APPENDIX A

Dissolved Oxygen- Winkler titration

1. Thoroughly rinse glass DO bottle with stream sample water. Then fill the DO bottle by either placing it in the collection bucket or submerging into the stream by hand (when stream depth is too shallow for bucket). Fill the bottle until it overflows and make sure that no air bubbles are trapped in the bottle. Insert stopper. Don't let the bottle sit around! Do the next steps right away or the DO may change.
2. It is recommended that you put gloves on at this point. **Also, avoid getting reagents on your skin or clothing.**
3. Add powder 1 (manganous sulfate) & then powder 2 (alkaline azide)
4. Shake bottle vigorously for 30 seconds.
5. Wait until the particulates settle ½ way down bottle
6. **Again**, shake bottle vigorously for 30 seconds. Make sure there are no large, undissolved chunks of reagent left.
7. Wait until the particulates settle ½ way down bottle.
8. Add powder 3 (sulfamic acid). Be sure to avoid getting this on your clothes.
9. Shake until sample is clear amber.
10. Rinse both the graduated cylinder and flask first with distilled water and then with a little of the amber sample before measuring and pouring into flask.
11. Measure out 200 ml of sample in graduated cylinder and pour it into the 250 or 500 ml flask (whichever is in your kit).
12. Load black titrator with sodium thiosulfide cartridge by sliding it all the way into the slot and twisting 90°. Lower the plunger (push button in and down) on the titrator until it contacts the cartridge.
13. Take cap off cartridge, rinse a delivery tube with distilled water and insert into cartridge.
14. Turn the black dial on top of the titrator clockwise and allow a little of the sodium thiosulfide to come out. Just enough to remove air bubbles from the line.
15. Zero titrator by turning dial next to counter.
16. Slowly add sodium thiosulfide to sample by submerging the delivery tube into the sample. Swirl flask while you do this to mix.
17. When the sample turns pale yellow add 1 ml of starch (1 dropperful) to the sample; swirl to mix; the sample will turn blue/black. If the sample is pale yellow to begin with you can add the starch before you add any sodium thiosulfide.
18. Continue adding sodium thiosulfide with digital titrator, swirling as you add it, until sample is clear. **Go very slowly when the sample becomes pale so you don't overshoot the mark!**
19. Enter the number on the titrator onto the ***data sheet***.
20. Put cap back on sodium thiosulfide cartridge, pull back plunger and remove cartridge from titrator.
21. Rinse all test containers with distilled water and replace in case.

pH

IMPORTANT: The hole at the top of the probe should be plugged during storage and uncovered when measuring. If fluid in probe has leaked out during storage then refill it with electrode filling solution and make a note in the logbook. If the fluid in the probe storage bottle spills out refill it with electrode storage solution. When using pH probe do not allow the hole at top of probe to be submerged by buffers or sample.

Meter must be calibrated once per day and checked at the end of the day for accuracy (see **C. Accuracy Check**). Check notebook to see if it has already been calibrated. If it hasn't then calibrate and record in the **logbook** found behind the lid foam of the pH meter case. If it has been calibrated skip to **B. Stream water measurement**.

A. Calibration:

1. Remove pH probe from bottle by unscrewing cap. You can secure the storage bottle somewhere in the foam part of the meter case to prevent it from spilling out while sampling.
2. Take cap off bottom of temperature probe.
3. Rinse both probes with distilled water. Shake off excess water and gently blot dry.
4. **Remove the blue rubber stopper from the hole at the top of the probe.**
5. Put both probes into the container with pH 7 buffer (yellow).
6. Turn meter on and wait for the screen to stabilize (will say "measure" in the upper right hand corner).
7. Hit the "mode" button once.
8. If the screen says 7 – 10 push "yes" button. If it says 4 – 10 hit "no" button, then when it shows 7 –10 push "yes" button. By hitting the yes button you are essentially telling the machine that you want to calibrate at pH 7 and then 10 (as opposed to pH 4 & 10).
9. Wait for the meter to calibrate while *slowly* stirring the probes in the solution. Meter will flash "ready" when it's through calibrating pH 7. **Note: if the machine is cold it may take a while for it to warm up. The reading on the pH meter should be close to the buffer value. For example, if you're calibrating with pH 7 buffer and the screen shows 6.2, you need to wait for the machine to warm up enough so that it's reading somewhere between 6.95 and 7.1. *Then* proceed to step 10.**
10. Push the Yes button and record in the logbook the pH that showed on the screen when it said ready. Put cap back on pH 7 buffer; **do not discard**.
11. Rinse probes well with distilled water. Shake off excess water, gently blot dry and place in the pH 10 buffer (blue). Slowly stir probes while calibrating until meter flashes ready. (Generally the machine is warmed up by now, and you don't need to wait for it like you did with the pH 7 buffer.) Record in the **logbook** the pH that showed on the screen when it said ready.
12. Push "yes" again. (Now, the meter will automatically switch back to measure mode as indicated in the upper right hand corner.)
13. Record in the **logbook** the temperature of the pH 10 buffer. The temperature is displayed below the pH value with the symbol °C. Put cap back on pH 10 buffer; **do not discard**.
14. Now you are ready to measure the pH of your stream sample (go to **B**).

B. Stream water measurement

1. Rinse100 ml sample beaker with distilled water and then stream water.
2. Pour 100 ml of stream sample water in the plastic beaker and add 1 ml of "pHisa".
3. Remove pH probe from bottle by unscrewing cap.
4. Take cap off temperature probe.
5. Thoroughly rinse both probes with distilled water. Shake off excess water and gently blot dry.
6. **Remove the rubber stopper from the hole at the top of the probe.**
7. Put both probes in sample.
8. Turn meter on and wait for it to stabilize. You can gently stir the probes in the stream sample or leave them still, or use a combination of stirring and letting them sit. It is fine to work on other measurements (like dissolved oxygen, turbidity, etc.) while letting the pH meter stabilize. But do keep an eye on it. It may take up to 10 minutes for the reading to stabilize. **A reading is considered stable when it changes no more than 0.02 units in 1 minute.** If it takes longer than 10 minutes to stabilize make a note in the **logbook.**

9. Record result on ***data sheet***.
10. Cover hole at top of pH probe, rinse both probes and sample container with distilled water, put pH probe back in storage container, put cap back on temperature probe and turn machine off.

C. Accuracy Check

If you are the last one to use the pH meter for the day *and* the equipment has been used for at least 2 sites that day then you need to do an accuracy check. The reason for doing this is to see how much the pH meter has "drifted" from its original calibration value. Perform the accuracy check after all pH measurements of stream samples have been completed for the day.

1. Rinse pH and temperature probes with distilled water. Gently blot dry.
2. Place probes in pH 7 buffer.
3. **Remove the rubber stopper from the hole at the top of the probe** (if it isn't already).
4. Turn meter on (if it isn't already) and measure the buffer like you would a stream sample (except ***don't*** put pHisa into the buffer like you would into a stream sample). Make sure you are in measure mode, not calibration mode. (You can verify you are in the right mode by looking for the word "measure" in the top right corner of the screen.)
5. Once the reading for pH 7 has stabilized (no more than 0.02 units/minute rule) record the value in the **logbook**. Make a note that this is an ***accuracy measurement*** so it can be distinguished from calibration values.
6. Rinse both probes thoroughly with distilled water and gently blot dry.
7. Place probes in pH 10 buffer.
8. Once reading has stabilized record the measurement in the logbook
9. Cover hole at top of pH probe, rinse both probes with distilled water, put pH probe back in storage container, put cap back on temperature probe and turn machine off.

Turbidity meter

Note: if you are storing the equipment overnight be sure to keep it indoors so it does not get cold. A cold turbidity meter gives erroneous readings. If it has accidentally gotten cold, let the machine warm up in your car or house before using it.

1. Place the meter on a flat, stable surface or leave in blue box.
2. Turn meter on (I/O button). Make sure the machine is in auto range ("auto rng" is indicated in lower left corner). If it's not then push the range button until it shows this.
3. **Do an accuracy check using the bottles with numbered labels on top. If you have more than one site you only need to do the accuracy check at your first site**.
   Here's how to do an accuracy check
   a. Place a drop of oil on bottle of 1st standard (around 5) and wipe off with the black cloth.
   b. Insert it into the slot in the meter so that the white diamond on the bottle aligns with the mark at the front of the bottle slot on the meter.
   c. Close lid and press the read button. Record results in the **logbook**.
   d. **Follow the same procedure for the other two numbered vials** (one is around 50, the other around 500).
4. Rinse sample bottle with stream sample water 2 – 3 times. **If sample has been sitting then gently shake it before filling sample vial.**
5. Pour stream sample into the rinsed sample vial.
6. Wipe off vial with a soft, absorbent cloth.
7. Place vial in meter, being sure to align mark on vial with mark on meter.
8. Close lid, push the read button and record reading on ***data sheet***.
9. When finished turn machine off, clean the sample vial with distilled water and return it to the box.

Conductivity & Water Temperature

1. **If you are the first person using the meter today you need to do an accuracy check.** If one has already been completed that day skip to 2. Accuracy check instructions:
   a. After thoroughly rinsing probe and shaking off excess water place it in the container labeled "conductivity standard".
   b. Turn machine on and **make sure it is in temperature compensating mode**. This is indicated when the Celsius symbol (C°) on the bottom right is flashing. If it isn't, push the mode button until you see this feature. Conductivity units are microsiemens per centimeter (µS/cm) and temperature is in C°
   c. Stir probe slowly in the standard solution without touching the sides or bottom of the container. **Make sure the hole on the side of the probe is submerged and doesn't have an air bubble trapped in it.**
   d. When the reading has stabilized enter the conductivity and temperature reading in the **conductivity logbook**.
   e. Put cover back on conductivity standard; **do not discard**.
   f. Skip to 4.

