GOAL: Healthy Streams

Chemical Water Quality + Physical Habitat Quality + Biotic Quality = Healthy Stream

(Healthy implies life)

If these 3 elements can be quantified, this equation can be solved for any variable and only two need be measured. In practice however, all three are measured whenever possible.

MONITORING

Chemical

- can be very expensive
- very time consuming for NPS pollutants
- necessary for problem and source identification
- doesn't tell you if stream is healthy

Biological

- much less expensive
- tells you if stream is healthy
- doesn't identify the cause or source of problem

Physical (Habitat)

- cheap
- tells you how much of biological impairment is due to WQ without having to actually perform, and pay for the tests (remainder is due to lack of habitat)
- doesn't tell you if stream is healthy

RESULTS

1. Biological monitoring alone measures stream health.
2. Physical habitat alone measures potential stream health if chemical quality is adequate.
3. Chemical monitoring alone measures potential stream health if physical habitat is adequate.
4. Biological community + physical habitat measures stream health and the amount of impairment (if any) due to lack of habitat. The amount of impairment due to chemical quality is then estimated by subtraction.
5. Biological community + chemical quality measures stream health and amount of impairment (if any) due to bad water quality. The amount of impairment due to lack of habitat is estimated by subtraction.
6. Biological community + physical habitat + chemical quality are necessary to understand and define function and health of the stream ecosystem.

Habitat Assessment Interpretation

The Oklahoma Conservation Commission's habitat assessment adheres to a modified version of the EPA Rapid Bioassessment Protocols (RBP) (Plafkin et al., 1989) and is designed to assess habitat quality in relation to its ability to support biological communities in the stream. The assessment is based on particular parameters grouped into three categories for a total of eleven components (Plafkin et al., 1989). The eleven components are discussed in more detail below. The three primary categories assessed include micro scale habitat, macro scale habitat, and riparian/bank structure. Micro scale habitat includes substrate makeup, stable cover, canopy, depth, and velocity. Macro scale assesses the channel morphology, sediment deposits, and other parameters. The third category looks at the riparian zone quality, width, and general makeup (trees, shrubs, vines, and grasses) as well as bank features. Bank erosion and streamside vegetative cover are incorporated into this section.

OCC's habitat assessment components include:

(1) **Instream cover** is the component of habitat that organisms hide behind, within, or under. High quality cover consists of things like submerged logs, cobbles and boulders, root wads, and beds of aquatic plants. Cover required by smaller members of the stream community will consist of gravel, cobbles, small woody debris, and dense beds of fine aquatic plants. At least 50% of the stream's area should be occupied by a mixture of stable cover types for this category to be considered optimal.

(2) **Pool bottom substrate** describes the type of stream bed found in pools. Pools are depositional areas of the stream, and as such, are easily damaged by materials that settle. A loose shifting pool bottom will not provide substrate for burrowing organisms and will not allow bottom-spawning fish to successfully spawn. It will not provide habitat to the smaller vertebrates and invertebrates that are necessary to support many of the pool dwelling fish. At least 80% of all pool bottoms must have stable substrate for a reach to be considered optimal for this habitat component.

(3) **Pool variability** describes the depth of pools. A healthy, diverse community of aquatic organisms requires both deep and shallow pools. A fairly even mix of pool depths from a few centimeters to 0.5 meters or greater is optimal.

(4) **Canopy cover** assesses the shading of the stream section. Plants lie at the base of almost all food chains. Since plants require light for growth and survival, a stream that is functioning well needs some amount of light. Moderation is optimal, however, because light is associated with heat, and most aquatic organisms are more stressed by the warmer waters and the lower oxygen solubility and higher metabolic rates that accompany the warming of water.

