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Status of the Benthic Macroinvertebrate Community in the Wenatchee River, 2010

by

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Abstract

In 2002 and 2003, the Washington State Department of Ecology conducted a study on the Wenatchee River for dissolved oxygen, pH, and phosphorus. The Wenatchee River and one of its tributaries, Icicle Creek, are impaired for temperature, dissolved oxygen, and pH. Potential implementation plans include increasing shade and reducing phosphorus loads to Wenatchee River and Icicle Creek. Only part of the implementation plan had started as of 2010. Although the 2002-2003 study did not include collection of macroinvertebrate data, shifts in the invertebrate community appear to reflect shifts in the environmental parameters analyzed in the study.

Benthic macroinvertebrates are valuable for our measuring of the biological integrity of a waterbody. Nineteen macroinvertebrate samples were collected between 2008 and 2010 upstream and within the Total Maximum Daily Load (TMDL) study area. Results suggest that there are signals in the invertebrate community that are consistent with stressors such as elevated temperature and associated low dissolved oxygen, as well as symptoms of phosphorus enrichment and associated pH issues. The data collected in this study provide a biological baseline with which to compare effectiveness of future implementation projects on the Wenatchee River and Icicle Creek.

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Background

Study Area

The Wenatchee River originates as the outflow of Lake Wenatchee in the Northern Cascades mountain range. This river flows southeast to the Columbia River in Wenatchee, WA. The watershed drains an area of approximately 1370 square miles. There are 3 cities within the watershed – Leavenworth, Peshastin, and Cashmere – that have public wastewater treatment plants that discharge treated wastewater into the lower Wenatchee year-round.

This biological assessment focuses on the Wenatchee River mainstem and Icicle Creek. Both waterbodies are included on Washington State's list of water quality-impaired waters because of low dissolved oxygen (DO) and high pH (Figure 1) (Carroll et al., 2006). Therefore, the river required a Total Maximum Daily Load (TMDL) study. TMDL studies are conducted to calculate the maximum amount of a pollutant that the waterbody can receive and still meet water quality standards.

Washington State water quality standards for DO and pH are dependent on the Aquatic Life Use of the waterbody. For the Wenatchee River watershed above the Chiwawa River confluence with the Wenatchee River, the aquatic life use designation is char spawning and rearing. The temperature, DO, and pH criteria are as follows:

- 7-day average of the daily maximum shall not be above 12 degrees C.
- DO shall not be below 9.5 mg/L as a 1-day minimum once every 10 years.
- pH shall be between 6.5 and 8.5 pH units with a human-caused variation in range less than 0.2 pH units.

For the Wenatchee River watershed above the confluence of the Peshastin Creek, but below the confluence of the Chiwawa River with the Wenatchee River, the aquatic life use designation is core summer habitat for salmonid spawning, rearing, and migration. The temperature, DO, and pH criteria are as follows:

- 7-day average of the daily maximum shall not be above 16 degrees C.
- DO shall not be below 9.5 mg/L as a 1-day minimum once every 10 years.
- pH shall be between 6.5 and 8.5 pH units with a human-caused variation in range less than 0.2 pH units.

For the Wenatchee River watershed below the confluence of Peshastin Creek, the aquatic life use designation is salmonid spawning, rearing, and migration with the following DO and pH criteria:

- 7-day average of the daily maximum shall not be above 17.5 degrees C.
- DO shall not be below 8.0 mg/L as a 1-day minimum once every 10 years.
- pH shall be between 6.5 and 8.5 pH units with a human-caused variation in range less than 0.5 pH units.

In addition, there are sections of the river that have supplemental Spawning and Incubation Temperature protection (Washington State Department of Ecology, 2006).

TMDL Study History

During the dry months of 2002 and 2003, Washington State Department of Ecology (Ecology) staff conducted surveys to assess stream water quality for water temperature, DO, and pH. Ecology found that, during critical conditions, water temperatures would remain naturally higher than the temperature criteria throughout the watershed, but that implementing riparian management techniques would reduce water temperatures by an average of 2.7°C from current conditions (Cristea, N. and G. Pelletier, 2005).

Ecology also found that DO was below the acceptable water quality criterion level of 9.5 mg/L in the upper Wenatchee River (above Leavenworth) and upper Icicle Creek (above Leavenworth National Fish Hatchery) during the summer months (Carroll et al., 2006). This was primarily due to naturally high water temperatures combined with high land elevation which decreases the level of oxygen saturation in the waterbodies. The implementation of measures recommended in the temperature TMDL should help alleviate the DO issues in the upper watersheds.

In addition, Ecology found that DO levels were lower than the minimum criteria of 8.0 mg/L and pH was higher than the criterion level of 8.5 in the lower reaches of the Wenatchee (from Leavenworth downstream) and Icicle Creek (below the Leavenworth National Fish Hatchery). Data demonstrated that the DO was diminished at night and pH was elevated during the afternoon hours. This is a pattern consistent with the shift in DO and pH as a result of algal photosynthesis and respiration. While a change in DO levels and pH is a common result of algal photosynthesis, excessive changes often result from the introduction of nutrients that fertilize the algae both in the water column and attached to the substrate. Specifically, the introduction of phosphorus, a limiting nutrient in freshwater systems, often leads to higher algal reproduction. Further investigation showed that excessive amounts of phosphorus were entering the lower Wenatchee River and Icicle Creek. This additional phosphorus load was linked to elevated pH through algal photosynthesis.

Although the Wenatchee Basin has lower phosphorus levels than other streams in the state, this system is very sensitive to nutrient loading. The phosphorus levels discharged in the lower Wenatchee and Icicle Creek result in low DO levels and elevated pH. Carroll and Anderson (2009) described the breakdown of sources for this high phosphorus load in the following way:

- 55% from treated municipal wastewater.
- 38% from diffuse (non-point) loads (groundwater).
- 3.5% from tributaries within the lower reaches.
- 2.5% attributed to upstream load.

To curtail the elevated pH, large reductions in phosphorus will be required from both wastewater and non-point sources within the watershed.

Recommendations made in the TMDL studies (Cristea, N. and G. Pelletier, 2005; Carroll et al., 2006; Carroll and Anderson, 2009) include:

- Develop and maintain a mature riparian corridor to increase shading.
- Encourage projects that would increase instream flow in the rivers.
- Manage erosion and limit projects that would result in channel widening processes.
- Prohibit discharge of phosphorus above 90 ug/L into the Wenatchee River from wastewater treatment plants from March through October.
- Inspect on-site wastewater treatment drainfields for adequate unsaturated soils to facilitate high-level phosphorus removal.
- Reduce phosphorus concentrations in the Leavenworth National Fish Hatchery effluent to below 5.7 ug/L.