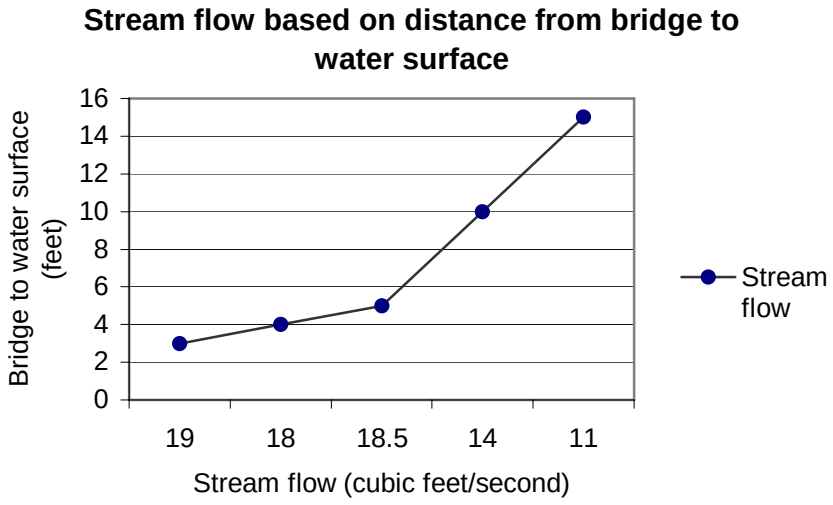
2. Turn machine on. **Make sure it is in temperature compensating mode**. This is indicated when the Celsius symbol (C°) on the bottom right is flashing. If it isn't, push the mode button until you see this feature. Conductivity units are microsiemens per centimeter (µS/cm) and temperature is in C°
3. Thoroughly rinse probe with distilled water and shake off excess water.
4. Measure water temperature and conductivity by placing probe into the blue bucket or the stream, being sure not to let the probe touch the sides of the container or bottom of stream. **Make sure the hole on the side of the probe is submerged and doesn't have an air bubble trapped in it.**
5. When reading has stabilized record water temperature and conductivity on ***data sheet***. (It's ok if the last unit for the conductivity reading fluctuates. For example, if it goes back and forth between 104.5, 104.6 and 104.7, just pick the middle value.)
6. Rinse conductivity probe with distilled water before replacing it in the meter slot.
7. Turn machine off and return to bag, leaving the cord outside of the bag. Make sure the machine doesn't accidentally turn on when you push it into its bag.

Height from Bridge to Stream Surface

This measurement will allow us to estimate stream flow. The way it works is that you record the height from a fixed point on the bridge to the surface of the water. If the weight on the tape is hanging below the end, then measure from the end of the weight. If the weight hangs above the end of the tape, then measure from the end of the tape. Be very precise and be sure to take it from the same point every month. Record on your ***datasheet*** in feet and 10^{th} of feet (e.g. 16.72 ft.)

Sometimes you might have trouble with the tape flapping in the breeze. If this happens try using the bucket to measure the distance. Lower it down until the bottom is at the stream surface (you can even fill it with a little water if necessary). Clamp your fingers on the rope where it hits the point on the bridge (i.e. white paint mark), and then pull the bucket up. Use the measuring tape to measure from the end of the bucket to the point on the rope that you have marked with your fingers. Record on ***data sheet***.

Several times during the year I will go out to these sites and measure stream flow and also the height from stream surface to bridge. This will allow me to develop a graph like the one below. By developing a graph like this we can later calculate what the stream flow was when monitoring occurred.



APPENDIX B

Benthic Macroinvertebrate Protocol for Wadeable Rivers and Streams

Revised July 18, 2003

Background

Evaluating the biological community of a stream through an assessment of the macroinvertebrates provides a sensitive and cost effective means of determining stream condition. The goal of the protocol described in this section is to collect an unbiased, representative sample of benthic macroinvertebrates in wadeable streams and rivers. At each stream reach, samples are collected by compositing eight D-Frame Net kick samples from a selected habitat unit (e.g. riffles, fastest flowing water). Samples are preserved in the field with ethanol.

Field Collection Methods

Equipment and Supplies

- 500 um mesh D-Frame kick net
- 5-gallon bucket
- Scrub brush
- forceps
- Long-sleeved rubber gloves
- Nalgene containers
- Sample labels
- Waders with slip-resistant soles

Targeted habitat sampling

1. Beginning at the downstream end of the reach, select the first riffle or pool habitat unit (riffles at all sites, pools only if no riffles present). Collect one kick sample from each riffle or pool unless fewer than eight are present within reach. In that case evenly spread the eight samples across the number of riffles or pools within the reach. EXCLUDE margin habitats (area within 5% of channel margins).

   Vissualize a 3x3 grid over each riffle (or habitat unit) to be sampled (see figure 1). For the first habitat unit, select the lower-left square; for the second habitat unit, select the lower-center; the third, the lower-right; for the fourth, select the middle-left; for the fifth select the middle-center; for the sixth select the middle-right; for the seventh select the upper-left; for the eigth select the upper-center. Collect the kick sample in the center of each grid square.

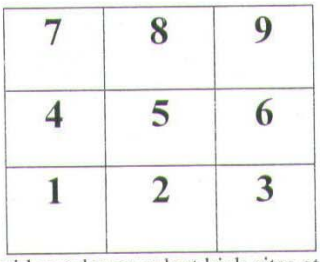


Figure 1. Visualize a grid overlay to select kick sites at each habitat unit (riffle or pool).

2. After locating the random sample location, place the net into the stream with the flat part of the hoop resting on the bottom and perpendicular to the stream flow. As much as possible, make sure to remove any substrate that prevents the flat part of the kicknet from sitting flush with the bottom. It may also be useful to remove large substrate particles downstream of the flat portion of the loop that may affect the flow entering the net. Collect the macroinvertebrate sample by disturbing a 30 by 30 centimeter area (1ft x 1ft).

3. Inspect the benthos in a 1 ft X 1ft area (approximately as wide as the kick net) of stream bottom directly in front of the net for any large organisms such as mussels. Pick these and place in the sieve bucket.

4. Carefully rub by hand all substrate larger than five centimeters (golf ball size and larger) in front of the net to dislodge any clinging macroinvertebrates. Then, with a small scrub brush dislodge organisms still clinging to the larger substrate particles. After rubbing, place the substrate outside of the sample plot. (Hand scrubbing is recommended prior to using the brush to prevent damage from occurring to fragile macroinvertebrate specimens. Also, be gentle with the brush, so as not to chew up the macroinvertebrates.)

5. Thoroughly disturb the remaining substrate in the 1ft * 1ft area with your hands or feet for 1 min to a depth of five to ten centimeters.

*(**NOTE:** Collecting a sample in slow moving water is a little more difficult. It may involve pulling the net through the water as the substrate is disturbed to capture suspended organisms.)*

6. After the sample is collected and the net removed, return the large substrate to the sample plot.

7. The contents of the net are placed in a bucket and the sampling procedure is repeated for that habitat type. Always sample downstream to upstream.

8. All kick samples for the same reach are composited in the bucket. Large organic material and rocks are rinsed, carefully inspected for clinging macroinvertebrates, and removed. As much fine sediment as possible should be washed away. Leaf packs from pool samples may require considerable rinsing and removal of debris before preserving the composite sample.

9. When finished sampling all 8 ft^2, sieve sample through 8" brass sieve. Place all insects or material that may have insects on it into Nalgene bottles. Do no fill bottles up more than 25% by volume with organic matter. Place a label (**Rite in the Rain paper**) written in **pencil** containing site and habitat unit information **inside the container**. Label the outside container with a **pencil written on a label, then tape the label to the outside of the jar. Do not use markers as most inks are soluble in alcohol**. Then pour enough ethanol to cover sample until you get back to the car. When you get back to the car, fill bottles up with ethanol to completely preserve them.

10. Fill out Targeted Riffle Benthos section in the Sample Collection Form. **In the comments section describe the habitat types you sampled from** (e.g., all riffles, 1 riffle/3 pools, etc.)

APPENDIX C

2004-2006 Long Tom Watershed Macroinvertebrate Survey
Sample Processing and Data Analysis

2004-2006 Long Tom Watershed Macroinvertebrate Survey

Sample Processing and Data Analysis

SUMMARY REPORT

Prepared for

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INTRODUCTION

ABR, Inc. was contracted in 2005 by the Long Tom Watershed Council to perform freshwater benthic macroinvertebrate sample processing and analysis services. Between fall 2005 and fall 2006, ABR received 98 benthic samples from the Council. Sample processing included subsampling and identification following standard laboratory protocols and a thorough quality control plan, as described herein. Taxonomic data were then analyzed using the Oregon Marine Western Coastal Forests (MWCF) predictive model and the western Oregon multimetric index.

METHODS

Upon arrival at our laboratory, we ensured that all samples were properly labeled and preserved. Each sample was assigned a unique internal tracking number (for this project, 05-477-XXX) that accompanied the project and sample information provided by the client. All of this information was entered into the project's sample log that was maintained in the laboratory.

ABR used four trained and tested laboratory technicians, Adam Harris, Jon Cheek, Nick Haxton, and Alden Miller, to sort macroinvertebrates from raw field samples for this project. Each sample was processed using strict laboratory sample handling and labeling protocols (**Cole, M. B. 2005. Macroinvertebrate Sample Handling and Sorting Procedures. Unpublished internal ABR training and reference document**). A Caton gridded tray was used to subsample approximately 525 organisms from each sample. Using this subsampling procedure, each sample was distributed evenly across a 30-square wire-mesh tray. Individual squares were randomly selected and the contents removed and placed into a Petri dish. Macroinvertebrates were removed from the sample material under a dissecting microscope. This process was repeated until a total count of 525-550 organisms was achieved. The remainder of the sample (the unsorted fraction) was then inspected for large or rare taxa that were not encountered during the subsampling procedure; these "large/rare" taxa were recorded on the laboratory bench sheet as such and placed in a separate vial.

All macroinvertebrate samples will be saved by ABR for a minimum of two years. More than 10% of all sample residues were inspected by the laboratory manager, Adam Harris, to determine whether macroinvertebrate sorts were attaining 95% efficacy.