(5) The **percent of rocky runs and riffles** is calculated for the fifth component. Rocky runs and riffles offer a unique combination of highly oxygenated, turbulent water, flowing over high quality cover and substrate. Turbulence prevents the formation of nutrient concentration gradients from cell membranes outward so that algae and other plants grow at a much higher rate than they would at the same concentration in pools. More food means more growth. Larger crops of algae are translated into larger invertebrate crops. It is these invertebrates, reared in riffle areas, that feed many of the fish in the stream. Because turbulent water is well oxygenated, there has been no selection pressure for riffle dwelling organisms to develop tolerance to poorly oxygenated waters. These are often the first animals to disappear from the stream if oxygen becomes scarce. The presence of rocky runs and riffles offers habitat for many highly adapted animals that will increase diversity of samples collected from the streams they occupy.

(6) **Discharge** at representative low flow reflects stream size. Water is the most basic requirement of aquatic organisms. Larger streams tend to have more water, and thus, more varied high quality habitat. Overall habitat quality should rise as streams increase in size and discharge, other factors being equal.

(7) **Channel alteration** is the seventh category. The presence of newly formed point bars and islands is very significant. Unstable streambeds support fewer types of animals than those that are stable. This is because unstable streambeds tend to have unstable pool bottom substrate, riffle areas whose cobbles are embedded in finer material, and little cover because it is continually being buried. Few or no signs of channel alteration are considered optimal.

(8) **Channel sinuosity** measures how far a channel deviates from a straight line. More sinuous channels tend to have more undercut banks, root wads, submerged logs, etc. IBI scores should be higher as channels become more sinuous. Sinuosity was calculated by taking GPS (global positioning system) readings at the beginning and end of the reach being assessed and diving the total distance (400 m) by the distance as the crow flies.

(9) The **bank erosion** index assesses the stability of the stream bank. Stable stream banks tend to increase IBI scores for many reasons. Most importantly, they do not contribute sediment to the stream channel. As a rule, channels with stable banks tend to be deeper and narrower than channels with unstable banks. Because of the increased depth and decreased width, they tend to be cooler and they also tend to grow less algae for a given amount of nutrients than do shallow, wide channels. Overall habitat quality should increase as bank stability increases.

(10) The **vegetative stability of the stream bank** is an important component. Stream banks can be stabilized with a number of materials including rock, concrete, and fabric. Banks that are stabilized with vegetation benefit the aquatic community more than those stabilized with other materials. This is because the

Habitat Assessment

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(10) **Vegetative stability of the stream bank** is an important component. Stream banks can be stabilized with a number of materials including rock, concrete, and fabric. Banks that are stabilized with vegetation benefit the aquatic community more than those stabilized with other materials. This is because the vegetation offers several extra advantages beyond that of bank stability. The riparian plants of the stream bank offer a high quality source of food and shade to the aquatic community. Riparian vegetation stabilizes point bars and contributes greatly to structure in the form of root wads and woody debris. Overall habitat quality should improve as bank vegetative stability increases.

(11) **Streamside cover**. Is the terrestrial vegetation along the banks. A mixture of grasses, forbs, shrubs, vines, saplings, and large trees transfer these necessities to the stream more effectively than does any single type of vegetation. Habitat quality should increase as the form of bank vegetation increases in diversity.

Fish Collection

Fish collections are obtained from a 400-meter reach at all sites using a combination of seining and electroshocking according to procedures outlined in OCC SOP (2009). The collection of fish follows a modified version of the EPA Rapid Bioassessment Protocol V (Plafkin et al., 1989) supplemented by other documents. Specific techniques and relative advantages of seining and electrofishing vary considerably according to stream type and conductivity. Depending upon workable habitat, seining is performed first at all sites and accomplished by use of either 6' X 10' or 6' X 20' seines of ¼ inch mesh equipped with 8' brailes. Electroshocking is undertaken at all sites with suitable conductivities (usually < 1000 μS/cm) and involves the use of a Smith Root LR24 backpack shocker. For sites possessing long pools too deep to seine or backpack shock, OCC field personnel employ a boat electrofishing unit consisting of a Smith-Root GPP 2.5 shocking unit powered by a Honda 5kw generator.

