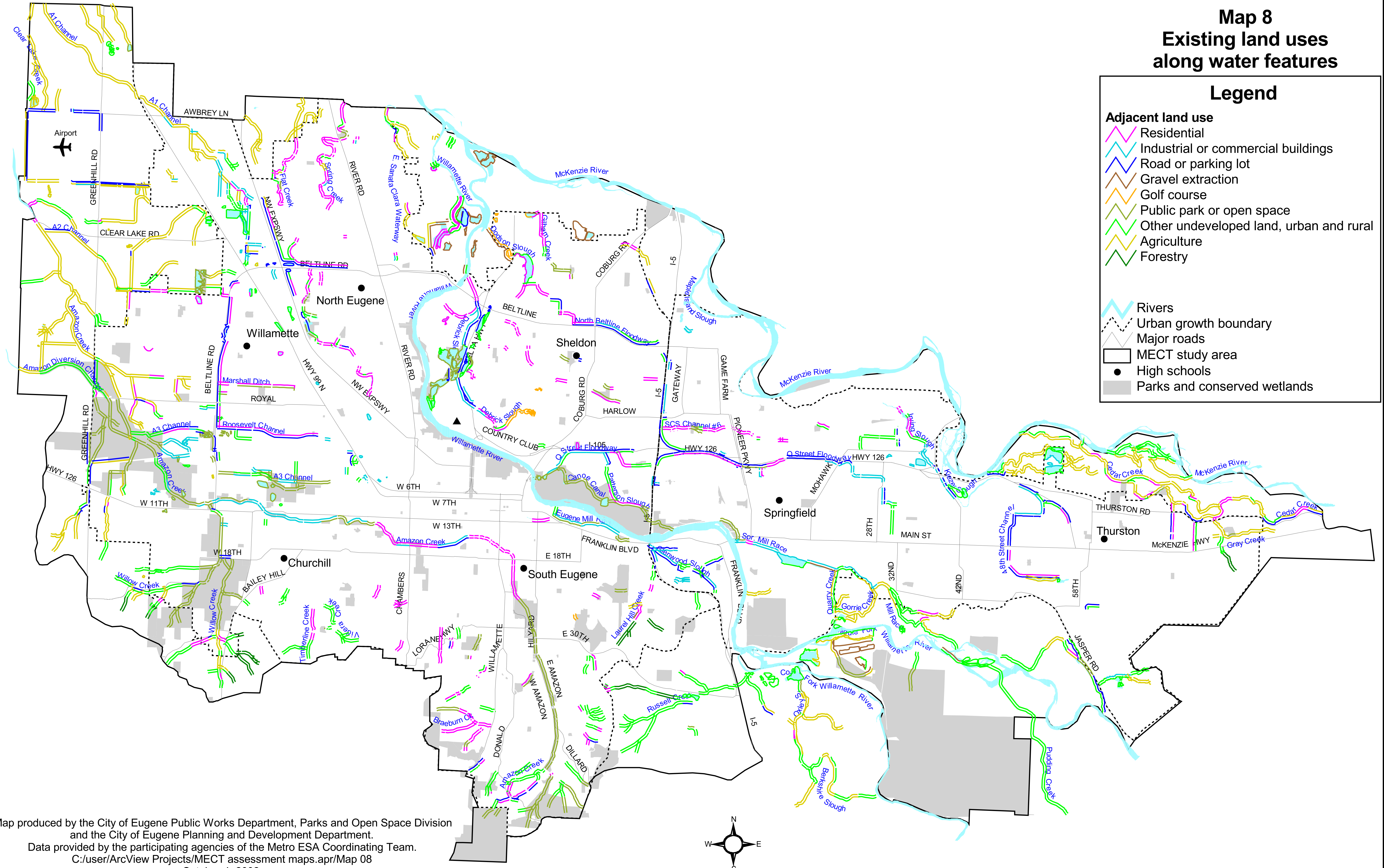
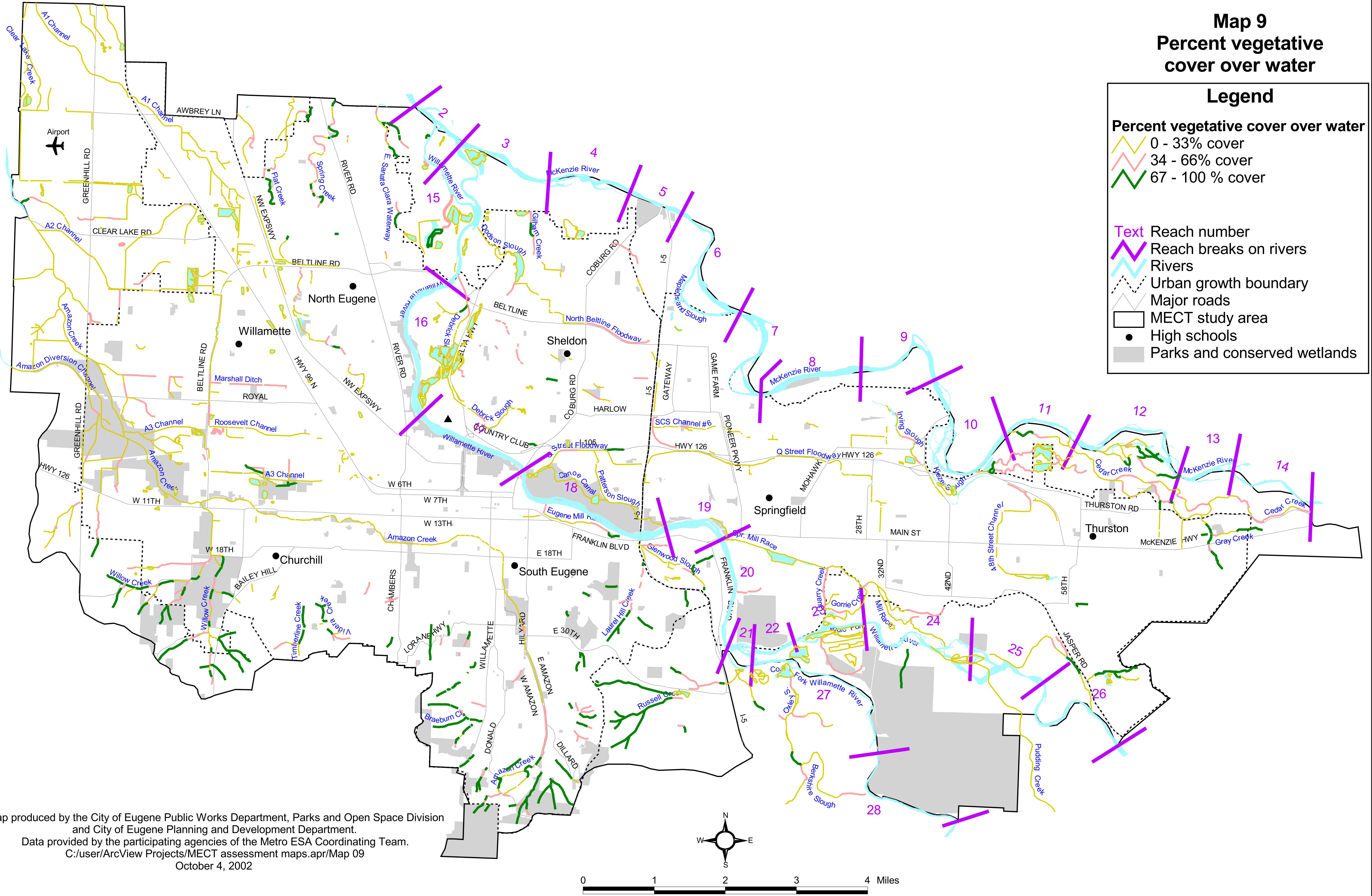
October 4, 2002

Map 8
Existing land uses along water features



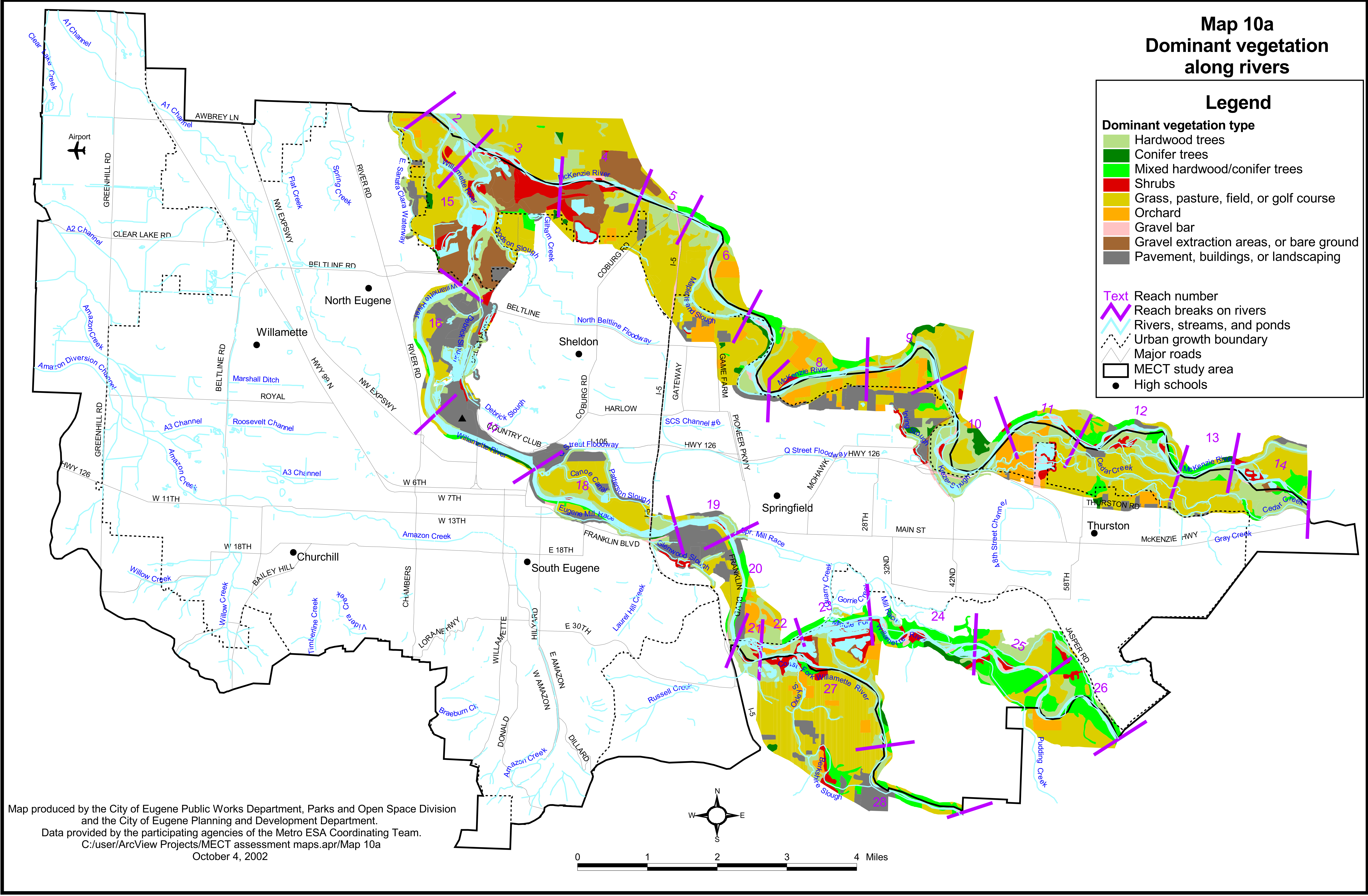
Map produced by the City of Eugene Public Works Department, Parks and Open Space Division
and the City of Eugene Planning and Development Department.
Data provided by the participating agencies of the Metro ESA Coordinating Team.