Why We Monitor Biological Communities

Biological communities have been shown to display detectable changes in community structure in response to disturbance (Karr, 1981; Karr and Kimberling, 2003; Kerans and Karr, 1994; Lyons et al., 1996; McCormick et al., 2001, Morley and Karr, 2002; Thorne and Williams, 1997). In Washington State, we analyze the benthic macroinvertebrate communities to monitor the health of streams.

Following the lead of Karr and colleagues from the 1990s to the 2000s, Ecology developed a multi-metric index model of biotic integrity for the Puget Lowlands ecoregion and for the Cascades ecoregion. These models use a summation of scores for 10 metrics to provide an overall statement of biological condition as Good, Fair, or Poor. Each of the 10 metrics that make up the model reflect this same condition (Good, Fair, or Poor) for individual components of the biological community under study. These metrics measure diversity, tolerance to disturbance, feeding groups, and life history characteristics of the community. Shifts in these metrics can tell us about the overall health of the community; they also may tell us the source of stress that led to the community shifting in predictable ways. These models have been accepted and recommended for use as a viable way to measure the biological condition of a stream by the U.S. Environmental Protection Agency (2002, 2005, 2006).

Expected Benthic Macroinvertebrate Community Response to These Changes

Macroinvertebrate communities are sensitive to changes in environmental conditions such as temperature, DO, and pH. The combination of elevated temperatures and phosphorus concentrations leads to algal blooms and a corresponding change in habitat. These environmental changes result in shifts both in macroinvertebrate community composition and taxa abundance. For example, communities often become dominated by insects that feed by grazing or scraping algae from rocks as opposed to being more diverse communities that also include shredders, predators, or collectors. This shift in dominance does not require that

species groups disappear. Rather, the abundance of more tolerant organisms may increase as the abundance and competitive effect of the less tolerant organisms decreases. Relative to the non-disturbed reaches, we may expect to see the following shifts in disturbed areas (Fore et al., 1996):

- Decreased Ephemeroptera-Plecoptera-Trichoptera (EPT) abundance and diversity (richness).
- Increased Hilsenhoff Biotic Index (HBI).
- Increased tolerance measures.
- Decreased community diversity (richness).
- Changes in dominant feeding groups (more scrapers relative to filterers, for example).

Project Objectives

The objective of this study was to describe the biological conditions in the Wenatchee River and Icicle Creek before implementation began. This baseline allows the use of biological data as a tool to track changes in water quality as the recommendations of the 2005 and 2006 TMDLs are carried out.

Methods

Nineteen benthic macroinvertebrate samples were collected from downstream of Lake Wenatchee to the mouth of the Wenatchee River and along Icicle Creek (Figure 1, Table 1). These samples were collected between July 1 and October 15 in 2008, 2009, and 2010. Although we wished to collect samples from the same locations as the previous TMDL studies (Cristea and Pelletier, 2005; Carroll et al., 2006), we were not granted permission to access the river. Our study sites were placed as close to those used in the TMDL as possible, given our knowledge of the area and permission to access the creek.

At each location, 8-1ft^2 kick-net samples were taken from multiple riffle habitats. The nets had a 500 micron mesh material attached to capture invertebrates. Sampling took place working upstream according to Ecology's Standard Operating Procedure (SOP) # EAP073, detailed below. (www.ecy.wa.gov/programs/eap/quality.html)

- Place the net firmly across the stream bottom so that it opens facing upstream and there are no gaps between the net and the substrate.
- Locate a sample area of 1ft^2 directly in front of the net.
- Pick up substrate particles larger than a golf ball from the sample area and brush in flowing water in front of the net to collect any invertebrates clinging to the particle surface. Once clean, set the particle outside of the sampling area.
- After removing all large substrate particles from the sample area, stand in front of the net and kick the substrate vigorously lifting it into the water column with the toe of the boot to a depth of 4-6 cm for 30 seconds.
- Quickly lift the net out of the water in an upstream sweeping motion. Wash material stuck to the sides of the net down to the bottom by splashing water on the *outside* of the net.
- Place contents of net into sample jar, and add enough ethanol to equal 2/3 of the sample volume. Seal the jar and label with date, sample location, and sample collector.

Invertebrate samples were identified and counted according to Plotnikoff and Wiseman (2001) using a 500-count sub-sample. Although the Wenatchee Basin falls in the North Cascades ecoregion, no model has yet been built to address that region. Therefore, data analysis on the most recent year of data from each site was conducted using a bioassessment model called the Washington State Multimetric Index Model for the Cascades Ecoregion, referred to here as the *Cascades model* (Wiseman, 2003). This model was built for the neighboring region to the Wenatchee watershed and is the most appropriate tool we have to assess the data for this report. In addition, individual metrics were also reviewed for signals consistent with responses that relate to the impairments outlined in the DO and pH TMDL. These individual metrics included:

- HBI.
- Percent Hemoglobin-bearing individuals in the sample.
- Percent Tolerant individuals in the sample.

Results

Cascade Model Results

While most of the individual metrics that make up the Cascade model vary without a clear pattern throughout the watershed, a few of the metrics do show a distinct pattern. The final scoring results from the Cascades model show that only the 2 downstream-most sites on the Wenatchee River (W-02 and W-01) and one in Tumwater Canyon (W-10) demonstrate poor biological conditions, while all other sites are in good to fair condition (Table 2, Figure 1).

The Cascade model results do not fully reflect the results of the TMDL studies, which found that lower Icicle Creek (below the Leavenworth National Fish Hatchery) and all sites on the Wenatchee River below Leavenworth had impairments for low DO, high pH and high water temperature (Cristea and Pelletier, 2005; Carroll et al., 2006).

The Cascades model ecoregion is distinct from the North Cascades ecoregion. It is possible that a closer correlation between water quality impairments and model scores is not present due to the fact that we do not have a bioassessment model built for the North Cascades ecoregion yet. This could lead to a lack of sensitivity in 2 ways:

- First, the metrics that are responsive to disturbance in the North Cascades may not be included in the Cascades model.
- Second, the metrics that are included may not be scaled properly to reflect the invertebrate community response to disturbance in the North Cascades.