Except for those individuals readily identifiable, fish are placed in 10% formalin upon capture and identified to species by a professional taxonomist. Fish species identified and released in the field are photographed for reference. All fixed fish samples are transferred to ethanol and retained for future reference.

Data Analysis

Fish data are compiled and analyzed by site using state biocriteria and methods outlined in the state's *Use Support Assessment Protocols* (OWRB 2007). In addition, each site is assessed using a modified version of Karr's Index of Biotic Integrity (IBI) (adapted from Plafkin et al., 1989). Descriptive statistics are determined for each metric using the *Minitab V 14* software. The condition of the fish community is based on indices of species richness, community quality, trophic structure, and by comparison to the average scores of high-quality streams in that ecoregion. The modified IBI score is calculated using the following metrics:

(1) The **total number of fish species** decreases with decreasing water or habitat quality.

(2) The **number of sensitive benthic species (darters, madtoms, sculpins)** decreases with increasing siltation and increasing benthic oxygen demand. Many of these fish actually live within the cobble and gravel interstices and are very good indicators of conditions that make this environment inhospitable. These species are weak swimmers that do not readily travel up and down a stream, so their presence or absence at a site relates well to both past and present habitat and water quality conditions at that site.

(3) The **number of sunfish species** decreases with decreasing pool quality and with decreasing cover. Sunfish also require a fairly stable substrate on which to spawn, so their long-term success is also tied to conditions that affect the amount of sediment that enters and leaves the stream.

(4) The **number of intolerant species** is a characteristic of the fish community that separates high quality from moderate quality sites. A high quality stream will have several members of the fish community that are intolerant to environmental stress. A stream of only moderate quality will have fish that are moderately and highly tolerant of environmental stress. The intolerant species will not be present in the moderate quality stream.

(5) The **proportion of tolerant individuals** is a characteristic that allows moderate quality streams to be separated from low quality streams. These are opportunistic, tolerant fish that dominate communities that have lost their competitors through loss of habitat or water quality.

(6) The **proportion of individuals as insectivorous cyprinids** increases as the quality and quantity of the invertebrate food base increases. These are the dominant minnows in North American streams but are replaced by either omnivorous or herbivorous minnows as the quality of the food base deteriorates. Often, as the density of aquatic invertebrates decreases, the standing crop of algae increases. This is because the aquatic invertebrates are the largest group of primary consumers. Fish that can switch their diet to algae or fish that eat only algae will replace fish that cannot adapt to the new conditions.

(7) The **proportion of individuals as lithophilic spawners** decreases as the quality of the stream decreases. Lithophilic spawners require cobble or gravel in order to spawn; hence, these fish are sensitive to siltation. This metric allows separation of excellent streams from moderate quality streams.

For each of these seven metrics, a score of 5, 3, or 1 is assigned (Table 2), and these scores are summed to get a total IBI score (35 point maximum) for each site. For all "proportion" metrics, the score is based on the actual metric. For all non-proportion metrics, the score is determined by dividing the monitoring site's metric by the average high quality site metric of the same ecoregion. Each monitoring site's total score is then compared to the high quality site total score in that ecoregion and given an integrity rating (as established and suggested by the EPA RBP; see Table 3, below). IBI scores that fall between the assessment ranges are classified in the closest scoring group. This score indicates the quality of the fish community (higher scores indicate higher quality) but says nothing about whether any deficiencies are due to degraded water quality or to degraded habitat.

Table 2. Index of Biotic Integrity (IBI) scoring criteria for fish.

Metrics	*5*	*3*	*1*
Number of species	>67%	33-67%	<33%
Number of sensitive benthic species	>67%	33-67%	<33%
Number of sunfish species	>67%	33-67%	<33%
Number of intolerant species	>67%	33-67%	<33%
Proportion tolerant individuals	<10%	10-25%	>25%
Proportion insectivorous cyprinid individuals	>45%	20-45%	<20%
Proportion individuals as lithophilic spawners	>36%	18-36%	<18%

Table 3. Index of Biotic Integrity (IBI) score interpretation for fish.

