ANNUAL STATE-OF-THE-RIVER REPORT (2006-2007)

FOR

THE CHEHALIS BASIN

Prepared By:

Randy Lehr, Ph.D.

Grays Harbor College
1620 Edward P. Smith Drive
Aberdeen, WA 98520
360-538-4177

Contributors:

Chehalis Basin Partnership, Confederated Tribes of the Chehalis Reservation and Washington State Department of Ecology

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Executive Summary

To better manage the Chehalis Basin, it is important to understand water quality in the Chehalis River and it tributaries. Previous studies throughout the Chehalis Basin have suggested that ambient water quality conditions range widely, and the primary water quality parameters of concern are temperature, dissolved oxygen, fecal coliform, pH and sediment runoff. To better understand water quality in the Chehalis Basin, we conducted a study to collect and analyze water samples from 83 sites on a monthly basis for dissolved oxygen, pH, temperature, turbidity, fecal coliform, and conductivity. During this study, between 14% and 21% of samples (across all parameters) violated Washington State water quality standards. Results from this study suggest that pH (followed by dissolved oxygen and temperature) account for the majority of water quality violations; however this was highly variable depending on location and season. In general, November had the most water quality violations (across all parameters) and March had the fewest. The frequency and magnitude of water quality violations was greater in the upper Basin (WRIA 23); however, within any given system (including the mainstem of the Chehalis), water quality was generally higher in headwater reaches and decreased downstream. These results support the findings of previous studies, further suggesting that, although there are general trends in water quality throughout the Chehalis Basin, specific needs for restoration and preservation of water quality are likely to be site-specific.

Introduction

Understanding water quality in the Chehalis Basin is an important component of the watershed management process. The Chehalis River Basin is a 2,660 square mile watershed (3,300 river-miles) located in Western Washington State (Figure 1). The Chehalis River, the second largest in the state (the Columbia River is the largest), originates from surface runoff in the Willapa Hills region near the city of Pe Ell and flows downstream to the Grays Harbor Estuary and its confluence with the Pacific Ocean (Figure 1). Within the Chehalis Basin, there are eight counties (Thurston, Lewis, Pacific, Cowlitz, Mason, Jefferson, Grays Harbor and Wahkiakum) and one tribal reservation (The Confederated Tribes of the Chehalis Reservation).

Given its size, the Chehalis Basin is divided into the Upper and Lower Basin. Although, the Upper and Lower Basins are separated to clarify management objectives, the watershed processes in each Basin are intimately linked. Throughout both the Upper and Lower Chehalis Basin, forestlands dominate the landscape, representing 85% of the total land coverage. Forestlands are primarily owned by private timber corporations, but a significant portion of the land is private or government owned. Although forestlands are the dominant land-use type, they are generally contained within the 1^{st}, 2^{nd}, and 3^{rd} order drainages and absent from the floodplain of the mainstem of the river. The remainder of the land within the basin is comprised of agricultural (~9%), range (~2%) and urban (~2%).

Values and uses of water resources in the Chehalis Basin are widely varied. Surface and groundwater (not glacial melt) are the primary water sources for drinking, irrigation and municipal/industrial effluent treatment and dilution in the Basin. In addition to these consumptive uses, waters in the Chehalis River Basin and Grays Harbor estuary support a variety of valuable shellfish and finfish resources. The Chehalis River supports 31 stocks of salmonid species (eight of which are currently Depressed) and 900 acres (of 9000 total acres) of the Grays Harbor estuary are farmed for shellfish. Waters of the Chehalis River Basin ecosystem also support eight species (both terrestrial and aquatic) listed as Threatened or Endangered under the Federal Endangered Species Act.

Water resources of the Chehalis Basin are collectively managed by the Chehalis Basin Partnership (CBP). "The CBP is a voluntary, consensus-based organization of cities, tribes, counties, and other local organizations working to protect water resources in the Chehalis watershed. The CBP was created by an intergovernmental agreement (dated August 31, 1998) to develop a watershed management plan for the Chehalis River Basin. The agreement designates the CBP (through Grays Harbor County) as lead in pursuing strategies addressing flood reduction, fish habitat, recreation, water quality and water quantity in the Chehalis River Basin and to examine their relationships to economic health and sustainability" (CBP, 2004). Although not a formal member of the CBP, the Quinault Indian Nation is also actively involved in the management of the water resources in the Chehalis Basin. To more effectively manage water resources in the Basin, the CBP and Grays Harbor County have formed three work groups, the Water Quality Committee, the Steering and Technical Advisory Committee and the Habitat Work Group. Members (representing diverse stakeholder groups) collaborate to solve technical issues related to water quality and provide recommendations and technical support to the CBP related to water resources management. Collective work of the CBP and individual efforts of various stakeholder groups have resulted in a number of technical studies and management plans that guide the management of water resources in the Basin (Table 1).