The following products resulted from the sample sorting procedure:

1) 525-550 macroinvertebrates sorted into a series (4-7) of small vials by order, class, and/or phylum.
2) A separate vial containing organisms found during the large-rare search
3) Sorted residue – material from which the 525-550 organisms were sorted.
4) Unsorted fraction – portion of the original sample that was not sorted.

Macroinvertebrate identification also followed standard protocols (Cole, M. B. 2006. Macroinvertebrate Sample Identification Standard Operating Procedures, Unpublished ABR training and reference manual). All identification work followed

taxonomic standards established by the Northwest Biological Assessment Workgroup and maintained by the Xerces Society. Specimens identified for this project but not previously encountered during processing of western Oregon samples were added to ABR's master reference specimen collection. A list of taxonomic literature sources used to aid in the identification of project specimens is provided at the end of this report.

All raw data were entered into an Excel spreadsheet and crosschecked against paper copies of the data for errors and omissions before the data were analyzed. Electronic data were also checked for outliers and other errors using summary statistics and graphic analyses. Data were analyzed using the Oregon Marine Western Coastal Forests (MWCF) predictive model located online at http://wmc2.bnr.usu.edu:8080/examples/servlets/LoginSession.html. The Oregon MWCF predictive model evaluates the biological condition of a site based on a comparison of observed (O) to expected (E) taxa. The observed taxa are those that occurred at the site, whereas the expected taxa are those predicted to occur at the site in the absence of disturbance. Impairment is determined by comparing the O/E score to the distribution of reference site O/E scores (Hawkins et al. 2000). Using the scoring criteria derived from the distribution of reference site scores for western Oregon, O/E scores of less than 0.75 (>95th percentile of reference site scores) were classified as "poor" (severely impaired), between 0.75 and 0.90 (90–95th percentile of reference site scores) as "fair" (or slightly impaired), and greater than 0.90 (<90th percentile of reference site scores) as "good" (unimpaired).

Two data files – one containing a taxa-by-site matrix and another containing predictor variables for each site – were assembled for input into the model. The taxon-by-site matrix (LT_matrix.txt) was created from a three-column text file (LT_bug_data.txt) using the program matrify.exe. Predictor variables for the second input file (phab_data.txt) were either entered by ABR (in the case of Julian dates) or were obtained from the Long Tom Watershed Council (in the case of site longitudes). Detailed descriptions of the procedures used to generate these files and run the model can be found at http://rm130.bnr.usu.edu/WMCPortal/modelSection.aspx?section=125&title=build&tabindex=-1.

The Excel file named 05-477_Long_Tom_Invert_Data contains all of the raw macroinvertebrate taxonomic data. A second Excel file named 05-477_Long_Tom_model_results contains the O/E score results. Eight additional HTML and text files provide all of the output generated by the online predictive model.

Data were also analyzed using the western Oregon multimetric index, developed by the Oregon Department of Environmental Quality. Multimetric analysis employs a set of metrics, each of which describes an attribute of the macroinvertebrate community that is known to be responsive to one or more types of pollution or habitat degradation. Each community metric is converted to a standardized score; standardized scores of all metrics are then summed to produce a single multimetric score that is an index of overall biological integrity. Reference condition data are required to develop and use this type of assessment tool. Metric sets and standardized metric scoring criteria are developed and calibrated for specific community types, based on both geographic location and stream/habitat type. DEQ has developed and currently employs a 10-metric set for use with riffle samples from higher-gradient streams in western Oregon (WQIW 1999).

The DEQ 10-metric set includes six positive metrics that score higher with better biological conditions, and four negative metrics that score lower with improved conditions (Table 1). The Modified Hilsenhoff Biotic Index (HBI), originally developed by Hilsenhoff (1982), computes an index to organic enrichment pollution based on the relative abundance of various taxa at a site. Values of the index range from 1 to 10; higher scores are interpreted as an indication of a more pollution tolerant macroinvertebrate community. Sensitive taxa are those that are intolerant of warm water temperatures, high sediment loads, and organic enrichment; tolerant taxa are adapted to persist under such adverse conditions. We used DEQ's taxa attribute coding system to assign these classifications to taxa in the data set (DEQ, unpublished information).

Metric values first were calculated for each sample and then were converted to standardized scores using DEQ scoring criteria for riffle samples from western Oregon streams (Table 1). The standardized scores were summed to produce a multimetric score ranging between 10 and 50. Sites were then assigned a level of impairment based on these total scores (Table 2). An Excel file entitled 05-477_MM_scores.exe accompanies this report and contains all of the metric values, standardized scores, and multimetric scores.

Table 1. Metric set and scoring criteria (WQIW 1999) used to assess condition of macroinvertebrate communities in the Long Tom watershed, Oregon.

	Scoring Criteria		
Metric	5	3	1
POSITIVE METRICS			
Taxa richness	>35	19-35	<19
Mayfly richness	>8	4-8	<4
Stonefly richness	>5	3-5	<3
Caddisfly richness	>8	4-8	<4
Number sensitive taxa	>4	2-4	<2
# Sediment sensitive taxa	≥2	1	0
NEGATIVE METRICS			
Modified HBI[1]	<4.0	4.0-5.0	>5.0
% Tolerant taxa	<15	15-45	>45
% Sediment tolerant taxa	<10	10-25	>25
% Dominant	<20	20-40	>40

[1] Modified HBI = Modified Hilsenhoff Biotic Index

Table 2. Multimetric score ranges for assignment of macroinvertebrate community condition levels (WQIW 1999).

Level of Impairment	Score Range (scale of 10 - 50)
None	>39
Slight	30 – 39
Moderate	20 – 29
Severe	<20

RESULTS

Of the 98 samples received by ABR, 97 were processed and analyzed. One sample – OLT03479-084 – was not processed because the contents were severely decomposed.

QUALITY CONTROL

Ten of the 97 samples (10%) were checked for sorting efficacy; all ten samples passed with a greater than 95% sorting efficacy. ABR's senior scientist and taxonomist, Dr. Michael Cole, encountered no unusual or rare taxa that were difficult to identify. As such, no specimens were sent to outside specialists.

PREDICTIVE MODEL OUTPUT AND SCORES

Site test results (see output file Site Test Results.html) were passing in all but one case, where the model flagged site, OLT03479-009 (highlighted in red in the HTML output file) sampled on May 9, 2006, as being outside the experience of the model. The O/E scores for this site should be considered tentative because the sample date occurred outside the window of sample dates used to construct and test the MWCF predictive model.

Predictive model observed-versus-expected (O/E) scores varied widely among the 97 samples (Table 3). Based on O/E scores, benthic biological integrity from 22 samples was classified as unimpaired (O/E >0.90), from samples as "fair" (0.75 to 0.90), and at 61 samples as "poor" (<0.75; Figure 1).

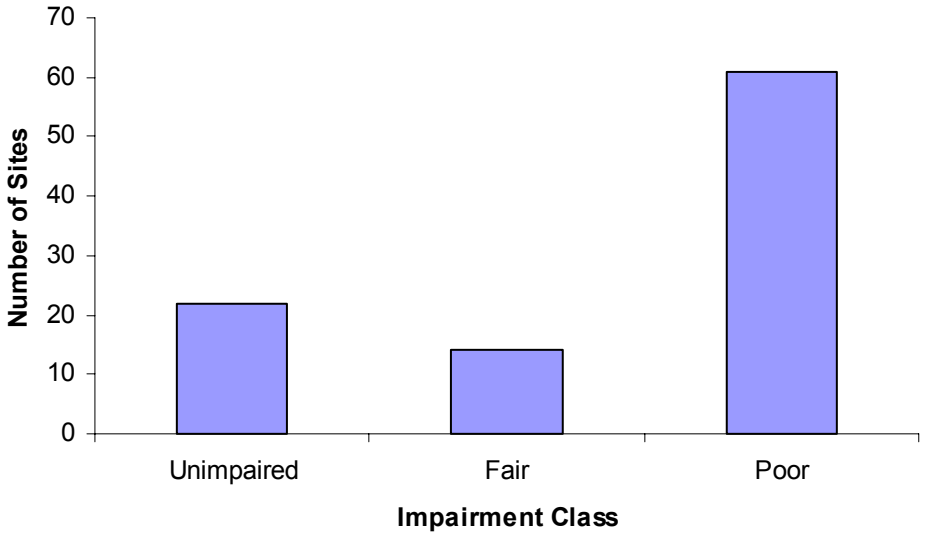

Figure 1. Distribution of 2004-2006 predictive model scores from the Long Tom Watershed macroinvertebrate survey program (n = 97 samples).

Table 3. Predictive model O/E scores (P > 0.5) of 97 macroinvertebrate samples collected from 92 stream reaches in the Long Tom Watershed, Oregon, 2004 to 2006.