% Comparison to the Reference Score	Integrity Class	Characteristics
>97%	Excellent	Comparable to pristine conditions, exceptional species assemblage
80 - 87%	Good	Decreased species richness, especially intolerant species
67 - 73%	Fair	Intolerant and sensitive species rare or absent
47 - 57%	Poor	Top carnivores and many expected species absent or rare; omnivores and tolerant species dominant

26 - 37%	Very Poor	Few species and individuals present; tolerant species dominant; diseased fish frequent

<u>General info:</u>

When the fish of a stream are examined, there are a few things that can be said about the stream immediately, but it is important to know what the **maximum potential** is for each metric for streams in a particular ecoregion. This is why we use a reference stream to compare to and to calculate a biological integrity score. The community of a reference/high quality stream should indicate the maximum potential for each metric. Each metric has a maximum potential that varies with the ecoregion it is located in and the stream size. Because of this, a list of fish does not say much about the water quality of the stream until it is compared with info from reference streams of similar size in the same ecoregion.

It is ideal to have a reference "condition" rather than a single stream since that will provide more data and allow the use of an average that is expected in that ecoregion, etc. To get the best estimate of stream health, it is good to average the scores of several years, since a single collection might be an anomaly due to drought, flood, etc. Assessing fish communities allows a look at the stream's health over a longer period than macroinvertebrate collections. Using both macroinvertebrate data and fish data together gives a more complete assessment of the biological health of a stream.

Macroinvertebrate Collection

Collection of macroinvertebrates is attempted at all fixed sites for both the winter and summer index periods according to procedures outlined in the OCC SOP (2009). Index periods represent seasons of relative community stability that afford opportunity for meaningful site comparisons. For Oklahoma, the summer index occurs from July 1 to September 15; the winter index occurs from January 1 to March 15. In order for macroinvertebrate collections to be obtained, flowing water must be present. Sampling efforts included attempts to procure animals from all available habitats at a site; thus, total effort at a site may entail up to three total samples with one from each of the following habitats: rocky riffles, streamside vegetation, and woody debris.

Collection methods involve sampling each of the habitats similar to methods outlined in the EPA Rapid Bioassessment Protocols (Plafkin et al., 1989). Riffle sampling effort consists of three, one meter squared kicknet samples in areas of rocky substrate reflecting the breadth of the velocity regime at a site. Riffles with substrates of bedrock or tight clay are not sampled. Any streamside vegetation in the current that appears to offer fine structure is sampled by agitation within a #30 mesh dip net for three minutes total agitation time. Any dead wood with or without bark which is in current fast enough to offer suitable habitat for organisms is sampled by agitation or by scraping/brushing upstream of a #30 mesh dip net for 5 minutes. Woody debris sampled generally ranged in size from 1/4" to about 8" in diameter. Each sample type is preserved independently in quart mason jars with ethanol, labeled, and sent to a professional taxonomist for picking and identification.

Data Analysis

To assess whether macroinvertebrates indicate a stream in good health or bad, the results must be compared to results from a reference stream or a "high quality site" condition. Data is compiled, collated by year, season, and sample type and entered into a spreadsheet for metric calculations. The six metrics used to assess the macroinvertebrate community include the following:

(1) The **number of taxa** refers to the total number of taxonomically different types of animals in the sample. As is the case with the fish, this number rises with increasing water and/or habitat quality (Plafkin et al., 1989). Manual Method: This is just the number of different species (different lines from Jack Davis)

(2) The **Modified Hilsenhoff Biotic Index (HBI)** is a measure of the invertebrate community's tolerance to organic pollution. It ranges between 0 and 10 with 0 being the most pollution sensitive. The index used in the RBP Manual is based on the pollution tolerance of invertebrates from the upper midwest. The Index used here is calculated the same way, but uses tolerance values of North Carolina invertebrates (Plafkin et al., 1989). Manual Method: Just get a weighted average HBI score. Multiply the number of individuals of a specific species by the HBI score for each species, add all those numbers up, and divide by the total number of individuals in the collection.