C:/user/ArcView Projects/MECT assessment maps.apr/Map 08
October 4, 2002

Map 9
Percent vegetative cover over water



Map produced by the City of Eugene Public Works Department, Parks and Open Space Division and City of Eugene Planning and Development Department.
Data provided by the participating agencies of the Metro ESA Coordinating Team.
C:/user/ArcView Projects/MECT assessment maps.apr/Map 09
October 4, 2002

Map 10a
Dominant vegetation along rivers



Map produced by the City of Eugene Public Works Department, Parks and Open Space Division
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Data provided by the participating agencies of the Metro ESA Coordinating Team.
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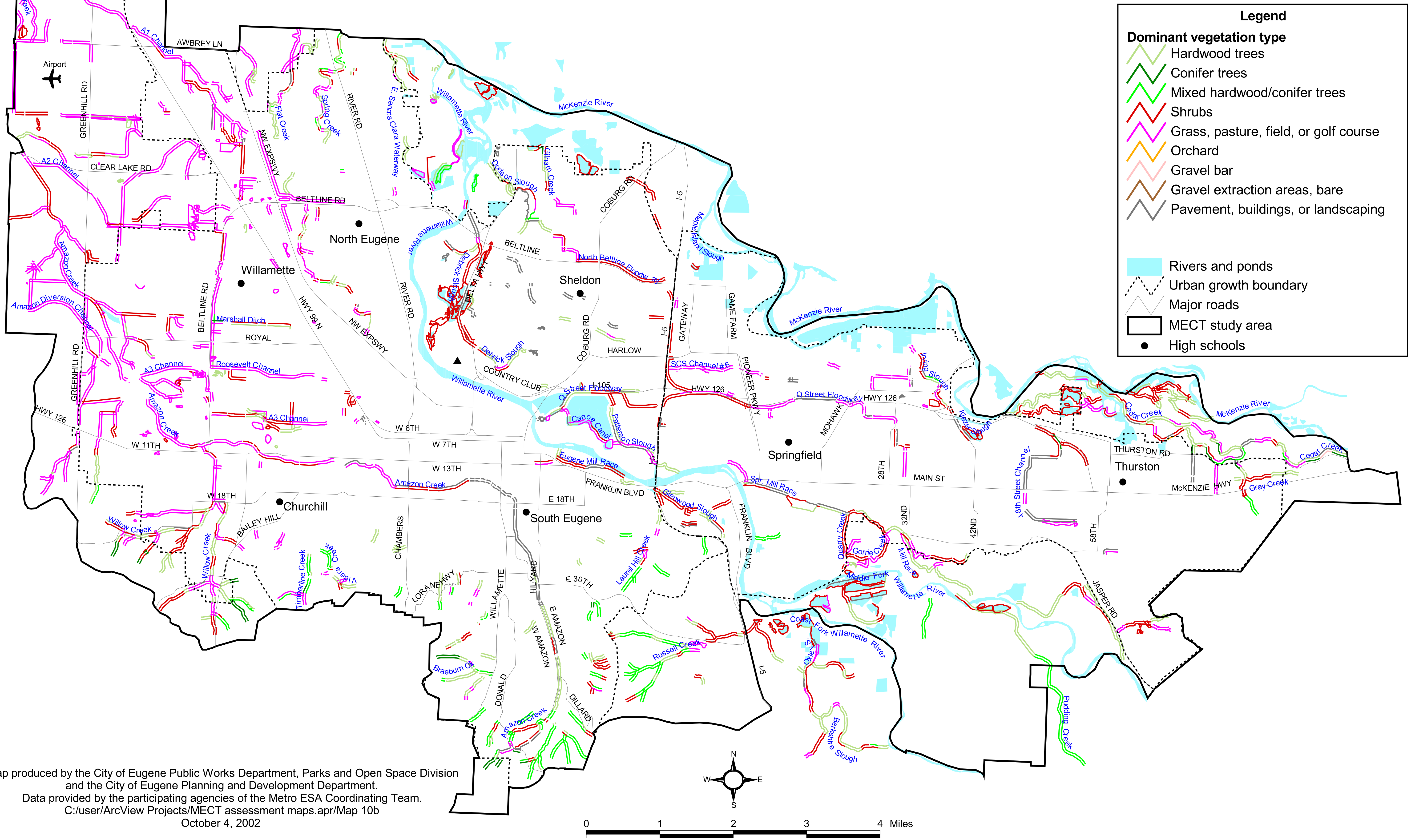