ABR Sample ID	LT Site Code	Sample Date	O/E
UNIMPAIRED			
05-477-48	OLT03479-171	7/13/2005	1.32224
05-477-34	OLT03479-067	8/5/2005	1.261525
05-477-41	OLT03479-087	8/10/2005	1.247395
05-477-75	OLT03479-252	9/28/2005	1.190785
05-477-46	OLT03479-163	8/18/2005	1.142642
05-477-64	OLT03479-251	9/7/2005	1.13971
05-477-23	OLT03479-037	8/31/2005	1.106374
05-477-61	OLT03479-229	9/18/2005	1.102833
05-477-24	OLT03479-046	7/28/2005	1.093574
05-477-11	OLT03479-046	8/15/2004	1.093035
05-477-27	OLT03479-055	9/13/2005	1.092221
05-477-59	OLT03479-208	8/23/2005	1.081903
05-477-71	OLT03479-187	9/20/2005	1.057569
05-477-74	OLT03479-215	9/22/2005	1.040092
05-477-39	OLT03479-083	8/11/2005	1.002531
05-477-43	OLT03479-099	9/14/2005	0.99571
05-477-16	OLT03479-007	8/24/2005	0.986495
05-477-91	OLT03479-025	5/12/2006	0.95321
05-477-62	OLT03479-235	8/29/2005	0.953017
05-477-08	OLT03479-037	8/4/2004	0.937253
05-477-37	OLT03479-080	8/26/2005	0.931318
05-477-63	OLT03479-236	8/25/2005	0.907645
FAIR			
05-477-20	OLT03479-019	8/21/2005	0.889345
05-477-21	OLT03479-030	8/19/2005	0.88658
05-477-10	OLT03479-043	8/18/2004	0.885384
05-477-92	OLT03479-293	6/14/2006	0.86459
05-477-05	OLT03479-016	9/3/2004	0.853024
05-477-22	OLT03479-035	8/19/2005	0.840408
05-477-04	OLT03479-014	8/20/2004	0.838203
05-477-14	OLT03479-172	9/12/2004	0.829483
05-477-01	OLT03479-003	9/8/2004	0.80693
05-477-58	OLT03479-206	9/14/2005	0.803237
05-477-47	OLT03479-167	8/30/2005	0.787254
05-477-66	OLT03479-272	9/6/2005	0.784199
05-477-94	OLT03479-137	6/22/2006	0.753779
05-477-93	OLT03479-044	6/30/2006	0.752858

Table 3. (continued)

ABR Sample ID	LT Site Code	Sample Date	O/E
POOR			
05-477-89	OLT03479-225	6/16/2006	0.741156
05-477-90	OLT03479-201	9/12/2006	0.718929
05-477-85	OLT03479-073	6/8/2006	0.714013
05-477-57	OLT03479-199	9/13/2005	0.711384
05-477-87	OLT03479-017	5/16/2006	0.699265
05-477-25	OLT03479-051	8/18/2005	0.693259
05-477-78	OLT03479-286	9/29/2005	0.686823
05-477-50	OLT03479-179	8/24/2005	0.670966
05-477-53	OLT03479-189	8/26/2005	0.664399
05-477-30	OLT03479-060	8/4/2005	0.651512
05-477-95	OLT03479-113	6/20/2006	0.644356
05-477-88	OLT03479-081	6/8/2006	0.64273
05-477-56	OLT03479-197	8/15/2005	0.63907
05-477-49	OLT03479-175	8/16/2005	0.638892
05-477-29	OLT03479-059	7/26/2005	0.632547
05-477-68	OLT03479-070	9/30/2005	0.622769
05-477-65	OLT03479-263	8/29/2005	0.619415
05-477-26	OLT03479-053	8/26/2005	0.616211
05-477-13	OLT03479-164	9/9/2004	0.598009
05-477-44	OLT03479-156	8/17/2005	0.5905
05-477-86	OLT03479-089	6/8/2006	0.583959
05-477-79	OLT03479-084	6/6/2006	0.575762
05-477-80	OLT03479-050	6/5/2006	0.575213
05-477-77	OLT03479-273	9/25/2005	0.574382
05-477-83	OLT03479-049	5/24/2006	0.574276
05-477-76	OLT03479-270	9/19/2005	0.549546
05-477-42	OLT03479-096	9/7/2005	0.520348
05-477-52	OLT03479-186	9/7/2005	0.473519
05-477-02	OLT03479-012	9/15/2004	0.45825
05-477-84	OLT03479-009	5/9/2006	0.444423
05-477-45	OLT03479-158	8/24/2005	0.431235
05-477-73	OLT03479-204	9/29/2005	0.430248
05-477-54	OLT03479-191	9/4/2005	0.426187
05-477-06	OLT03479-021	9/1/2004	0.425689
05-477-51	OLT03479-184	8/31/2005	0.425142
05-477-12	OLT03479-153	8/27/2004	0.413157
05-477-72	OLT03479-170	9/25/2005	0.412893
05-477-81	OLT03479-034	6/5/2006	0.385312
05-477-09	OLT03479-041	9/6/2004	0.383467
05-477-96	OLT03479-015	9/5/2006	0.381931
05-477-82	OLT03479-178	5/25/2006	0.381578
05-477-07	OLT03479-026	9/16/2004	0.366448
05-477-55	OLT03479-194	8/5/2005	0.34502
05-477-69	OLT03479-153	9/28/2005	0.341228

Table 3. (continued)

ABR Sample ID	LT Site Code	Sample Date	O/E
05-477-97	OLT03479-Stroda N	9/5/2006	0.318655
05-477-36	OLT03479-077	7/29/2005	0.297283
05-477-67	OLT03479-041	9/28/2005	0.292528
05-477-70	OLT03479-176	9/25/2005	0.287145
05-477-03	OLT03479-013	9/4/2004	0.275475
05-477-98	OLT03479-Stroda S	9/5/2006	0.254882
05-477-32	OLT03479-062	8/10/2005	0.24933
05-477-18	OLT03479-013	7/27/2005	0.248684
05-477-35	OLT03479-074	8/3/2005	0.247491
05-477-31	OLT03479-061	7/29/2005	0.246916
05-477-15	OLT03479-173	8/6/2004	0.238058
05-477-60	OLT03479-217	8/26/2005	0.229725
05-477-17	OLT03479-010	8/3/2005	0.198044
05-477-19	OLT03479-018	8/2/2005	0.197865
05-477-28	OLT03479-057	8/30/2005	0.184422
05-477-38	OLT03479-082	8/2/2005	0.148257
05-477-33	OLT03479-064	8/11/2005	0.098165

MULTIMETRIC SCORES

Multimetric scores also varied widely among sampled sites. Nine samples received unimpaired scores, while 34 samples received severely impaired at scores (Table 4). Twenty-eight samples received moderately impaired scores, while 26 samples received slightly impaired scores.

Table 4. Multimetric scores of 97 macroinvertebrate samples collected from 92 stream reaches (5 reaches were sampled twice) in the Long Tom Watershed, Oregon, between 2004 and 2006.

ABR Sample Code	Site Code	Sample Date	MM Score
No Impairment			
05-477-46	OLT03479-163	8/18/2005	46
05-477-59	OLT03479-208	8/23/2005	46
05-477-39	OLT03479-083	8/11/2005	44
05-477-41	OLT03479-087	8/10/2005	44
05-477-75	OLT03479-252	9/28/2005	42
05-477-43	OLT03479-099	9/14/2005	40
05-477-64	OLT03479-251	9/7/2005	40
05-477-88	OLT03479-081	6/8/2006	40
05-477-91	OLT03479-025	5/12/2006	40

Table 4. (Continued)

Slight Impairment			
05-477-24	OLT03479-046	7/28/2005	38
05-477-27	OLT03479-055	9/13/2005	38
05-477-48	OLT03479-171	7/13/2005	38
05-477-90	OLT03479-201	9/12/2006	38
05-477-11	OLT03479-046	8/15/2004	36
05-477-25	OLT03479-051	8/18/2005	36
05-477-71	OLT03479-187	9/20/2005	36
05-477-74	OLT03479-215	9/22/2005	36
05-477-78	OLT03479-286	9/29/2005	36
05-477-85	OLT03479-073	6/8/2006	36
05-477-01	OLT03479-003	9/8/2004	34
05-477-10	OLT03479-043	8/18/2004	34
05-477-16	OLT03479-007	8/24/2005	34
05-477-21	OLT03479-030	8/19/2005	34
05-477-61	OLT03479-229	9/18/2005	34
05-477-86	OLT03479-089	6/8/2006	34
05-477-34	OLT03479-067	8/5/2005	32
05-477-50	OLT03479-179	8/24/2005	32
05-477-58	OLT03479-206	9/14/2005	32
05-477-63	OLT03479-236	8/25/2005	32
05-477-83	OLT03479-049	5/24/2006	32
05-477-84	OLT03479-009	5/9/2006	32
05-477-89	OLT03479-225	6/16/2006	32
05-477-94	OLT03479-137	6/22/2006	32
05-477-22	OLT03479-035	8/19/2005	30
05-477-62	OLT03479-235	8/29/2005	30

Table 4. (Continued)

Moderate Impairment			
05-477-47	OLT03479-167	8/30/2005	28
05-477-87	OLT03479-017	5/16/2006	28
05-477-08	OLT03479-037	8/4/2004	26
05-477-20	OLT03479-019	8/21/2005	26
05-477-65	OLT03479-263	8/29/2005	26
05-477-80	OLT03479-050	6/5/2006	26
05-477-92	OLT03479-201	6/14/2006	26
05-477-93	OLT03479-044	6/30/2006	26
05-477-04	OLT03479-014	8/20/2004	24
05-477-23	OLT03479-037	8/31/2005	24
05-477-30	OLT03479-060	8/4/2005	24
05-477-42	OLT03479-096	9/7/2005	24
05-477-44	OLT03479-156	8/17/2005	24
05-477-56	OLT03479-197	8/15/2005	24
05-477-57	OLT03479-199	9/14/2005	24
05-477-05	OLT03479-016	9/3/2004	22
05-477-13	OLT03479-164	9/9/2004	22
05-477-37	OLT03479-080	8/26/2005	22
05-477-76	OLT03479-270	9/9/2005	22
05-477-77	OLT03479-273	9/25/2005	22
05-477-79	OLT03479-084	6/6/2006	22
05-477-96	OLT03479-015	9/5/2006	22
05-477-97	OLT03479-Stroda N	9/5/2006	22
05-477-07	OLT03479-026	9/16/2004	20
05-477-14	OLT03479-172	9/12/2004	20
05-477-29	OLT03479-059	7/26/2005	20
05-477-53	OLT03479-189	8/26/2005	20
05-477-66	OLT03479-272	9/6/2005	20

Table 4. (Continued)