(3) The **percent EPT** is a measure of how many individuals in the sample are members of the EPT group. This metric helps to separate high quality streams from those of moderately high quality. The highest quality streams will have many individuals of many different taxa of EPT. As conditions deteriorate, animals will begin to die or to drift downstream. At this point, the community will still have many taxa of EPT, but there will be fewer individuals (Plafkin et al.,

1989). Manual Method: Add all individuals that are in the genus Ephemeroptera, Plecoptera, or Trichoptera and divide by the total number of individuals in the sample.

(4) The **EPT Index** is the number of different taxa from the orders Ephemeroptera, Plecoptera, and Trichoptera, the mayflies, stoneflies, and caddis flies respectively. With few exceptions, these insects are more sensitive to pollution than any other groups. As a stream deteriorates in quality, members of this group will be the first to disappear. This robust metric allows discrimination between all but the worst of streams (Plafkin et al., 1989). Manual Method: This is just the number of species that are Ephemeroptera, Plecoptera, or Trichoptera

(5) **Percent dominant two taxa** is the percentage of the collection composed of the most common two taxa. As more and more species are excluded by increasing pollution, the remaining species can increase in numbers due to the unused resources left by the excluded animals. This metric helps to separate the high quality streams from those of moderate quality (Plafkin et al., 1989). Manual Method: Add the individuals in the two most abundant groups and divide by the total number of individuals in the collection.

(6) The **Shannon-Weaver Species Diversity Index** measures the evenness of the species distribution. It increases as more and more taxa are found in the collection and as individual taxa become less dominant. This metric increases with increasing biotic quality (Plafkin et al., 1989). Manual Method: Take the number of individuals of each species and divide by the total number of individuals in the collection. Save that and then take the natural log of that number. Multiply the two numbers together. Do the same for each species, and then sum all of those products. Finally, multiply that final number by -1. Here's the formula: $H' = -\sum(Ni/N) \times \ln(Ni/N)$, where Ni is the number of individuals in a particular species, and N is the total number of individuals in the collection.

Descriptive statistics of each season-specific sample type (e.g., summer riffle, winter vegetation, summer woody) for each site are determined and compared to the average respective metric of high-quality streams in the ecoregion. A bioassessment score is calculated. For each site, scores of 6, 4, 2, or 0 are assigned for each metric (according to the criteria in Table 5, below) and then summed to get a total bioassessment score for each site, with a maximum of 36 points.

For **taxa richness** and **EPT taxa richness**, the percentages used to assign scores were obtained by dividing each monitoring site metric by the average high quality site metric in a particular ecoregion.

For the **HBI** metric, the high quality site value was divided by the monitoring site value (high quality site metric / monitoring site metric).

For the **remaining metrics**, the score was based on the actual values obtained instead of being relative to the high quality site metric. Each monitoring site's total score was then compared to the average high quality sites' total score (in that ecoregion) and classified according to the condition gradient outlined in Table 6 (adapted from Plafkin et al., 1989).

Table 5. Bioassessment scoring criteria for macroinvertebrates. *Modified HBI Using North Carolina Tolerance Values, **RBP for Use in Streams and Rivers 1989, ***Modified by OCC

Metrics	*6*	*4*	*2*	*0*
Taxa Richness**	>80%	60-80%	40-60%	<40%
Modified HBI* (**)	>85%	70-85%	50-70%	<50%
EPT/Total***	>30%	20-30%	10-20%	<10%
EPT Taxa**	>90%	80-90%	70-80%	<70%
% Dominant 2 Taxa**	<60%	60-70%	70-80%	>80%
Shannon-Weaver***	>3.5	2.5-3.5	1.5-2.5	<1.5

Table 6. Bioassessment score interpretation for macroinvertebrates.