Map 10b Dominant vegetation along streams



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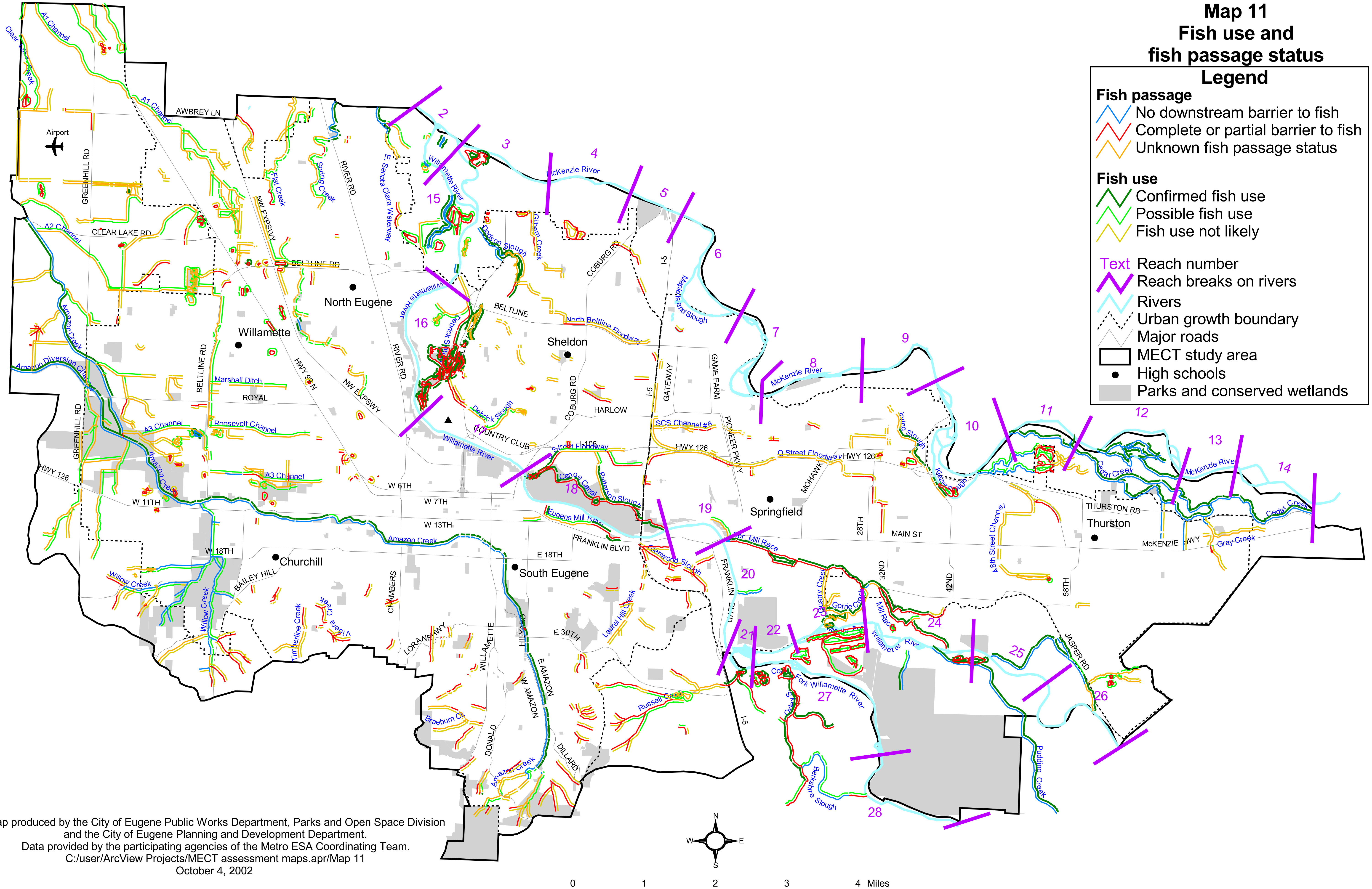
Map 11
Fish use and fish passage status



Map produced by the City of Eugene Public Works Department, Parks and Open Space Division and the City of Eugene Planning and Development Department.