Severe Impairment			
05-477-02	OLT03479-012	9/15/2004	18
05-477-06	OLT03479-021	9/1/2004	18
05-477-45	OLT03479-158	8/24/2005	18
05-477-51	OLT03479-184	8/31/2005	18
05-477-54	OLT03479-191	9/4/2005	18
05-477-95	OLT03479-113	6/20/2006	18
05-477-98	OLT03479-Stroda S	9/5/2006	18
05-477-26	OLT03479-053	8/26/2005	16
05-477-49	OLT03479-175	8/16/2005	16
05-477-52	OLT03479-186	9/7/2005	16
05-477-55	OLT03479-194	8/5/2005	16
05-477-68	OLT03479-070	9/30/2005	16
05-477-73	OLT03479-204	9/29/2005	16
05-477-81	OLT03479-034	6/5/2006	16
05-477-18	OLT03479-013	7/27/2005	14
05-477-67	OLT03479-041	9/28/2005	14
05-477-82	OLT03479-178	5/25/2006	14
05-477-60	OLT03479-217	8/26/2005	12
05-477-70	OLT03479-176	9/25/2005	12
05-477-72	OLT03479-170	9/25/2005	12
05-477-03	OLT03479-013	9/4/2004	10
05-477-09	OLT03479-041	9/6/2004	10
05-477-12	OLT03479-153	8/27/2004	10
05-477-15	OLT03479-173	8/6/2004	10
05-477-17	OLT03479-010	8/3/2005	10
05-477-19	OLT03479-018	8/2/2005	10
05-477-28	OLT03479-057	8/30/2005	10
05-477-31	OLT03479-061	7/29/2005	10
05-477-32	OLT03479-062	8/10/2005	10
05-477-33	OLT03479-064	8/11/2005	10
05-477-35	OLT03479-074	8/3/2005	10
05-477-36	OLT03479-077	7/29/2005	10
05-477-38	OLT03479-082	8/2/2005	10
05-477-69	OLT03479-153	9/28/2005	10

There was general agreement between MM scores and O/E scores, as the correlation between the two sets of scores was highly significant ($p < 0.0001$) with a correlation coefficient of 0.84 (Figure 2). However, in a number of cases, sites received disparate MM scores relative to their O/E scores. Most notably, several sites received low MM scores relative to their O/E scores. For example, site code OLT03479-037 received an O/E score of 1.1, suggesting an unimpaired condition. In contrast, the same site received a MM score of 24, suggesting moderately impaired biology. Disagreements of the same extent and nature were found in a recent assessment of macroinvertebrate communities in the Tualatin River basin (Cole et al. 2006) and were attributed to the ability of the multimetric approach to discriminate among sites based not only on the presence, but also based on the relative abundance, of taxa. In both the Tualatin Basin assessment and in this assessment of the Long Tom watershed, it appears that sites that were dominated by large numbers of disturbance-tolerant organisms such as the snail, *Juga*, but otherwise supported taxonomically rich macroinvertebrate communities would score considerably higher using the predictive model approach. Predictive models, in their current form, only take into account the *presence* of a taxon at a test site, not its relative abundance, and therefore would be less able to detect impairment when changes in the relative abundance of taxa occur without any significant loss or replacement of taxa.

Further assessment and comparison of the two approaches will be needed before it is known under what community conditions each best performs and to what types of community changes each best responds. In the meantime, it would be useful to report scores based on both assessment approaches and, where disparities in impairment determinations occur, a closer inspection of the data could be performed.

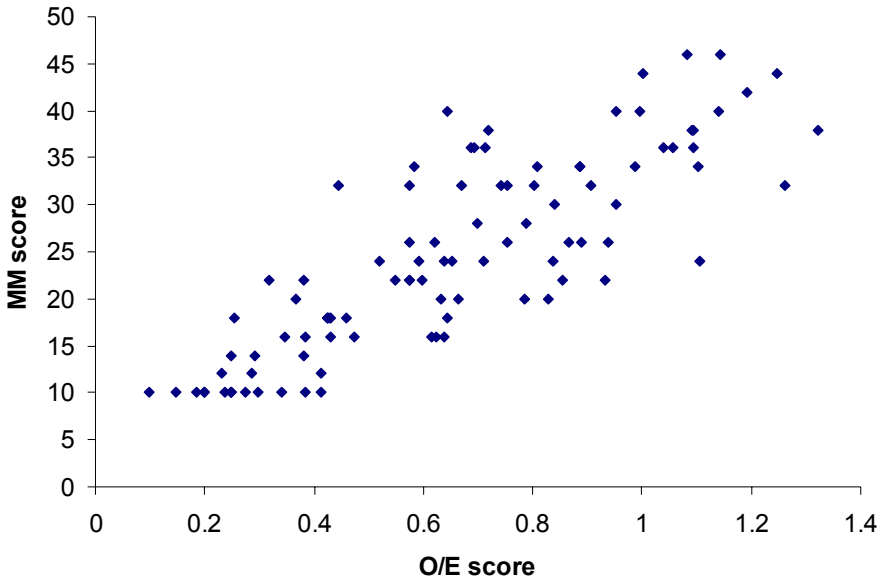

Figure 2. Relation between O/E scores and multimetric scores calculated from 97 macroinvertebrate samples collected from the Long Tom watershed, Oregon, between 2004 and 2006.

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APPENDIX D

Long Tom Watershed Council Macroinvertebrate and Stream Survey Project
Sequence of Measurements

1. Locate x-site using GPS, aerial photo, and map.
2. Scout the area to make sure you won't run into a stream order change upstream of the x-site, or other condition that would make the stream unsampleable (e.g., stream changes to a marsh, goes into an underground pipe, etc.). If one of these situations occurs, you'll need to start the reach far enough downstream of x-site to avoid this.
3. Take several wetted width measurements up and downstream of the x-site to determine your average wetted width. Record. Notice whether this stream seems to have a lot of riffles or few to none so that you can plan your bug sample sites accordingly.
4. Multiply your average wetted width by 40 to determine reach length. Record. Remember: minimum reach length is 150 m.
5. Starting about 50 feet downstream of the x-site and walking upstream on the bank (or whatever path is quickest), pace off the reach length and either flag or otherwise note where the reach will end. Since we are not going to flag transects or macroinvertebrate sites ahead of time, this is so you don't collect bug samples significantly outside of the reach.
6. Walk about 50 feet downstream of x-site (don't need to measure, just estimate) and clip Transect A flag to nearest branch or set on bank. Begin collecting your insect samples as you move up through the reach. If you feel it's necessary, you can walk up and downstream to identify where you want to collect insect samples. Remember, if there's only one good riffle or fastest moving section, then you can collect all eight samples from this location. If there are more than this, spread your samples throughout the reach.
7. Collect eight 1-square foot samples as described in DEQ protocol and place each one in the bucket.
   When finished:
   - Sieve contents of bucket (Rinse and discard any large sticks or rocks. Make sure there are no insects clinging to them before discarding)
   - Spoon sediment, leaves, insects, etc. from sieve into plastic Nalgene container(s). Only fill the bottle ¼ - ½ full. Use more than one plastic container if necessary to avoid exceeding the ¼ - ½ full guideline.
   - Top off with alcohol.
   - Place label(s) inside jar and tape to outside. USE PENCIL ONLY for writing on labels, as alcohol dissolves ink.

8. Measure water temperature and take several photos that are representative of the reach. (You can do these two things at any time. Just don't forget!)
9. Go back to Transect A and begin physical habitat survey. Divide total reach length by 10 to determine distance between transects.
10. At each transect make 5 substrate and depth measurements: left bank edge, ¼ across, ½-way across, ¾ across, right bank edge. *Estimate* ¼, ½, and ¾ of the way across. You do not need to estimate % embeddedness.
11. At each transect make estimates for riparian vegetation and shade.
12. As you walk up the stream between transects:
    - Measure thalweg depth
    - Record stream habitat type (riffle/cascade/run/glide or pool)
    - Tally large wood
13. The last steps are to fill out the human disturbance inventory form for the reach and do a written assessment of stream condition (can do this one driving to next site or on your way back)

Physical Habitat Inventory	**Site ID:**	**Date: __ __/__ __/__ __**	**Transect:**

Substrate Cross-Section Information			
	Depth (cm)	Size Class	Flag
Left Bank			
One-quarter			
Half-way			
Three-quarters			
Right Bank			

Total wetted width __ __.__m

Substrate Size Class Codes
RS= Bedrock (smooth) - (Larger than a car)
RR= Bedrock (rough)-(Larger than a car)
RC= Concrete/Asphalt
XB= Large boulder (meterstick to car)
SB= Small boulder (basketball to meterstick)
CB= Cobble (tennisball to basketball)
GC= Coarse gravel (marble to tennisball)
GF= Fine gravel (ladybug to marble)
SA= Sand (gritty to ladybug)
FN= Silt/clay/muck (not gritty)
HP= Hardpan (firm, consolidated fine substrate)
WD= Wood
OT= Other (flag and describe)

Note: if reach is 150 m, measure thalweg depth every meter; if greater than 150 m, measure thalweg at 10 evenly spaced intervals between transects.

Station	**Thalweg Depth (cm)**	**Stream Habitat Type**	**Flag**
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			

Stream Habitat Types	ER= riffle, glide, cascade, rapid, or waterfall
	DE= pool

Substrate Only	Stn (5 or 7)	LFT	LCTR	CTR	RCTR	RGT

% Shade Covering Channel (30' upstr./30' dwnstr.)		
<40%	40% - 70%	>70%

Tally of Large Wood in Stream At & Between Transects	
# pieces 1' - 2' dia. @ large end:	
# pieces > 2' dia. @ large end:	

Riparian Zone: 30' X 30' plot from edge of stream		
	Left Bank	Right Bank
Trees > 15' tall	D C M N	D C M N
# conifers >1' dbh		
Understory	None Spar Mod Den	None Spar Mod Den
Ground cover	None Spar Mod Den	None Spar Mod Den

D= >70% deciduous, C= >70% conifer, M= mixed, N= No trees
Spar= sparse, Den= dense, Mod= moderate
Ground cover: none= bare dirt/duff, sparse= some bare dirt/duff
dbh= diameter at breast height

Invasive Plant Species (circle all present)

blackberry Eng. ivy reed canarygrass none

Comments

Oregon DEQ Watershed Assessment Section

Human Disturbance Index Reach Checklist

Stream Name: **SITE ID/STATION KEY:** **DATE:**

Crew: **Comments:** (Reconn or Sampling)