Individual Metric Results

When looking at individual metric scores that relate to the types of pollution mentioned in the TMDL reports, more sites show signs of moderate to high disturbance (Table 3), although these sites are not limited to the lower watershed (Figures 2-5):

- The HBI is a measure of the impact of organic pollution on the invertebrate community. A score of >3.8 is considered a poor score, while a score of <2.8 is considered a good score. HBI scores indicate high disturbance in the lower Wenatchee River downstream of Leavenworth at sites W- 07 and W-06; and at sites W-03, W-02, and W-01; but also on upper Icicle Creek at site WC-0274 (Figure 2). Moderate disturbance is indicated at I-02, W-08, W-217, and W-04 in the lower watershed. Moderate disturbances are also indicated at WC-021, WC-0154, W-10, and W-09 in the upper Wenatchee and I-03 in the upper Icicle Creek.
- We also see that the percentage of hemoglobin-bearing invertebrates is elevated (>5%) relative to other sites in this system in the lower Wenatchee River near Leavenworth (W-08) and again at the lowest downstream sites (W-03, W-02, W-01) (Figure 3). Hemoglobin-bearing taxa are often associated with poorly oxygenated and, often, warmer water. In most of the sites in the upper Wenatchee watershed (outside of the area

designated as impaired by the DO and pH TMDL), they make up a nominal proportion of the community, often less than 1% (Table 3). Moderate disturbance is indicated at the Tumwater Canyon sites (W-10 and W-09) and W-06 and W-04 in the lower watershed.

- There are also high percentages of *pollution tolerant* individuals (>23%, Wiseman 2003) in the lower Wenatchee River at sites W-02 and W-01 and moderate percentages (≥12%) in the lower Icicle Creek (I-02) and in the Wenatchee River (W-08) near Leavenworth (Figure 4). These sites are in the area designated as impaired by the DO and pH TMDL. We also see moderately elevated percentages of *pollution tolerant* individuals in the Tumwater Canyon of the upper Wenatchee (W-10) and in upper Icicle Creek (I-03) near Eight-mile Creek.

- A higher percentage of filtering invertebrates can signal a shift in trophic status and food availability. % Filterers was the most effective discriminating metric between reference (undisturbed) sites and disturbed sites for the Cascade model development (Wiseman, 2003). Based on % Filterers, the lower Wenatchee shows high disturbance (>28%) at sites W-05, WC-0217, W-04, W-03, W-02, and W-01; and moderate disturbance (≥15%) at site W-07 near Leavenworth (Figure 5).

  In the upper watershed, a moderate disturbance is indicated at I-04 and WC-0274 in Icicle Creek and WC-021 and WC-0154 in the Wenatchee River. There may be two explanations for the pattern observed in the lower Wenatchee. It is possible that the nutrient pollution entering the river from the wastewater treatment plants and from agricultural activities may contribute to the increase in the number of filterers due to an increase in small particle food sources, such as suspended algae.

  However, in this study, we cannot rule out that at least a small amount of this is due to the natural phenomenon of the "River Continuum Concept." The relevant part of this concept states that as you move from the headwaters to the mouth of rivers, food sources transition from course organic matter to fine particle organic matter. Therefore a corresponding increase is seen in the percentage of filterers that are specialized to capture the fine particles in the water column. Implementation of TMDL recommendations could lead to a reduction in the number of filterers found in sites with a high percentage of filterers.

Lower Icicle Creek and Wenatchee River

Generally, we see the worse scores for all indices at the 2 lowest sites in the Wenatchee (W-01 and W-02). Both sites scored Poor with the Cascade model and all 4 individual metrics:

- W-01 is at the mouth of the Wenatchee River and is influenced by the backwater of the Columbia River which floods the mouth once a day due to dam operations on the Columbia.
- W-02 is at the Sleepy Hollow Bridge (river mile 2.7) and is not influenced by the Columbia River.

Based on the TMDL studies, both sites are impaired for temperature, DO, and pH.

Based on the Cascade model, all of the other sites in the DO and pH impaired area are in Fair condition; however, some of the sites indicate high disturbance based on the individual metrics:

- Of the sites near Leavenworth, high disturbance is indicated at W-08 based on the % Hemoglobin-bearing invertebrates, and W-07 and W-06 based on their HBI scores.
- All sites from the City of Peshastin to the mouth (W-05 through W-01) showed high disturbance based on % Filterers.
- Additionally, the site at Monitor (W-03) showed high disturbance based on HBI score and % Hemoglobin-bearing invertebrates.

Again, all of these sites are known to have impairments for DO and pH, with known pollutants from municipal point source discharges and nonpoint contributions (groundwater seepage) to the river. All are scheduled to improve after the TMDL recommendations are implemented.

Upper Icicle Creek and Wenatchee River

Only 2 sites (WC-0255 and W-11) in the upper watershed indicate consistently good conditions based on both the Cascade model scores and individual metric scores. These two sites are in the uppermost and least disturbed areas sampled in the Icicle Creek and Wenatchee River watersheds.

Indications of moderate disturbance are seen at other sites in the upper Wenatchee and upper Icicle watersheds including:

- The sites downstream of city of Plain (WC-021 and WC-0154) are in Fair condition based on the Cascade model and show moderate disturbance for organic pollution (HBI) and % Filterers. Both sites are near communities with on-site septic systems.
- The site at the bottom of Tumwater Canyon (W-09) shows moderate disturbance based on HBI score and % Hemoglobin-bearing invertebrates.
- The other site at the top of Tumwater Canyon, W-10, has a Poor score with the Cascade model and shows moderate disturbance for 3 out of 4 of the individual metrics. Being in a canyon, this site may have different habitat than other reaches of the river, but it still had an unexpected poor and potentially disturbed invertebrate community. This site may also be heavily impacted by State Highway 2 that runs through the canyon and a U.S. Forest Service campground upstream.
- An upper Icicle Creek site, I-03, also has unexplained disturbance that may be due to habitat change. There is also a nearby heavily-used campground.
- Disturbance is also seen at 2 other sites in upper Icicle Creek (I-04 and WC-0274). They both had moderately high % Filterers and the site WC-0274 also showed a high disturbance based on the HBI score. WC-0274 was sampled at an RV park on Icicle Creek, one of several private in-holdings in the upper Icicle Creek watershed.

While all of the upper sites may have naturally high water temperatures, the upper watershed did not show impairments for DO and pH in 2002 during the DO and pH TMDL study. There may be other factors impacting the macroinvertebrate community. A full suite of habitat data was not collected at the sites; however, localized changes in habitat, like substrate change, can affect the invertebrate community.

Still, many areas of the upper watershed are subject to changing land use and development pressures which usually lead to changes in water quality and habitat. Some of the poor or marginal scores in the upper watershed may reflect early indications of this type of stress.

Conclusions and Recommendations

The Cascades model scores showed a clear signal of poor conditions in the lowest reach of the Wenatchee River with varied signs of fair to good conditions further upstream.

While the Cascades model scores did not reflect complete agreement with the impairments described by the DO and pH TMDL study, other individual metrics indicate moderate to high disturbance in the DO and pH TMDL impairment area.