% Comparison to the Reference Score	Biological Condition	Characteristics
>83%	Non-impaired	Comparable to the best situation expected in that ecoregion; balanced trophic and community structure for stream size
54 - 79%	Slightly Impaired	Community structure and species richness less than expected; percent contribution of tolerant forms increased and loss of some intolerant species
21 - 50%	Moderately Impaired	Fewer species due to loss of most intolerant forms; reduction in EPT index
<17%	Severely Impaired	Few species present; may have high densities of 1 or 2 taxa

Volunteer James Huffman has been working with the Tulsa County Blue Thumb Program since 2002. He monitors Little Joe Creek but also helps in other areas of the state. James is presently a cytotechnologist, but is working to earn a master's degree from Oklahoma State University in environmental management.

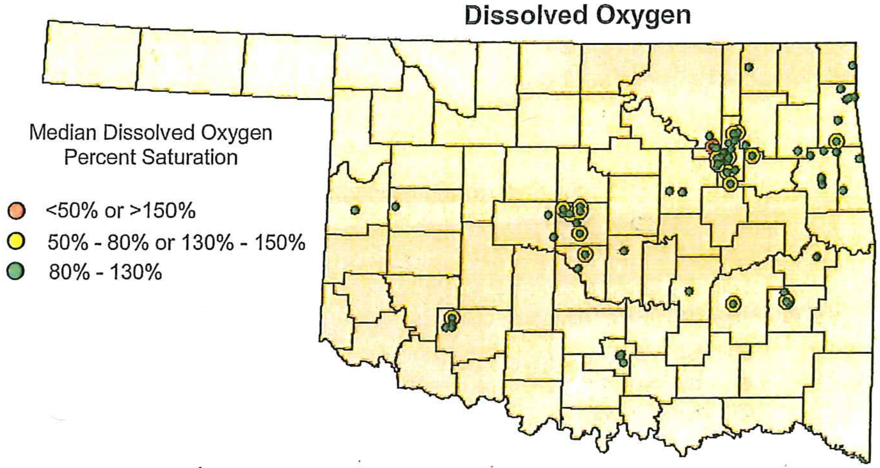
James prepared these Blue Thumb data maps in his "GIS Applications of Natural Resource Management" class using ARCview GIS 8.x. James and his wife Elyssa have two young daughters, Denali and Winter.

James said "Volunteering for Blue Thumb has been a blessing. The 'hands on' experience from water monitoring, fish and macroinvertebrate collections, and habitat assessments has provided not only the opportunity to apply what I have learned in graduate school, but also the chance to gain new knowledge along the way."

Blue Thumb Data

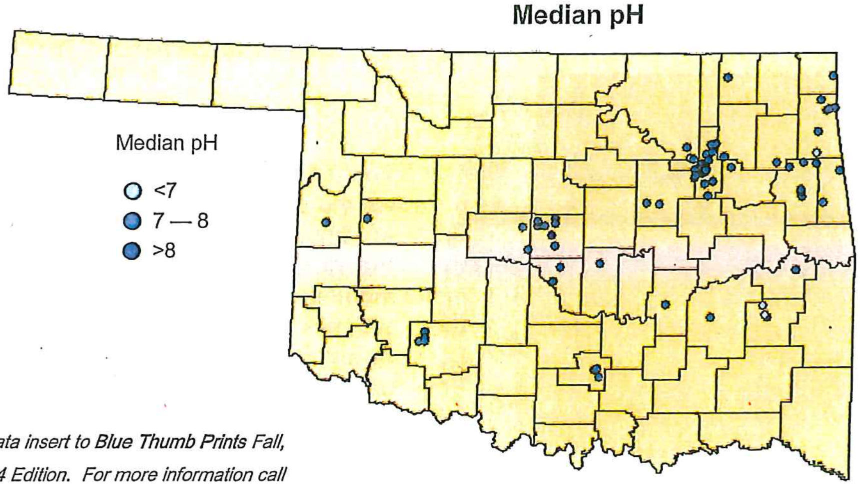
Blue Thumb volunteers have been collecting data from Oklahoma streams since 1993. What have we found? How do results compare around the state? The following maps are an attempt to put all of the Blue Thumb chemical data through December 2003 into a simple visual format. The caption will tell a little bit about each particular map. The legend is set up like a stop light. If your area has a green symbol you should focus on protection of your water resources. If the symbol is yellow or red there are areas of concern and you should focus on cleanup. The chemical results only indicate some threat and it will be necessary to check the fish community to see if there is any impairment in the water quality of the stream.