Activity Checklist: Circle all that apply

Agriculture-Urban				
CAFOs (Cattle,Poultry)	0	1	3	5
Channelization	0	1	3	5
Chemical treatment/Liming	0	1	3	5
Construction/storm water	0	1	3	5
Cropland	0	1	3	5
Dams	0	1	3	5
Industrial plants/commercial	0	1	3	5
Irrigation equipment	0	1	3	5
Maintained Lawns/run-off	0	1	3	5
Orchards, Tree farms	0	1	3	5
Pavement/cleared lot	0	1	3	5
Power plants/oil/gas wells	0	1	3	5
Residences/buildings	0	1	3	5
Riprap/Wall/Dike	0	1	3	5
Sewage/pipes/outfalls/drains	0	1	3	5
Water level Fluctuations	0	1	3	5
Other:	0	1	3	5
Rangeland				
Cattle, Livestock use	0	1	3	5
Pasture/Range/Hayfield	0	1	3	5
Other:	0	1	3	5
Roads				
Bridges/culverts/RR crossings	0	1	3	5
Railroads	0	1	3	5
Roads paved/gravel/dirt	0	1	3	5
Other:	0	1	3	5

Silviculture				
Logging Ops - Active	0	1	3	5
Logging Ops -Recent (< 5 years ago)	0	1	3	5
Logging Ops -History (> 5 years ago)	0	1	3	5
Other:	0	1	3	5
Miscellaneous (Mining, recreational, etc.)				
Angling pressure	0	1	3	5
Dredging	0	1	3	5
Dumping/garbage/trash/litter	0	1	3	5
Exotic Plant species	0	1	3	5
Fish stocking	0	1	3	5
Hiking trails	0	1	3	5
Mines/Quarries	0	1	3	5
Parks, campgrounds	0	1	3	5
Primitive parks, camping	0	1	3	5
Surface films/Odors	0	1	3	5
Other:	0	1	3	5
Natural Disturbance				
Fire	0	1	3	5
Flood Effects	0	1	3	5
Mass Wasting (landslides)	0	1	3	5
Other:	0	1	3	5

Legend -Proximity Score		
Activity **absent**	O	0
Activity **present in watershed but > 10 meters from bank**	P	1
Activity **present within 10 meters from bank**	C	3
Activity **present on stream bank (or channel)**	B	5

Rank Score calculation (For each category, enter maximum proximity score)

Disturbance Category		
Agriculture & Urban	Maximum proximity score -------->	
Rangeland	Maximum proximity score -------->	
Roads	Maximum proximity score -------->	
Silviculture	Maximum proximity score -------->	
Miscellaneous (Mining, recreational, etc.)	Maximum proximity score -------->	
	HDIreach Score (sum) --------->	

Reference Site Candidate Category

Stream a candidate reference site? (Circle One) If no, state reason why	YES	NO
Best Professional Judgment Grade (Check one):		
A = Ideal watershed & stream conditions - **wilderness** area or watershed with **virtually no human disturbance**.		
B = Good watershed & stream conditions; **some human disturbances but not extensive**, and/or BMPs are well implemented.		
C = Marginal watershed & stream conditions for a reference site. Human disturbance is present, site is **best available for basin/region**.		
D = Sub-marginal stream & watershed conditions. **Considerable human disturbance** is present at **reach or** in large portions of **watershed**.		
E = Poor stream & watershed conditions. **Considerable human disturbance** is present at **reach and** in large portions of **watershed**.		
F = Very poor stream & watershed conditions. Completely **unraveled stream and watershed.**		

APPENDIX E

Description of Test and Data Analysis Provided by Tom Mendes, City of Eugene

Water Quality Trends - The Seasonal Kendall statistic Z describes the long-term analyte trend with consideration given to seasonal variation. This trend estimator is free of distributional assumptions. Seasonal variation is based on average monthly precipitation with four seasons defined here; November through January (season 1) are generally the wettest months followed by February through April (season 2), May through July (season 3), and the driest months August through October (season 4).

The USGS has developed a DOS-executable program to run the Seasonal Kendall test statistic. In this application, rejection of the null hypothesis of no trend is calculated at $\rho = 5\%$, that is, a ρ value of 0.05 indicates there is a 5% probability of the observed trend due to random sample variability. Program output includes the slope estimator, *m*, to describe the overall analyte trend. The tables below summarize the Seasonal Kendall test results, listing only those analytes with statistically significant trends. Shaded cells indicate increasing trend, non-shaded cells represent decreasing trends. In general, increasing concentration trends are observed for nitrogen, measured as nitrate+nitrite, turbidity, and at one location for temperature or pH. Decreasing concentration trends are observed for dissolved oxygen, conductivity, and at one location for total phosphorus or pH.

Bear Creek Sub-basin:
At the lower reach of Bear Creek at monitoring station BC1, a long-term increasing trend is observed for nitrate+nitrite as nitrogen.

Coyote Creek Sub-basin:
The trend for turbidity increases at the lower reach of Coyote Creek at station CC1. At CC2, located at the upper reach, pH and conductivity follow decreasing trends; conductivity is typically correlated with dissolved solids in the stream.

Elk Creek Sub-basin:
In the Elk Creek sub-basin, pH follows an increasing trend at the lower reach of the basin at station EC1.

Ferguson Creek Sub-basin:
Nitrogen follows an increasing trend at the lower reach sub-basin monitoring station FC1. Interestingly, stream temperature follows a decreasing trend. At the upper reach of the basin, dissolved oxygen concentrations decreased over the monitored period.

Spencer Creek Sub-basin:
Trends for ortho phosphorus and conductivity were significant at monitoring station SC1; both analytes follow decreasing trends over the monitored period.

Lower Amazon Sub-basin:
In the Lower Amazon sub-basin, nitrogen follows a strong increasing trend while the opposite is true for dissolved oxygen, which follows a strong decreasing trend.

Long Tom Sub-basin:
Significant increasing concentrations trends were observed for nitrogen at both the lower and upper reaches of the Long Tom River, as measured at LL1, LL2, UL1, and UL2. Conversely, dissolved oxygen followed a decreasing trend at the LL1 and LL2; no statistically significant differences were observed for dissolved oxygen at the upper basin monitoring locations. Total phosphorus follows a decreasing trend at the end of the upper basin above Fern Ridge Reservoir at UL1.

Summary of Trends
Analytes Showing Significant Seasonal Trend
Utilizing Seasonal Kendall Test Statistic[1]

Monitoring Location	Analyte	tau	S	Z	ρ	m	B
BC1	Nitrate+Nitrite – as N	0.433	29	2.3690	0.0178	0.0200	0.07
CC1	Turbidity	0.363	33	2.2720	0.0231	0.9333	14.07
CC2	pH	-0.5	-14	-1.9900	0.0466	-0.1125	7.501
CC2	Conductivity	-0.319	-29	-1.9880	0.0468	-6.3000	142.1
EC1	pH	0.5	14	1.9900	0.0466	0.05	6.845
FC1	Water Temperature	-0.319	-29	-1.9880	0.0468	-0.4333	11.98
FC1	Nitrate+Nitrite – as N	0.597	40	3.3120	0.0009	0.0300	0.0825
FC2	Dissolved Oxygen	-0.333	-28	-2.0280	0.0426	-0.1283	10.65
LA1	Dissolved Oxygen	-0.551	-43	-3.3170	0.0009	-0.4075	9.91
LA1	Nitrate+Nitrite – as N	0.537	36	2.9790	0.0029	0.125	-0.075
LL1	Dissolved Oxygen	-0.333	-28	-2.0280	0.0426	-0.1502	9.641
LL1	Nitrate+Nitrite – as N	0.433	29	2.3520	0.0186	0.0866	0.1486
LL2	Dissolved Oxygen	-0.381	-32	-2.3280	0.0199	-0.1775	9.65
LL2	Nitrate+Nitrite – as N	0.418	28	2.2770	0.0228	0.022	0.022
SC1	Conductivity	-0.352	-32	-2.2070	0.0273	-7.2	173
SC1	Ortho Phosphorus	-0.5	-8	-1.9670	0.0492	-0.00292	0.01083
UL1	Nitrate+Nitrite – as N	0.478	32	2.6140	0.009	0.02	0.0875
UL1	Total Phosphorus	-0.769	-10	-2.2500	0.0244	-0.02	0.095
UL2	Nitrate+Nitrite – as N	0.463	31	2.5210	0.0117	0.02867	0.06783

[1] Significant at $\alpha = 0.05$

tau = correlation coefficient
S = Mann-Kendall statistic
m = slope of trend
Z = Seasonal Kendall statistic
ρ = significance of observed trend
b = trend y-intercept

Shaded cells indicate increasing trend.

Description of Test and Data Analysis Provided by Tom Mendes, City of Eugene

Mann-Whitney *U* Test

The Mann-Whitney U test compares two independent sample sets to determine whether they are equivalent in location. Mann-Whitney is a nonparametric calculation based on the sums of ranks for independent samples and is suitable for data sets when values are less than the reporting limit. An advantage of the Mann-Whitney test is that it can be applied to data sets whose values do not follow a normal distribution; hence the test is termed nonparametric. Here we use the test to determine whether a statistically significant difference exists between samples collected from, say, the upper and lower reaches of a sub-basin. Comparison of sample sets whereby each come from within the same basin is termed an intra-basin comparison, when the sample sets come from different sub-basins we are making an inter-basin comparison. Comparisons using the Mann-Whitney *U* test is set at $\alpha = 0.05$, in other words, the probability that we have distinguished two sample sets as being "different" when they are not is 5%.

Independent Samples *t* Test

The Independent Samples t test compares the means of a variable from two data sets. Our analysis includes Levene's test for equality of variances, as well as equal- and unequal-variance *t* values. Use of these tests presumes the data are normally distributed. Two techniques were used to determine whether the data follow a normal distribution, including the Kolmogorov-Smirnov and Shapiro-Wilk tests, the latter being used when there were less than 50 values in the data set. About 15% of the water quality parameters in this study follow a normal distribution; hence the Mann-Whitney *U* test is used to identify significant differences between data sets with results of the *t* test provided when both data sets being compared are normally distributed.