Considering the Cascade model scores and the individual metrics together, the macroinvertebrate community appears to be most disturbed in 2 main locations (both of which are in the impairment area designated by the DO and pH TMDL):

- In the reach of the Wenatchee River from Cashmere downstream to the mouth.
- On the Wenatchee River around and below Leavenworth.

Additionally, sites of concern and in need of further assessment include:

- In upper Icicle Creek
  - I-03 for potential contamination from nearby campground.
  - WC-0274 for potential organic pollution from nearby RV park.
- In upper Wenatchee River
  - W-10 for potential contamination.
  - WC-021 and WC-0154 for potential contamination from residents near Plain.

Individual metrics that reflect changes associated with elevated temperature and nutrient enrichment, particularly the HBI, the Percent Hemoglobin-bearing organisms, and % Filterers, should be revisited in future effectiveness monitoring projects.

The Percent Pollution Tolerant organisms did not demonstrate such a clear pattern. This metric could be responding to localized factors in the stream, such as changes in habitat and sediment regimes.

Implementing measures to reduce water temperature and moderate DO and pH levels by controlling phosphorus, as recommended in the TMDL studies, should lead to decreases in all of the above metrics and to less disturbance in the invertebrate communities. Thresholds for the appropriate amount of decrease in the values of these metrics should be explored. It is possible that by the time any effectiveness monitoring takes place we may have built a more appropriate bioassessment model for the North Cascades. We could revisit the data used for this study and compare that with data collected after implementation of TMDL recommendations for Wenatchee River.

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References

Carroll, J., S. O'Neal, and S. Golding, 2006. Wenatchee River Basin Dissolved Oxygen, pH, and Phosphorus Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. Publication No. 06-03-018. 151 pgs. www.ecy.wa.gov/biblio/0603018.html

Carroll, J., and R. Anderson, 2009. Wenatchee River Watershed Dissolved Oxygen and pH Total Maximum Daily Load. Washington State Department of Ecology, Olympia, WA. Publication No. 08-10-062. 123 pgs. www.ecy.wa.gov/biblio/0810062.html

Cristea, N. and G. Pelletier, 2005. Wenatchee River Temperature Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. Publication No. 05-03-011. 83 pgs. www.ecy.wa.gov/biblio/0503011.html

Fore, L.KS., J.R. Karr, and R.W. Wisseman, 1996. Assessing invertebrate responses to human activities: Evaluating alternative approaches. Journal of the North American Benthological Society 15:212-231.

Karr, J.R., 1981. Assessment of biotic integrity using fish communities. Fisheries 6(6): 21-27.

Karr, J.R. and D.N. Kimberling, 2003. A terrestrial arthropod index of biological integrity for shrub-steppe landscapes. Northwest Science **77**: 202-213.

Kerans, B.L. and J.R. Karr, 1994. A benthic index of biotic integrity (B-IBI) for rivers of the Tennessee Valley. Ecological Applications 4: 768-785.

Lyons J., L. Wang, and T. Simonson, 1996. Development and validation of an index of biotic integrity for coldwater streams in Wisconsin. North American Journal of Fisheries Management **16**: 241-256.

McCormick, F.H., R.M. Hughes, P.R. Kaufmann, A.T. Herlihy, and D.V. Peck, 2001. Development of an index of biotic integrity for the Mid-Atlantic Highlands Region. Transactions of the American Fisheries Society 130: 857-877.

Morley, S.A. and J.R. Karr, 2002. Assessing and restoring the health of urban streams in the Puget Sound Basin. Conservation Biology 16: 1498-1509.

Plotnikoff, R.W. and C. Wiseman, 2001. Macroinvertebrate Biological Monitoring Protocols for Rivers and Streams. Washington State Department of Ecology, Olympia, WA. Publication No. 01-03-028. www.ecy.wa.gov/biblio/0103028.html.

Thorne, R.St-J. and W.P. Williams, 1997. The response of benthic invertebrates to pollution in developing countries: A multimetric system of bioassessment. Freshwater Biology 37: 671-686.

U.S. Environmental Protection Agency, 2002. Summary of Biological Assessment Programs and Biocriteria Development for States, Tribes, Territories, and Interstate Commissions: Streams and Wadeable Rivers. EPA- 822-R-02-048. U.S. Environmental Protection Agency, Washington, DC.

U.S. Environmental Protection Agency, 2005. Use of Biological Information to Better Define Designated Aquatic Life Uses in State and Tribal Water Quality Standards: Tiered Aquatic Life Uses. EPA-822-R-05-001. U.S. Environmental Protection Agency, Washington, DC.

U.S. Environmental Protection Agency, 2006. Wadeable Streams Assessment: A Collaborative Survey of the Nation's Streams. EPA 841-B-06-002. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

Washington State Department of Ecology, 2006. Water Quality Standards for Surface Waters of the State of Washington. Chapter 173-201A WAC. Publication No. 06-10-091. www.ecy.wa.gov/biblio/0610091.html

Wiseman, C.W., 2003. Multimetric Index Development for Biological Monitoring in Washington State Streams. Washington State Department of Ecology, Olympia, WA. Publication No. 03-03-035. www.ecy.wa.gov/biblio/0303035.html