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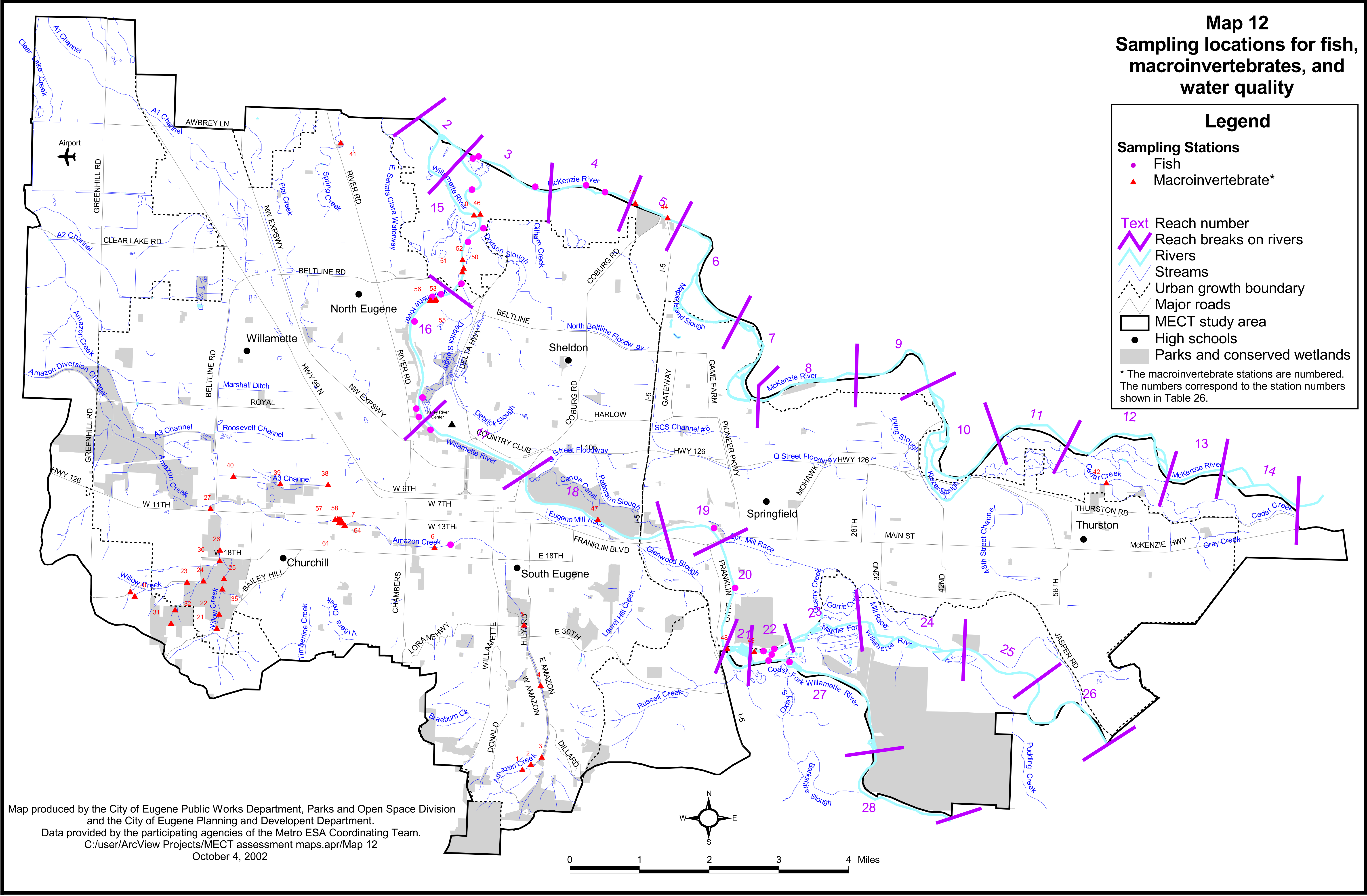
Map 12
Sampling locations for fish, macroinvertebrates, and water quality
Legend
Sampling Stations
Fish
Macroinvertebrate*
Text Reach number
Reach breaks on rivers
Rivers
Streams
Urban growth boundary
Major roads
MECT study area
High schools
Parks and conserved wetlands