Summary of Intra-Basin Comparisons

A total of 35 intra-basin comparisons were made whereby upstream water quality was compared to that at a downstream monitoring location. Those comparisons that were determined to be statistically significant at $\alpha = 0.05$ are summarized in the tables for the Independent Samples *t* and Mann-Whitney *U* tests below, which lists the sub-basin sites compared, the water quality parameter and its units, averages for the analyte at the upstream and downstream sites, and the significance level for the Mann-Whitney *U* and Independent Samples *t* tests. Shaded cells are of the largest value in the upstream-downstream comparison. These data were further simplified and presented in the table below, which shows the counts of significant values for each water quality parameter in the upstream-downstream comparisons.

In general, measurements for temperature, turbidity and suspended solids, conductivity, bacteria, nitrogen, and total phosphorus are greater at downstream monitoring sites than those measured upstream. Dissolved oxygen and ortho phosphorus concentrations tend to be higher at upstream locations, while pH varies depending on the location. A range of the difference of averages for the set of significant parameters is also shown to provide an indication of the magnitude of change between the upstream and downstream sites. Though differences may appear to be small for some analytes, the water quality differences observed are statistically significant.

Summary of Inter-Basin Comparisons

Four inter-basin water quality comparisons were made using the Mann-Whitney *U* and Independent Samples *t* tests; they are: Lower Amazon (LA1) to Upper Amazon (UA1), LA1 to Coyote Creek (CC1), Lower Long Tom (LL2) to UA1, and CC1 to UA1. With few exceptions, water quality values for the Lower and Upper Amazon sites tend to be greater than those to which the site is compared. Nitrogen, phosphorus and bacteria tend to be higher at the Amazon sites than in the Lower Long Tom and Coyote Creek. Turbidity tends to be higher at Coyote Creek when compared to the Lower Amazon, but lower when compared to the Upper Amazon; turbidity is significantly lower in the Lower Amazon when compared to the Upper Amazon. Slightly higher turbidity values are observed at the Upper Amazon when compared to the Lower Long Tom. Higher dissolved oxygen concentrations are generally associated with lower nutrient concentrations; an exception is the comparison of the Lower to Upper Amazon sites where the lower reach has become oxygen deficient and the nutrient level has become somewhat depleted.

Counts of Significant Analytes for Inter-Basin Comparisons Using Independent Samples *t* and Mann-Whitney *U* Tests				
Analyte	**Upstream Count**	**Downstream Count**	**Difference of Averages Range**	**Units**
Water Temperature	0	3	1.6 – 2.3	˚F
Turbidity	1	8	2 – 24	NTU
pH	4	5	0.1 – 0.4	Units
Conductivity	1	11	2 – 69	µS/cm
Dissolved Oxygen	4	2	0.2 – 1.7	mg/L
Escherichia coli	3	9	27 – 405	MPN/100mL
Nitrate+Nitrite as N	1	4	0.06 – 0.19	mg/L
Ortho Phosphorus	3	1	0.01 – 0.11	mg/L
Total Phosphorus	1	9	0.01 – 0.11	mg/L
Total Suspended Solids	1	4	1 – 15	mg/L

Summary of Significant Water Quality Differences
Intra-Basin Comparison
Independent Samples *t* & Mann-Whitney *U* Tests

Sub-Basin IDs Compared	Analyte	Units	Upstream Average	Downstream Average	Significance[a]	
					Mann-Whitney *U*	*t* Test
BC1 (D) to BCA (U)	Escherichia coli	MPN / 100 mL	210	509	0.027	
BC1 (D) to BC2 (U)	Turbidity	NTU	13	23	0.000	
	pH	Units	6.9	7.2	0.000	
	Conductivity	µS/cm	71	73	0.000	
	Dissolved Oxygen	mg/L	7.6	8.9	0.000	0.000
	Escherichia coli	MPN / 100 mL	104	509	0.000	
	Nitrate+Nitrite	mg/L	0.12	0.19	0.000	
	Ortho Phosphorus	mg/L	<0.01	0.02	0.009	
	Total Phosphorus	mg/L	0.02	0.07	0.000	
	TSS	mg/L	4	14	0.000	
BC1 (D) to BCT2 (U)	Escherichia coli	MPN / 100 mL	323	509	0.033	
CC1 (D) to CC4 (U)	Turbidity	NTU	13	24	0.000	
	pH	Units	7.0	7.2	0.009	
	Conductivity	µS/cm	72	141	0.000	
CC1 (D) to CC2 (U)	Turbidity	NTU	29	24	0.042	
CC1 (D) to CC3 (U)	Water Temperature	˚F	9.1	11.4	0.050	0.011
	Turbidity	NTU	16	24	0.000	
	Conductivity	µS/cm	95	141	0.005	
	Dissolved Oxygen	mg/L	9.7	8.0	0.001	
	Escherichia coli	MPN / 100 mL	58	276	0.000	
	Ortho Phosphorus	mg/L	0.04	0.02	0.002	
	TSS	mg/L	10	14	0.002	
CC1 (D) to SC1 (U)	Turbidity	NTU	21	24	0.032	
	pH	Units	7.3	7.2	0.007	
	Conductivity	µS/cm	198	141	0.027	
	Nitrate+Nitrite	mg/L	0.03	0.09	0.000	

[a] Independent Samples *t* and Mann-Whitney *U* tests significant at α = 0.05.
Shaded cells are of the largest value in the upstream-downstream comparison.

Summary of Significant Water Quality Differences Continued
Intra-Basin Comparison
Independent Samples *t* & Mann-Whitney *U* Tests

Sub-Basin IDs Compared	Analyte	Units	Upstream Average	Downstream Average	Significance[a]	
					Mann-Whitney *U*	*t* Test
SC1 (D) to SC2 (U)	pH	Units	7.0	7.3	0.000	
	Conductivity	µS/cm	130	198	0.000	
FC1 (D) to FCB (U)	Escherichia coli	MPN / 100 mL	127	447	0.001	
	Total Phosphorus	mg/L	0.02	0.05	0.016	
FC1 (D) to FCC (U)	Escherichia coli	MPN / 100 mL	117	447	0.000	
FC1 (D) to FC2 (U)	Turbidity	NTU	7	16	0.000	
	pH	Units	7.2	7.1	0.040	
	Conductivity	µS/cm	47	59	0.000	0.000
	Dissolved Oxygen	mg/L	10	9.2	0.000	0.001
	Escherichia coli	MPN / 100 mL	124	447	0.000	
	Nitrate+Nitrite	mg/L	0.09	0.28	0.000	
	Ortho Phosphorus	mg/L	0.01	0.02	0.046	
	Total Phosphorus	mg/L	0.02	0.05	0.000	
	TSS	mg/L	7	14	0.000	
FC1 (D) to FCD (U)	Escherichia coli	MPN / 100 mL	66	447	0.000	
	Total Phosphorus	mg/L	0.02	0.05	0.031	
LL2 (D) to LL3 (U)	Conductivity	µS/cm	70	76	0.024	
LL2 (D) to UL1 (U)	Turbidity	NTU	10	34	0.000	
	pH	Units	7.0	7.3	0.000	0.000
	Conductivity	µS/cm	52	76	0.000	
	Total Phosphorus	mg/L	0.04	0.10	0.002	
	TSS	mg/L	7	22	0.003	
LL2 (D) to CC1 (U)	Water Temperature	˚F	11.4	13.1	0.15	
	pH	Units	7.2	7.3	0.044	
	Conductivity	µS/cm	141	76	0.000	
	Escherichia coli	MPN / 100 mL	276	249	0.045	

[a] Independent Samples *t* and Mann-Whitney *U* tests significant at α = 0.05.
Shaded cells are of the largest value in the upstream-downstream comparison.

Summary of Significant Water Quality Differences Continued
Intra-Basin Comparison
Independent Samples *t* & Mann-Whitney *U* Tests

Sub-Basin IDs Compared	Analyte	Units	Upstream Average	Downstream Average	Significance[a]	
					Mann-Whitney *U*	*t* Test
UL1 (D) to UL2 (U)	Water Temperature	˚F	9.9	11.5	0.049	
	pH	Units	7.2	7.0	0.047	0.013
	Conductivity	µS/cm	49	52	0.049	0.046
	Dissolved Oxygen	mg/L	10	9.1	0.001	0.000
	Total Phosphorus	mg/L	0.03	0.04	0.025	
	TSS	mg/L	8	7	0.002	
UL1 (D) to EC1 (U)	Conductivity	µS/cm	47	52	0.001	
	Escherichia coli	MPN / 100 mL	200	100	0.049	
EC1 (D) to EC2 (U)	Turbidity	NTU	7	9	0.000	
	Conductivity	µS/cm	38	47	0.000	
	Dissolved Oxygen	mg/L	10	9.2	0.000	
	Escherichia coli	MPN / 100 mL	25	200	0.000	
	Nitrate+Nitrite	mg/L	0.32	0.22	0.018	
	Total Phosphorus	mg/L	0.02	0.04	0.031	
LA1 (D) to LAB (U)	Total Phosphorus	mg/L	0.13	0.20	0.001	0.001
LA1 (D) to LAC (U)	Total Phosphorus	mg/L	0.13	0.20	0.001	0.001
LL1 (D) to LA1 (U)	Turbidity	NTU	18	26	0.044	
	pH	Units	7.6	7.2	0.007	0.024
	Dissolved Oxygen	mg/L	8.5	8.7	0.000	0.000
	Escherichia coli	MPN / 100 mL	350	168	0.000	
	Ortho Phosphorus	mg/L	0.13	0.02	0.000	
	Total Phosphorus	mg/L	0.20	0.09	0.000	
LL1 (D) to LLB (U)	Nitrate+Nitrite	mg/L	0.32	0.50		0.014

[a] Independent Samples *t* and Mann-Whitney *U* tests significant at α = 0.05.
Shaded cells are of the largest value in the upstream-downstream comparison.