Figures

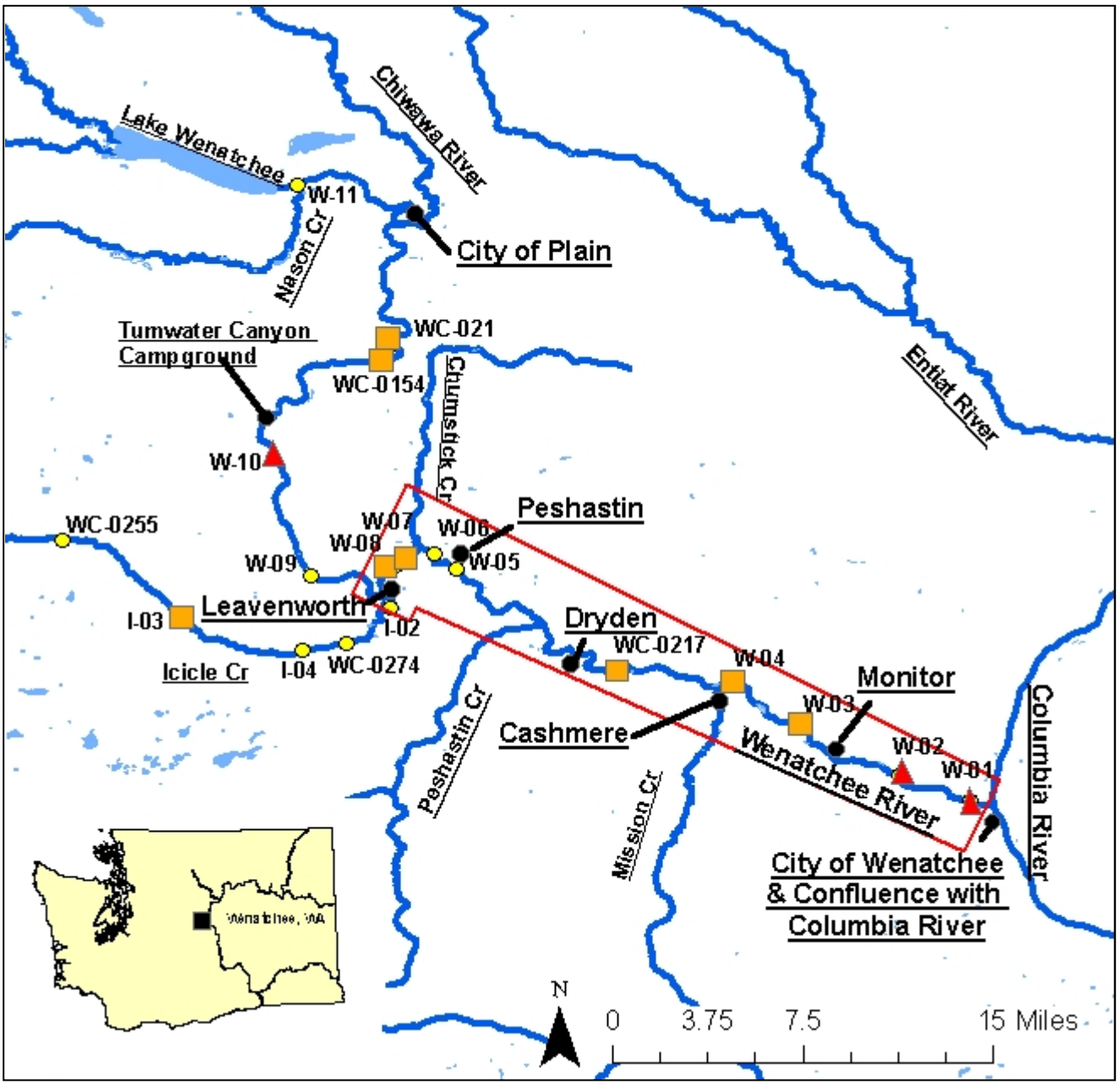

Figure 1. Aquatic macroinvertebrate collection sites in the Wenatchee Basin.

Biological assessment scores for sites with triangles are in Poor condition, sites with squares are in Fair condition, and sites with circles are in Good Condition (Table 3). The TMDL covers the region enclosed in red.

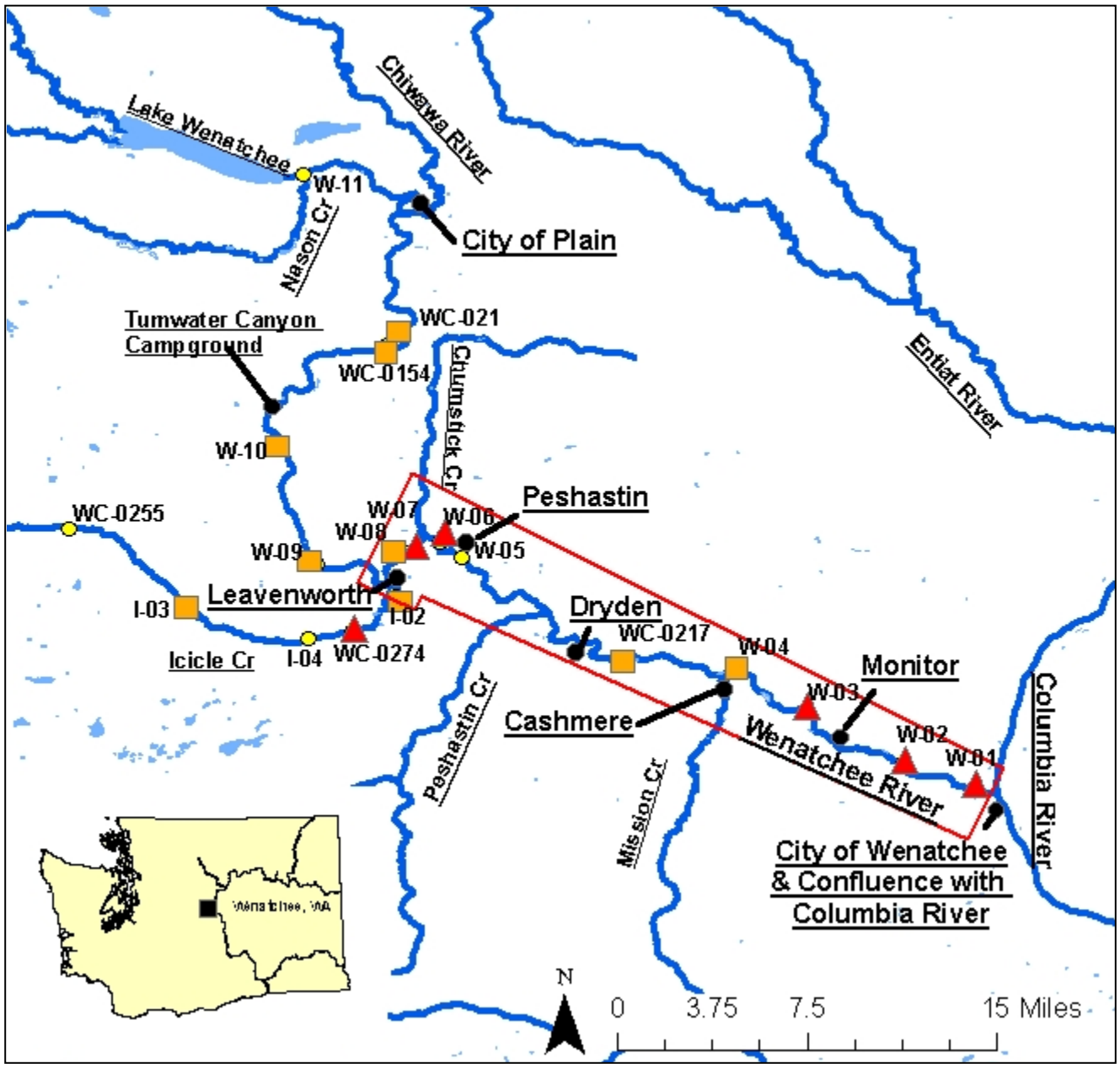

Figure 2. Metric scores for Hilsenhoff Biotic Index.