Dissolved Oxygen



Dissolved Oxygen saturation changes with the temperature of the water. By looking at the percent saturation, we can see when there are problems with the amount of oxygen available in the water for aquatic life. Too little oxygen can cause aquatic animals to die. Too much oxygen is an indicator that there are wide swings in the amount of oxygen available during a 24 hour period.

Median pH

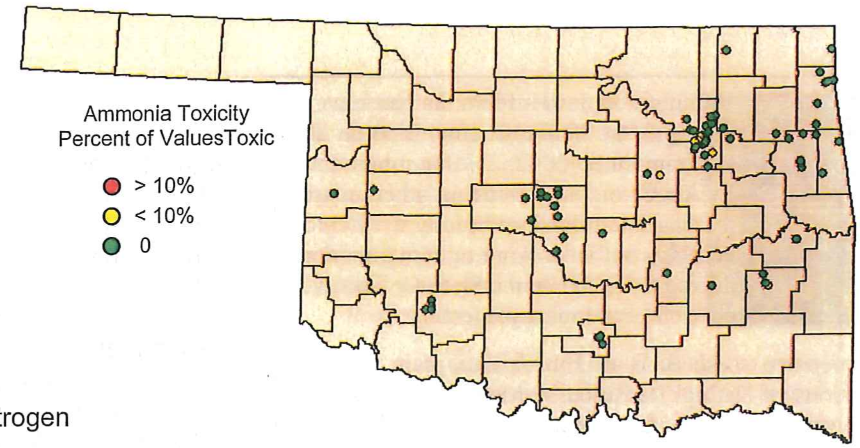


pH in the State of Oklahoma is normal between 6.5 and 9. All of the Blue Thumb sites fall in that range.

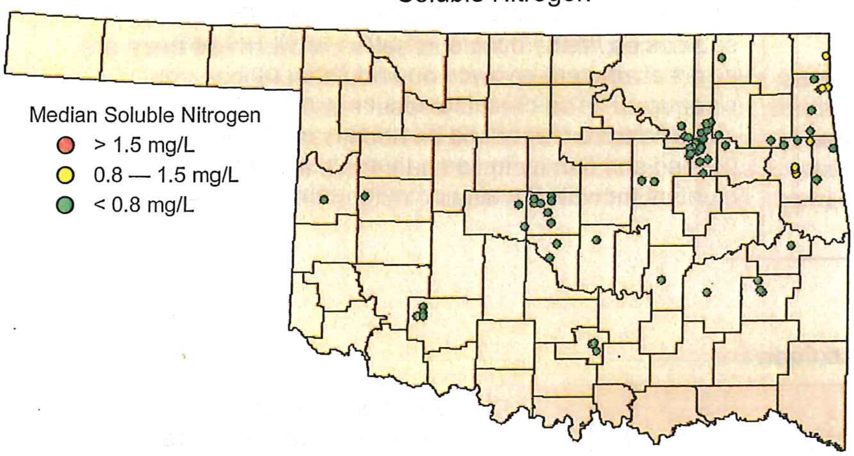
Data insert to Blue Thumb Prints Fall, 2004 Edition. For more information call 918-280-1598.