Summary of Significant Water Quality Differences Continued Inter-Basin Comparison Independent Samples *t* & Mann-Whitney *U* Tests						
Sub-Basin IDs Compared	**Analyte**	**Units**	**Upstream Average**	**Downstream Average**	**Significance[a]**	
					Mann-Whitney *U*	***t* Test**
LA1 (D) to CC1 (U)	Water Temperature	˚F	11.4	13.5	0.019	0.011
	Turbidity	NTU	24	18	0.000	
	pH	Units	7.2	7.6	0.000	
	Conductivity	µS/cm	141	212	0.000	
	Nitrate+Nitrite	mg/L	0.09	0.75	0.000	
	Ortho Phosphorus	mg/L	0.02	0.13	0.000	
	Total Phosphorus	mg/L	0.07	0.20	0.000	
LA1 (D) to UA1 (U)	Turbidity	NTU	27	18	0.044	
	pH	Units	7.5	7.6	0.007	0.024
	Dissolved Oxygen	mg/L	6.9	8.5	0.000	0.000
	Escherichia coli	MPN / 100 mL	786	350	0.000	
	Ortho Phosphorus	mg/L	0.05	0.13	0.000	
	Total Phosphorus	mg/L	0.11	0.20	0.000	0.000
LL2 (D) to UA1 (U)	Turbidity	NTU	27	26	0.001	
	pH	Units	7.5	7.2	0.001	0.000
	Conductivity	µS/cm	234	99	0.000	
	Dissolved Oxygen	mg/L	6.9	8.7	0.000	0.000
	Escherichia coli	MPN / 100 mL	786	168	0.000	
	Nitrate+Nitrite	mg/L	0.31	0.50	0.005	
	Ortho Phosphorus	mg/L	0.05	0.02	0.000	
CC1 (U) to UA1 (D)	Turbidity	NTU	24	27	0.006	
	pH	Units	7.2	7.5	0.000	
	Conductivity	µS/cm	141	234	0.000	
	Dissolved Oxygen	mg/L	8.0	6.9	0.005	
	Escherichia coli	MPN / 100 mL	276	786	0.000	
	Nitrate+Nitrite	mg/L	0.09	0.31	0.000	
	Ortho Phosphorus	mg/L	0.02	0.05	0.000	
	Total Phosphorus	mg/L	0.07	0.11	0.000	

[a] Independent Samples *t* and Mann-Whitney *U* tests significant at α = 0.05.
Shaded cells are of the largest value in the upstream-downstream comparison.

Appendix F. Percent of Samples at each Site that did not Meet State Standards or Guidelines.

		Turbidity	Dissolved Oxygen	*E. coli* (single)	*E. coli* (ave.)[1]	pH	Nitrate-Nitrite-N	Total Phosphorus
State standard or guideline*[2] (shown as values that do *not* meet criteria)	**Site ID**	**> 50 NTU***	**< 8 mg/L**	**> 406 cells/ 100 mL**	**>126 cells /100 mL**	**< 6.5 or > 8.5**	**> 0.3 mg/L***	**> 0.1 mg/L***
Bear Cr. at Territorial Hwy.	BC1	**6%** (81)	**31%** (67)	**41%** (73)	**80%** (25)	**0%** (25)	**20%** (46)	**20%** (41)
Bear Cr. at Templeton Rd.	BC2	**1%** (80)	**55%** (67)	**8%** (59)	**8%** (25)	**0%** (25)	**10%** (31)	**0%** (27)
Bear Cr. at Hall Rd.	BCA	N.C.	N.C.	**7%** (14)	N.C.	N.C.	**7%** (14)	**0%** (14)
Owens Cr. at Smyth Rd.	BCT1	N.C.	N.C.	**36%** (14)	N.C.	N.C.	**29%** (14)	**21%** (14)
Jones Cr. at Hall Rd.	BCT2	N.C.	N.C.	**27%** (15)	N.C.	N.C.	**21%** (14)	**7%** (15)
Coyote Cr. at Petzold Rd.	CC1	**4%** (81)	**40%** (70)	**15%** (73)	**20%** (25)	**0%** (25)	**3%** (32)	**22%** (41)
Coyote Cr. at Powell Rd.	CC2	**14%** (80)	**32%** (68)	**14%** (73)	**20%** (25)	**0%** (25)	**3%** (32)	**11%** (27)
Tributary of Coyote Cr. off Hamm Rd.	CC3	**4%** (23)	**13%** (24)	**6%** (35)	**0%** (25)	**0%** (25)	**0%** (10)	**33%** (6)
Tributary of Coyote Cr. off Powell Rd.	CC4	**0%** (54)	**51%** (45)	**8%** (24)	N.C.	**0%** (25)	**26%** (34)	**11%** (35)
Coyote Cr. at Battle Cr. Rd.	CC5	N.C.	N.C.	**9%** (11)	N.C.	N.C.	**0%** (1)	**33%** (12)
Battle Cr. at Battle Cr Rd.	CCT3	N.C.	N.C.	**0%** (9)	N.C.	N.C.	N.C.	**11%** (9)
Elk Cr. at Vaughan Rd.	EC1	**0%** (81)	**21%** (68)	**14%** (73)	**40%** (25)	**0%** (25)	**31%** (45)	**11%** (27)
Cedar Cr. off Bishop Rd.	EC2	**1%** (82)	**0%** (66)	**2%** (56)	**0%** (25)	**0%** (25)	**42%** (43)	**0%** (27)
Ferguson Cr. at Territorial Hwy.	FC1	**2%** (82)	**26%** (66)	**40%** (73)	**60%** (25)	**0%** (25)	**37%** (46)	**17%** (41)
Ferguson Cr. at Ferguson Rd.	FC2	**2%** (82)	**1%** (68)	**7%** (59)	**0%** (25)	**0%** (25)	**6%** (31)	**4%** (27)
Ferguson Cr. at River Mile 3	FCA	N.C.	N.C.	**36%** (14)	N.C.	N.C.	N.C.	N.C.
Ferguson Cr. at Turnbow Rd.	FCB	N.C.	N.C.	**14%** (14)	N.C.	N.C.	**14%** (14)	**0%** (14)
South Fork Ferguson Cr. near Mouth	FCC	N.C.	N.C.	**14%** (14)	N.C.	N.C.	**21%** (14)	**0%** (14)
Ferguson Cr. at Ferguson Rd.	FCD	N.C.	N.C.	**0%** (14)	N.C.	N.C.	**7%** (14)	**0%** (14)

[1] To calculate this average: $10^{\wedge [(\log A + \log B + \log C + \log D + \log E) /5]}$, where A – E are the *E. coli* levels (cells/100 mL) for 5 samples taken within a 30-day period

[2] These guidelines have been suggested by staff at the DEQ as interim evaluation criteria. These numbers may change when formal guidelines based on ecoregional data are available.

		Turbidity	**Dissolved Oxygen**	***E. coli* (single)**	***E. coli* (ave.)[3]**	**pH**	**Nitrate-Nitrite-N**	**Total Phosphorus**
Amazon at High Pass Rd. (near mouth)	LA1	**6%** (81)	**47%** (68)	**26%** (73)	**0%**	**0%** (25)	**54%** (46)	**90%** (41)
Lower Amazon at Alvadore Rd.	LAA	N.C.	N.C.	N.C.	N.C.	N.C.	**71%** (14)	**100%** (13)
Lower Amazon at Meadowview Rd.	LAB	N.C.	N.C.	**29%** (14)	N.C.	N.C.	**71%** (14)	**64%** (14)
Lower Amazon at Bodenhamer Rd.	LAC	N.C.	N.C.	N.C.	N.C.	N.C.	**64%** (14)	**71%** (14)
Long Tom at Bundy Bridge (near mouth)	LL1	**13%** (82)	**33%** (69)	**11%** (72)	**0%** (25)	**0%** (25)	**64%** (45)	**33%** (40)
Long Tom at Hwy. 36 (mid-basin)	LL2	**19%** (80)	**35%** (69)	**16%** (74)	**20%** (25)	**0%** (25)	**15%** (46)	**37%** (41)
Lower Long Tom at Spillway (mid-basin)	LL3	**29%** (58)	**30%** (47)	**22%** (36)	N.C.	**0%** (25)	**12%** (33)	**42%** (33)
Lower Long Tom at Monroe	LLA	N.C.	N.C.	N.C.	N.C.	N.C.	**50%** (14)	N.C.
Lower Long Tom at Cox Butte Rd.	LLB	N.C.	N.C.	N.C.	N.C.	N.C.	**57%** (14)	N.C.
Noti Cr. at Vaughn Rd. (near mouth)	NCT1	N.C.	N.C.	**0%** (14)	N.C.	N.C.	**0%** (14)	N.C.
Poodle Cr. at Hwy. 126 (near mouth)	PCT1	N.C.	N.C.	**29%** (14)	N.C.	N.C.	**57%** (14)	N.C.
Spencer Cr. at Pinegrove Rd. (near mouth)	SC1	**4%** (77)	**49%** (65)	**12%** (58)	**20%** (25)	**0%** (25)	**0%** (32)	**26%** (39)
Spencer Cr. at Summerville Rd. (headwaters)	SC2	**6%** (63)	**37%** (51)	**13%** (55)	**75%** (25)	**0%** (25)	**0%** (26)	**10%** (21)
Spencer Cr. at Lorane Hwy.	SCA	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	**45%** (11)
Amazon at Danebo Ave. (mid-basin)	UA1	**10%** (78)	**64%** (67)	**52%** (73)	**100%** (25)	**0%** (25)	**43%** (46)	**59%** (41)
Long Tom at Hwy. 126 (mid-basin)	UL1	**4%** (82)	**25%** (71)	**5%** (59)	**20%** (25)	**0%** (25)	**24%** (46)	**7%** (27)
Long Tom at Alderwood State Park (mid-basin)	UL2	**4%** (82)	**1%** (68)	**14%** (73)	**20%** (25)	**0%** (25)	**28%** (46)	**4%** (27)

N.C.= Not collected

Numbers in Parenthesis = Total Number of Samples/Measurements

[3] To calculate this average: $10^{\wedge [(\log A + \log B + \log C + \log D + \log E)/5]}$, where A – E are the *E. coli* levels (cells/100 mL) for 5 samples taken within a 30-day period