Sites with triangles are in Poor condition, sites with squares are in Fair condition, and sites with circles are in Good Condition (Table 3). The TMDL covers the region enclosed in red.

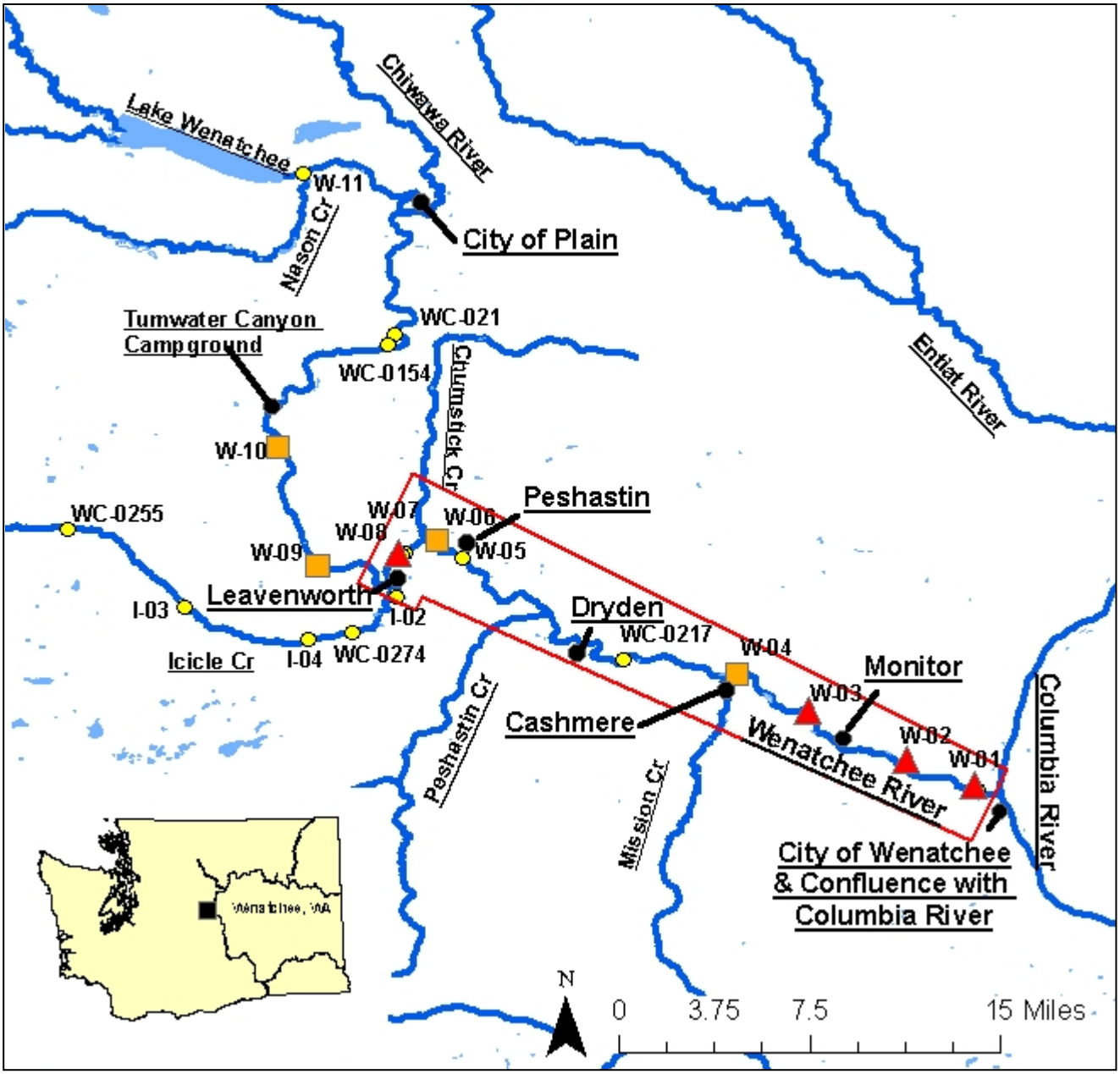

Figure 3. Metric scores for Percent of Community that are Hemoglobin Bearers.

Sites with triangles are in Poor condition, sites with squares are in Fair condition, and sites with circles are in Good Condition (Table 3). The TMDL covers the region enclosed in red.