Ammonia Toxicity

Ammonia toxicity is dependent upon the amount of ammonia, the water temperature and the pH of the water. This chart shows the percentage of time each of the sites had ammonia at toxic levels. As you can see, most of the sites have never had toxic levels of ammonia.



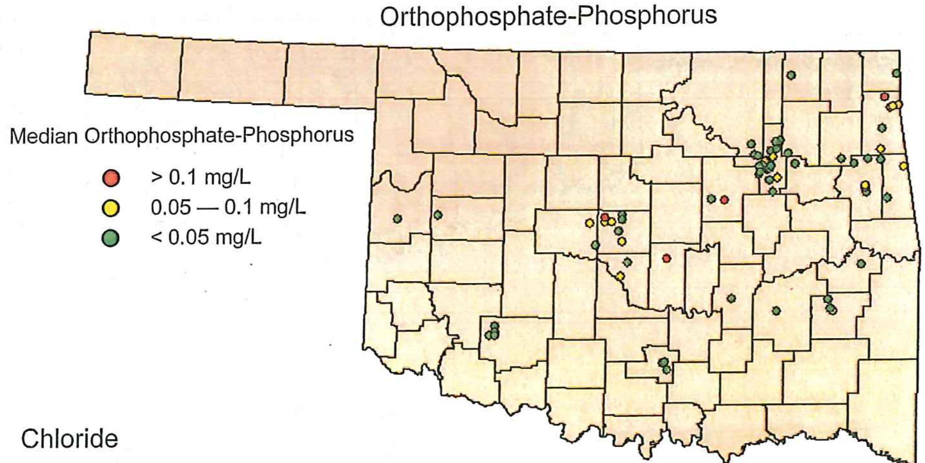
Soluble Nitrogen



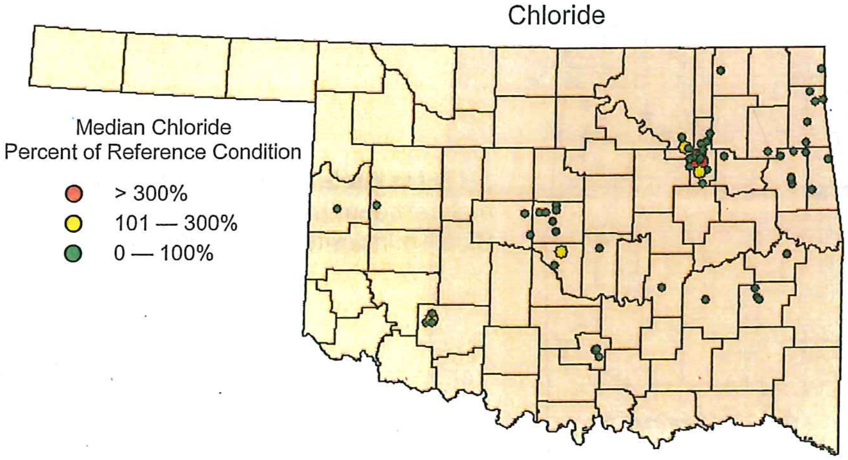
An estimate of soluble nitrogen is made by adding the amounts of ammonia-nitrogen and nitrate-nitrogen found in the water.

Orthophosphate-Phosphorus

The amount of phosphorus allowed in Oklahoma's Scenic Rivers is 0.037 mg/L. You can see from the cluster of yellow and red dots in the Illinois River basin in the NE corner of the state that we are not achieving that level at this time. Other parts of the state, principally urban areas, also have high phosphorus.



Chloride



The amount of chloride naturally in the waters of the state increases in a gradient from east to west. To account for that gradient, and to make a more meaningful map, each site was compared to the other sites in the vicinity to determine how it compares to a reference condition. This chart shows that most of our sites fall within the reference condition for their area of the state.