The aforementioned studies suggest that ambient water quality conditions in the Chehalis Basin range from relatively undisturbed to severely impacted. These studies suggest that the primary water quality parameters of concern in the Chehalis Basin are temperature, dissolved oxygen, fecal coliform, pH and sediment runoff. The TMDL studies listed above have identified 114 impaired stream segments throughout the Basin. These studies also suggest that the primary sources of water quality impairment are non-point sources, specifically runoff from urban, agricultural and commercial forestlands.

To further understand the ambient water quality throughout the Chehalis Basin and determine seasonal and temporal trends, we implemented a monitoring program that collected and analyzed samples on a monthly basis from 83 sites. The details of this study are described within.

Methods

Methods for site selection, sample collection and analysis are described in detail in the Quality Assurance Project Plan (QAPP) for The Comprehensive Chehalis Basin Monitoring Program (CBMP). The CBMP QAPP was approved by the Washington Department of Ecology (DOE) in March of 2007. All chemical measurements were performed by an accredited laboratory in the natural resource department of The Confederated Tribes of the Chehalis Reservation (CTCR).

Briefly, water samples were collected and analyzed on a monthly basis (i.e., one sample collected ~ every 4 weeks) from 83 sites throughout the Chehalis Basin (Figure 2). Samples sites were chosen based on: **(1)** their alignment with identified goals and objectives for the Chehalis Basin; **(2)** the availability of ongoing data sets and concurrent monitoring programs; **(3)** accessibility of the sampling site; **(4)** a need for representative coverage throughout the Basin; and **(5)** location upstream and downstream of major river confluences and suspected pollutant sources. Samples were collected from November 2006 to June 2007 (for comparison, data from an additional study conducted by the CTCR was included for the month of October). Samples were analyzed for dissolved oxygen, conductivity, pH, temperature, turbidity and fecal coliform. Dissolved oxygen, conductivity, pH, and temperature were all measured in the field using field deployable, *in situ* water quality probes. Turbidity and fecal coliform were measured in the laboratory, using standard techniques. Data quality was assessed using a series of positive/negative controls, replicate samples and trend analysis; this process is also described in detail in the QAPP.

Data Analysis

All data was analyzed to determine compliance with Washington State water quality standards. Water quality throughout the Chehalis Basin was initially assessed by comparing monthly and site-specific averages to State standards. Water quality was also assessed using a relative ranking index (described below). All graphs/maps are color coded to highlight compliance with State water quality standards described in Table 2 (except conductivity which lacks a State standard). All spreadsheet and data analysis was performed using Microsoft Excel (Microsoft, Redmond, WA) and SAS Institute JMP statistical software (SAS Institute, Cary, NC). Data is presented using Sigmaplot 10.0 (Systat Inc. San Jose, CA) and ArcGIS (ESRI, Redlands, CA).

Water Quality Standards
Washington State water quality standards (generated by the Washington DOE) are described in detail in the Water Quality Standards for Surface Waters of the State of Washington Chapter 173-201A WAC (Publication number – 06-10-09; 2006). The specific standards used to determine water quality in this study are described in more detail in Table 2. To assess water quality in the Chehalis River, data was compared to two standards representing uses of water that require high (e.g., salmon summer habitat) and/or extraordinary water quality (e.g., oyster culture). Compliance with State standards for temperature, dissolved oxygen, pH and fecal coliform were based directly on the aforementioned DOE standards. State standards for conductivity have not been generated and thus compliance was not calculated. To estimate compliance with turbidity several assumptions were made (described below).

Washington State standards for turbidity are based on an increase in NTU (of 5 or 10, depending on watershed characteristics and beneficial uses) over background levels. Generally, background levels are established by collecting and analyzing samples upstream and downstream of a potential point source. For this study, a watershed-wide background level was operationally defined as the average 25^{th} percentile for turbidity across all sites. To calculate the watershed-wide background turbidity level, the 25^{th} percentile (i.e., the value below which 25% of the data fall) was calculated for each site. The 25^{th} percentile values for all sites were then averaged to define the background level (1.99 NTU). Compliance with the State turbidity standards was then based on an increase of a 5 and/or 10 NTU over the background level of 1.99 NTU. This technique of estimating compliance with State turbidity standards does not account for natural site and/or season-specific variability. However, to establish a more realistic site and/or season-specific background level, a larger and more inclusive data set would be necessary.