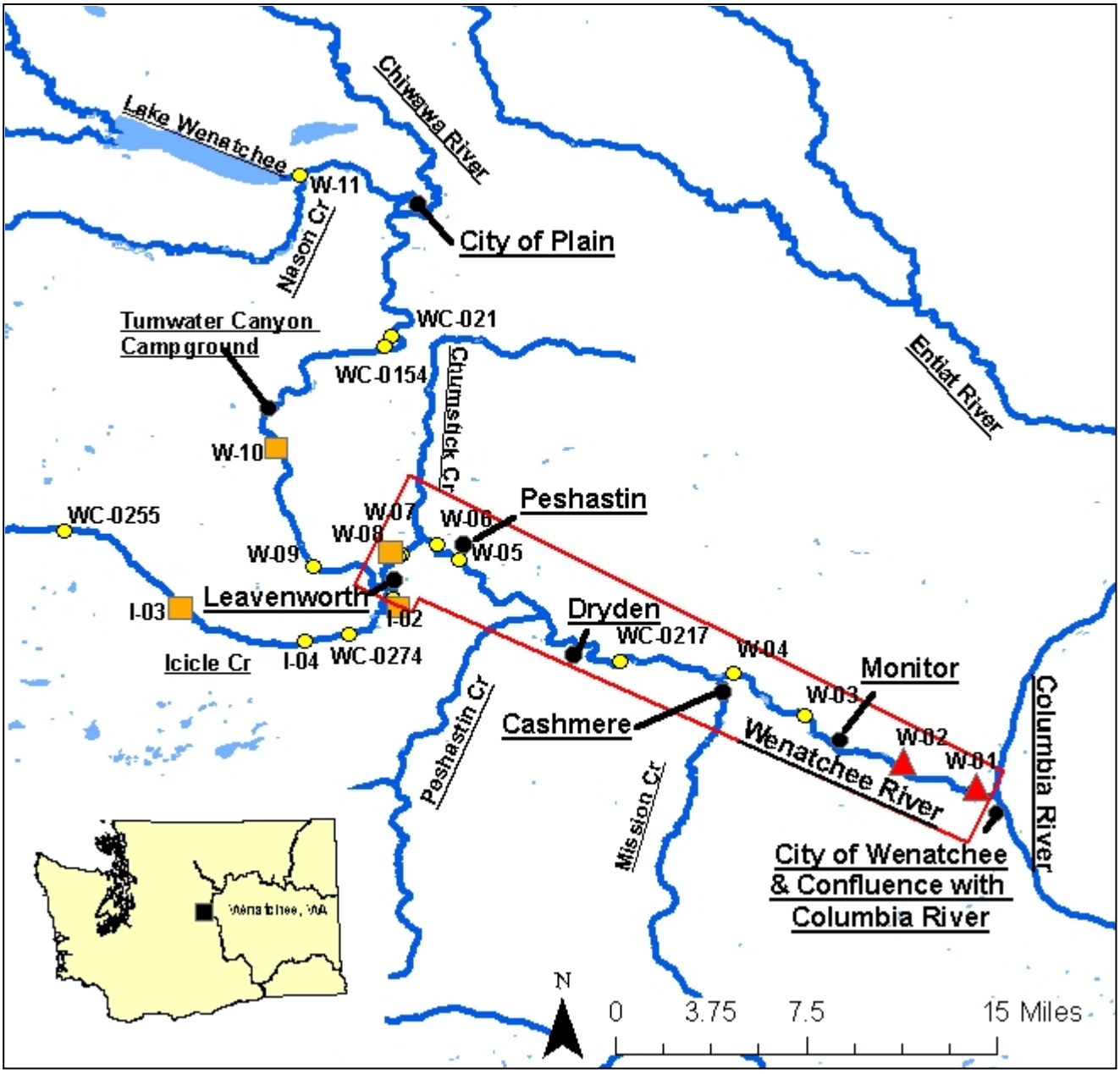

Figure 4. Metric scores for Percent of Community that are Pollution Tolerant.

Sites with triangles are in Poor condition, sites with squares are in Fair condition, and sites with circles are in Good Condition (Table 3). The TMDL covers the region enclosed in red.

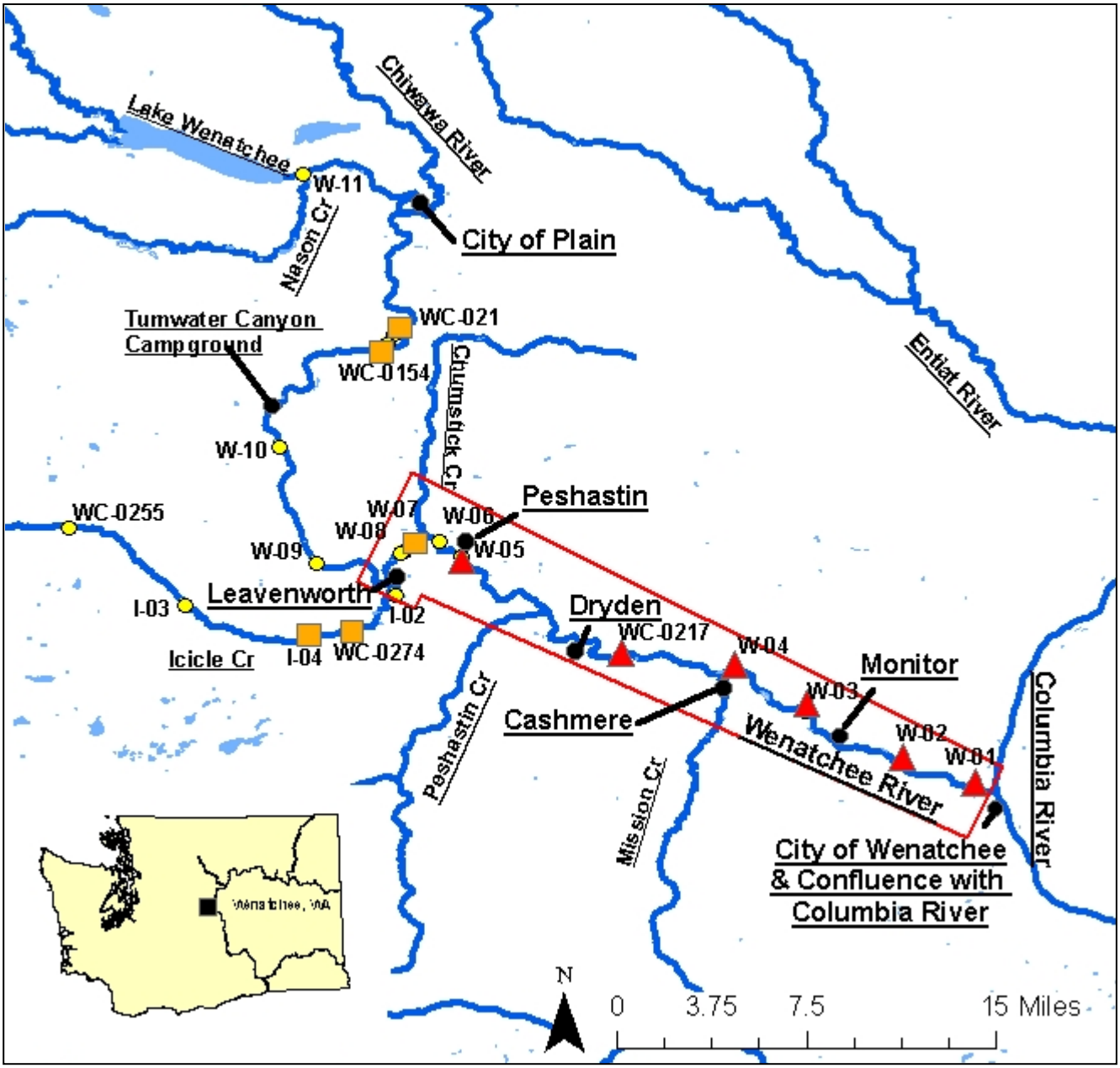

Figure 5. Metric scores for Percent of Community that are Filterers.

Sites with triangles are in Poor condition, sites with squares are in Fair condition, and sites with circles are in Good Condition (Table 3). The TMDL covers the region enclosed in red.

Tables

Table 1. Biological data collection sites in downstream order along Icicle Creek and the Wenatchee River.