* The macroinvertebrate stations are numbered. The numbers correspond to the station numbers shown in Table 26.
North Eugene
Willamette
Sheldon
Churchill
South Eugene
Springfield
Thurston
Airport
McKenzie River
Willamette River
Coast Fork Willamette River
Amazon Creek
Willow Creek
Russell Creek
Cedar Creek
Gray Creek
Pudding Creek
Berkshire Slough
Map produced by the City of Eugene Public Works Department, Parks and Open Space Division
and the City of Eugene Planning and Development Department.
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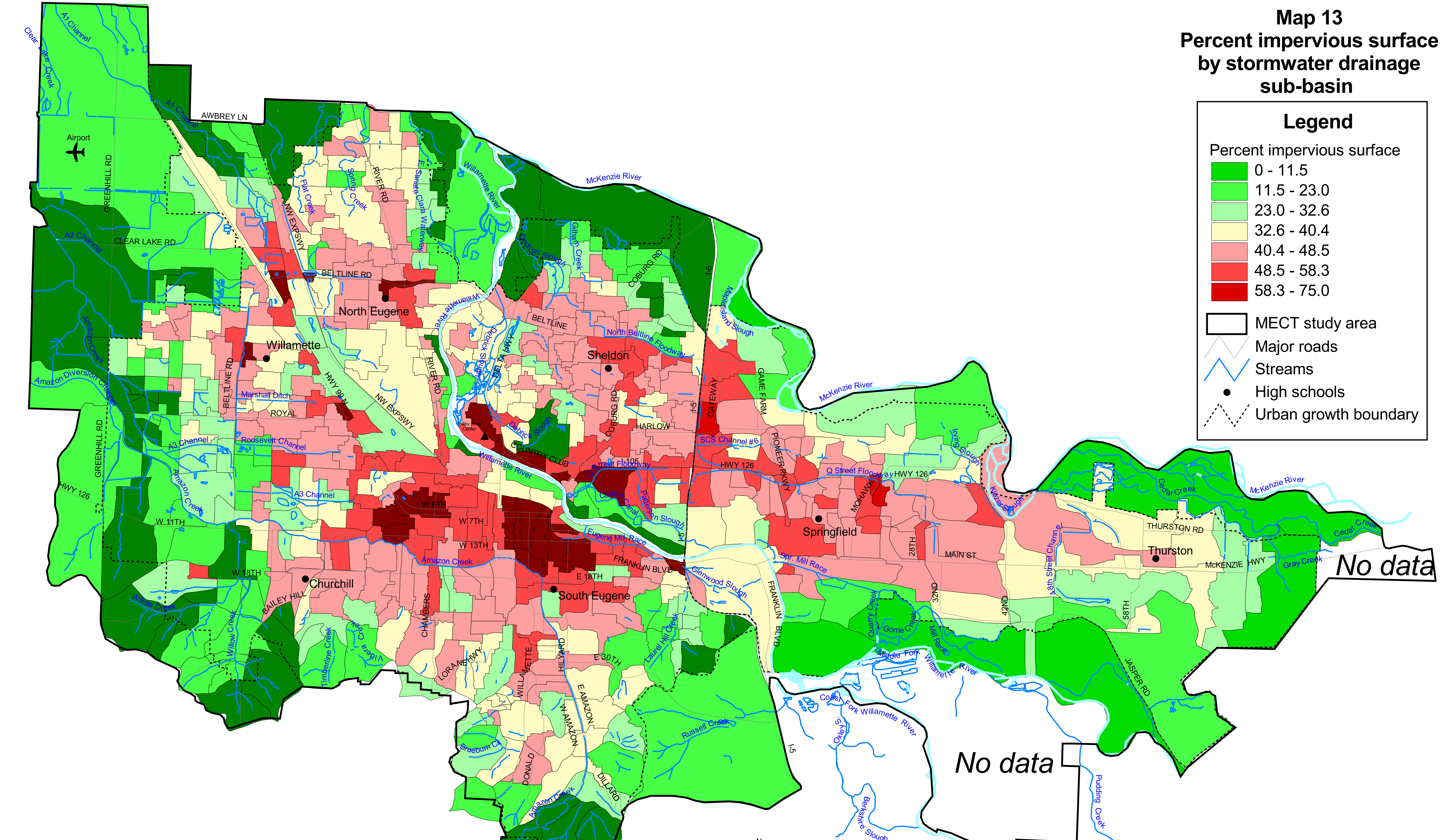
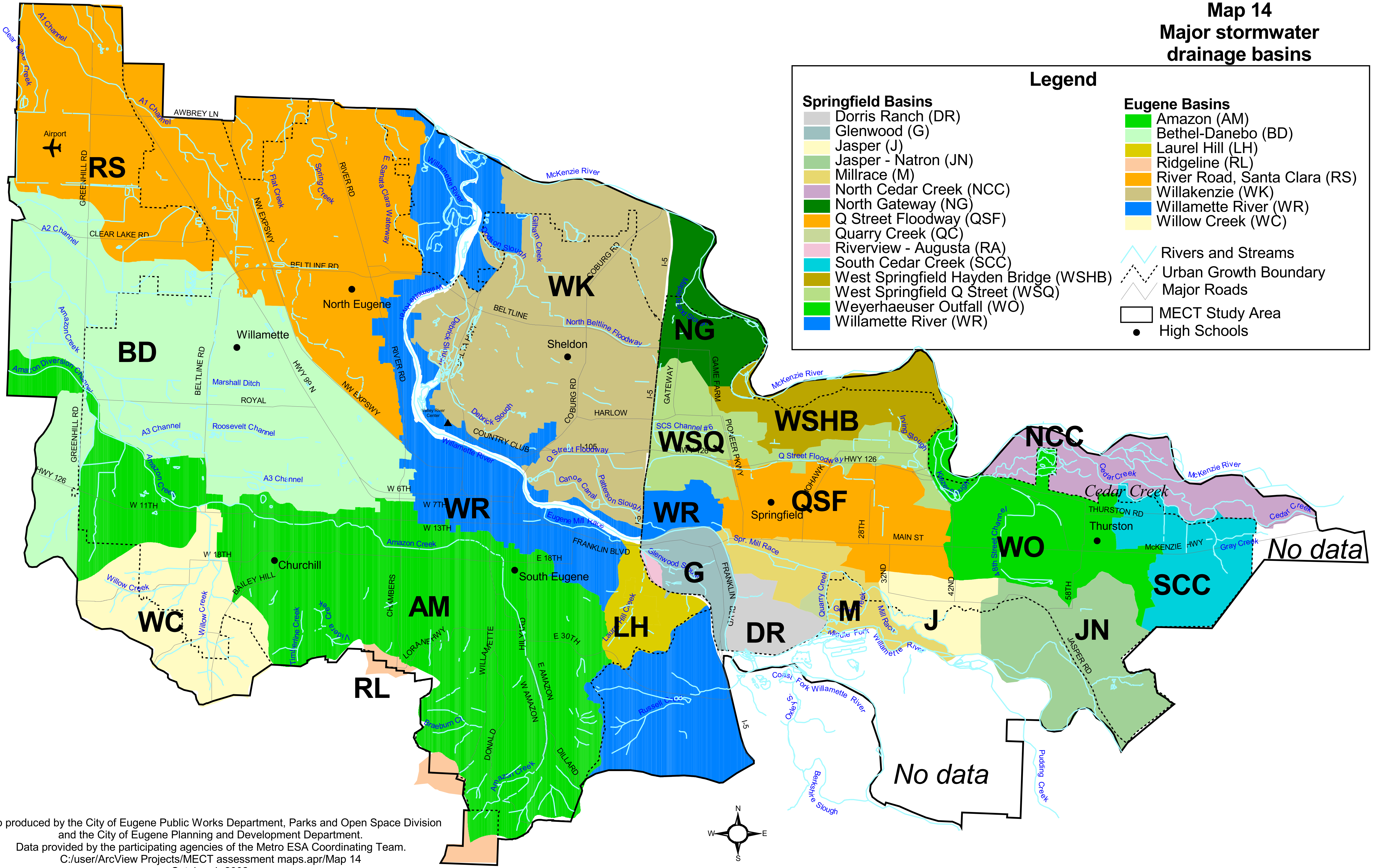
October 4, 2002
0 1 2 3 4 Miles



Map produced by the City of Eugene Public Works Department, Parks and Open Space Division and the City of Eugene Planning and Development Department.
Data provided by the participating agencies of the Metro ESA Coordinating Team.
C:/user/ArcView Projects/MECT assessment maps.apr/Map 13
October 4, 2002

Map 14
Major stormwater drainage basins



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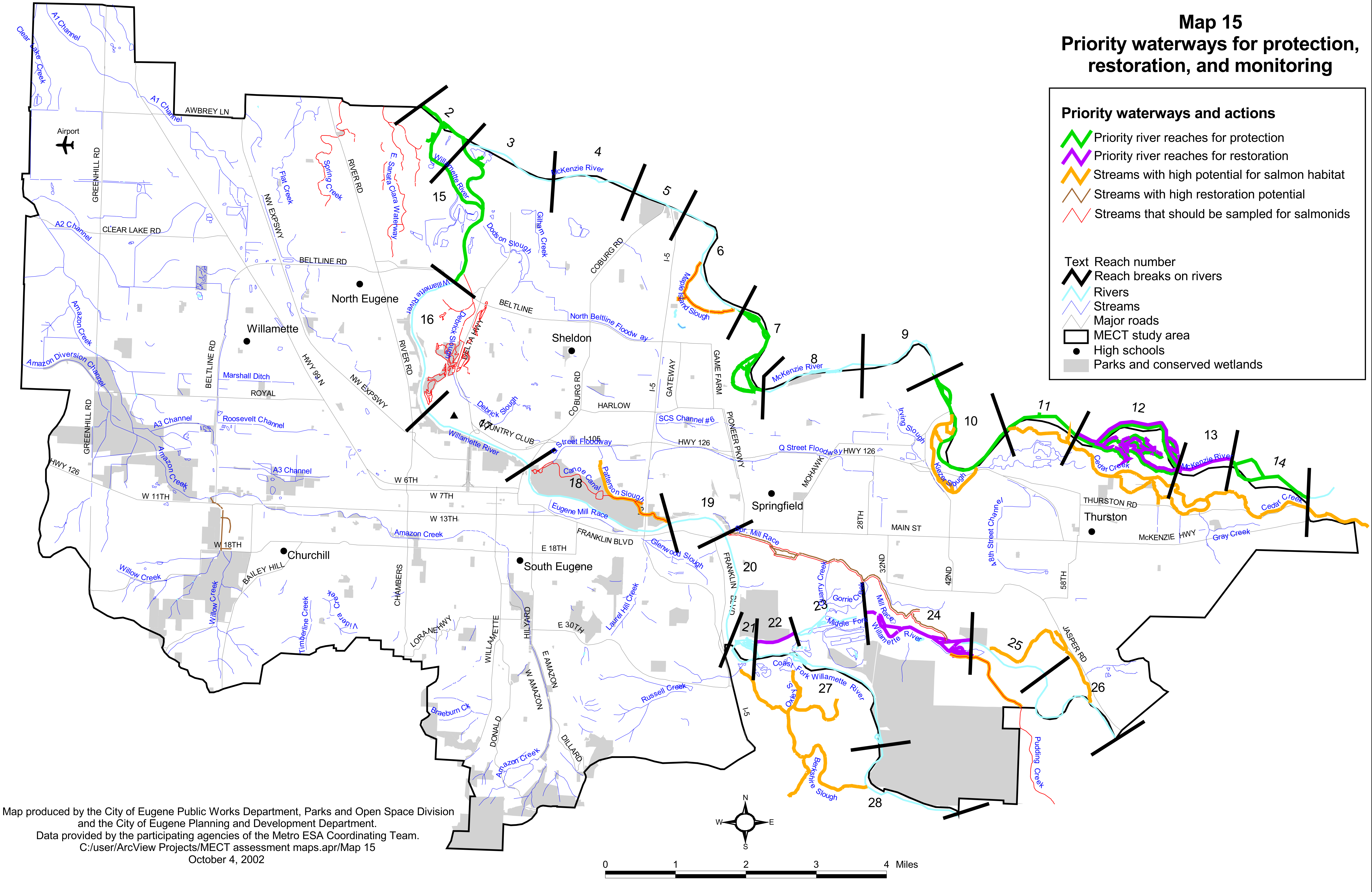
Map 15
Priority waterways for protection, restoration, and monitoring



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