Site ID	Waterbody	Location Description	Designated Aquatic Life Use**	Latitude	Longitude
WC-0255	Icicle	Ida Creek Campground	CSH	47.6070	-120.8497
I-03	Icicle	Near Eight-mile creek	CSH	47.5627	-120.7823
I-04	Icicle	Upstream of Snow Creek	CSH	47.5438	-120.7125
WC-0274	Icicle	Icicle Creek RV Park	CSH	47.5479	-120.6867
*I-02	Icicle	On East Leavenworth Rd	CSH	47.5680	-120.6622
W-11	Wenatchee	Lake Wenatchee Bridge	CSR	47.8098	-120.7154
WC-021	Wenatchee	South of Plain @ RR Bridge	CSH	47.7181	-120.6626
WC-0154	Wenatchee	South of Plain near Gravel Pit	CSH	47.7118	-120.6669
W-10	Wenatchee	Tumwater Canyon 1st Pullout	CSH	47.6532	-120.7291
W-09	Wenatchee	Lower Canyon Bridge Pulloff	CSH	47.5866	-120.7076
*W-08	Wenatchee	Leavenworth Put-in	CSH	47.5922	-120.6593
*W-07	Wenatchee	Leavenworth Beach	CSH	47.5937	-120.6568
*W-06	Wenatchee	1st Rapid Below Leavenworth	CSH	47.5988	-120.6373
*W-05	Wenatchee	Bridge near Peshastin	SRM	47.5904	-120.6239
*WC-0217	Wenatchee	below Dryden	CSH	47.5326	-120.5326
*W-04	Wenatchee	Cashmere River Park	SRM	47.5254	-120.4674
*W-03	Wenatchee	Old Monitor Bridge	SRM	47.5018	-120.4268
*W-02	Wenatchee	Sleepy Hollow Bridge	SRM	47.4723	-120.3716
*W-01	Wenatchee	Confluence Park	SRM	47.4579	-120.4579

*Site located in area designated as impaired by the DO and pH TMDL (Carroll et al., 2006).
** Aquatic Life Use codes:
CSH: Core Summer Habitat
CSR: Char Spawning and Rearing
SRM: Spawning, Rearing, and Migration

Table 2. Multimetric Index Scores (1=poor, 3=fair, 5=good) for the Wenatchee Basin calculated using the Cascades model (Wiseman, 2003). *Final model scores are interpreted in the following way: <23 = Poor condition, 23-28 = Fair condition, and >28 = Good condition.*

Sites	% Epheme-roptera	Total Richness	Plecoptera Richness	Trichoptera Richness	Clinger Richness	Intolerant Taxa Richness	% Tolerant Taxa	Hilsenhoff Biotic Index	% Clingers	% Filterers	Final model scores	Interpre-tation
WC-0255	1	3	3	5	5	3	5	5	5	5	40	Good
I-03	3	1	1	1	5	1	3	3	3	5	26	Fair
I-04	1	3	1	3	5	1	5	5	5	3	32	Good
WC-0274	3	3	3	1	5	3	5	1	5	3	32	Good
*I-02	1	3	3	1	5	1	3	3	5	5	30	Good
W-11	1	3	3	1	5	1	5	5	5	5	34	Good
WC-021	1	3	1	1	5	1	5	3	5	3	28	Fair
WC-0154	1	3	3	1	5	1	5	3	3	3	28	Fair
W-10	1	3	1	1	3	1	3	3	1	5	22	Poor
W-09	1	3	1	1	5	1	5	3	5	5	30	Good
*W-08	3	3	1	1	3	1	3	3	5	5	28	Fair
*W-07	1	3	1	1	5	1	5	1	3	3	24	Fair
*W-06	1	3	1	1	5	1	5	1	1	5	24	Fair
*W-05	1	1	1	1	5	1	5	5	5	1	26	Fair
*WC-0217	1	3	3	1	5	1	5	3	5	1	28	Fair
*W-04	1	3	1	1	5	1	5	3	5	1	26	Fair
*W-03	1	3	1	1	5	1	5	1	5	1	24	Fair
*W-02	1	1	1	1	3	1	1	1	5	1	16	Poor
*W-01	1	3	1	3	3	1	1	1	3	1	18	Poor

*Site located in area designated as impaired by the DO and pH TMDL (Carroll et al., 2006).

Table 3. Values of individual metrics relevant to the areas designated as impaired by the DO and pH TMDL.

Bold-underlined values indicate values that exceed a high disturbance threshold.

Sites	Hilsenhoff Biotic Index	Hemoglobin Bearer Percent**	Pollution Tolerant Percent	Filterers Percent
High disturbance	>3.8	>5.0%	>23.0%	>28%
Low disturbance	<2.8	<1.0%	<12.0%	<15%
WC-0255	1.8	0.0%	0.1%	<15%
I-03	3.5	0.0%	12.2%	<15%
I-04	2.7	0.8%	6.8%	17%
WC-0274	**4.0**	0.0%	0.2%	16.3%
*I-02	2.9	0.2%	18.7%	<15%
W-11	2.6	0.6%	11.6%	<15%
WC-021	3.6	0.0%	0.1%	18%
WC-0154	2.9	0.1%	0.1%	26%
W-10	2.9	1.1%	21.1%	<15%
W-09	3.0	2.3%	11.1%	<15%
*W-08	3.6	**8.5%**	12.2%	<15%
*W-07	**4.4**	0.6%	4.2%	20.6
*W-06	**4.7**	1.1%	3.0%	<15%
*W-05	1.9	0.2%	1.3%	**>28%**
*WC-0217	3.2	0.6%	0.1%	**>28%**
*W-04	3.0	3.7%	5.0%	**>28%**
*W-03	**4.4**	**24.6%**	9.8%	**>28%**
*W-02	**4.2**	**12.6%**	**28.3%**	**>28%**
*W-01	**4.9**	**6.7%**	**27.3%**	**>28%**

*Site located in area designated as impaired by the DO and pH TMDL (Carroll et al., 2006).
** The interpretation of this indicator is site specific. These thresholds were set relative to the sites within this study only.

Appendix.
Glossary, Acronyms, and Abbreviations

Benthic macroinvertebrates: Invertebrate organisms large enough to see unaided by microscopes found in or on the substrate of waterbodies.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

Hemoglobin-bearing organism: An organism that uses hemoglobin as a means of oxygen transport through the body. Hemoglobin is a protein that gives blood its red color due to the use of iron molecules to bind and carry oxygen through the body of vertebrates. Some invertebrate species known to be tolerant of low oxygen conditions also use hemoglobin to store and carry oxygen.

Nonpoint source: Pollution entering waters of the state from dispersed land-based or water-based activities, including atmospheric deposition, surface water runoff, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Point source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity (Kammin, 2010).

Taxa: Species or group of organisms having similar characteristics. The lowest level of identification for organisms.

Total Maximum Daily Load (TMDL): Water cleanup plan. A distribution of a substance in a waterbody designed to protect it from not meeting (exceeding) water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a Margin of Safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Acronyms and Abbreviations

DO	(See Glossary above)
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
HBI	Hilsenhoff Biotic Index
SOP	(See Glossary above)
TMDL	(See Glossary above)

Units of Measurement

cm	centimeter
ft	feet
mg/L	milligrams per liter (parts per million)