Relative Ranks
Relative ranks were determined by identifying the percentage of samples collected at a given site (across all parameters) that violated Washington State Standards (described in Table 1). Relative ranks are presented graphically and geographically. Graphic representation depicts sites according to their respective relative rank. Geographic data presentation was conducted by Dr. Narendran Kodandapani and Don Loft (Evergreen State College Student) as part of the Chehalis Basin GIS Clearinghouse project at Grays Harbor College. Briefly, each site (based on site number) was assigned a data point feature that corresponded with it latitude-longitude coordinates. Points were plotted on a Chehalis Basin hydrology GIS layer (WDOE 100K). Individual data points were then color-coded based on relative rank values using a color ramping program. Points were coded such that sites that violated State standards most frequently were marked as bright red and those that violated standards least frequently were marked as blue/purple; intermediates sites were shaded in transition. Rank data were also analyzed to determine the frequency of non-compliance for individual parameters with State water quality standards.

Results and Discussion
A total of 4152 samples were collected from 83 sites throughout the Chehalis Basin from October 2006 through June of 2007. Over this sampling period, between 21% and 14% (depending on the water quality standard) of samples violated Washington State water quality

standards. Water quality throughout the Chehalis Basin varied widely depending on site, parameter and time of year. Site-specific, temporal and geographic trends are described below as they correspond to specific parameters. Results from the QA/QC yearly audit are also described below.

Quality Assurance/Quality Control

The level of data quality varied widely depending on the parameter being analyzed. QA/QC is described below as it correlates to: calibration; replicate and control samples analysis; data transfer errors; and trend analysis.

Calibration

All calibrations for laboratory and field analyses were performed as described in the QAPP. In the event of instrument malfunction (e.g., inability to effectively calibrate), samples were not collected. Two-hundred and thirty-one samples were not collected because of instrument malfunction. Frequency of field instrument calibration varied depending on the parameter measured and ranged from once each week to once every two weeks.

Replicate and Control Sample Analysis

Not all replicate and blank samples described in the QAPP were consistently collected and analyzed, thus making the assessment of the QA/QC goals for precision, bias and sensitivity described in the QAPP difficult. For fecal coliform, results from replicate and control sample analysis were consistent with quality goals described in the QAPP, suggesting limited potential for laboratory contamination. However, field blanks were not consistently collected and analyzed and thus, potential for field contamination cannot be effectively calculated. Similarly, replicates and/or positive and negative controls were not consistently analyzed using *in situ* monitoring instruments and thus, precision, bias and sensitivity cannot be effectively calculated. Field measurements were not independently verified using a second analytical method. Outlier data points (i.e., data outside of the 20% long-term average) were not independently re-analyzed.

Transfer Errors

During the final data audit, ~10% of sample entries were rechecked to eliminated transfer errors during data processing/transfer; no transfer errors were detected.

Trend Analysis

Temporal trend analysis also highlighted a QA/QC problem with the pH data. When compared using linear regression, pH data collected after March 16th exhibited a distinct correlation with sample collection date and DO. The strength and pattern of this correlation suggests that it resulted from instrument malfunction. pH data collected after March 16th 2007 were excluded from all analysis and presentation.

To address the QA/QC problems that arose throughout sampling and analysis, we are switching to a monthly data reporting process that will implement a new data reporting form. These modifications will facilitate a more timely identification of potential data problems and minimize the number of samples that are excluded from analysis for QA/QC purposes.

Dissolved Oxygen

The average dissolved oxygen concentration observed throughout all months of sampling was 10.12 mg/L. Dissolved oxygen concentrations ranged from below detection limit (1 mg/L) to 18.16 mg/L. Maximum DO concentrations were present during January and minimum concentrations were present during November (Figure 3). Sites where dissolved oxygen concentrations were most commonly in compliance with Washington State Standards (i.e., "healthy" sites) were the E. Fork of the Wishkah and Wynoochee (at reservoir) Rivers. Sites that were most frequently in violation of water quality standards were the Black River (at 110th Ave) and Winter Creek (Figure 4). **Although the Skookumchuck River (at the mouth) appears to have the lowest DO level, this site is highly influenced by a single outlier.*

Compliance with Washington State standards for dissolved oxygen varied considerably depending on the specific standard used to evaluate water quality. When using 9.5 mg/L as the standard, ~27% of the samples did not meet State standards (Figure 4). When using 8 mg/L as the standard, ~15% of the samples did not meet State standards. For the data reported in this study, the standard of 9.5 mg/L is most appropriate to evaluate data for summer months (June 15 – September 15); this standard is intended to protect salmon during core summer months. The 8 mg/L standard is most appropriate for dates outside of summer months (September 16 – June 14); this standard is intended to protect salmon spawning, rearing and migration.

Fecal Coliform

The average fecal coliform concentration observed throughout all months of sampling was 24 colonies/100mL. Fecal coliform concentrations ranged from the below detection limit (4 colonies) to >2000 (maximum of numerable colonies) colonies/100mL. Maximum fecal coliform concentrations were present during November and minimum concentrations were present during June (Figure 5). Sites where fecal coliform concentrations were most commonly in compliance with Washington State standards (i.e., "healthy" sites) were the Chehalis (at Prather), Wynoochee (at reservoir) and John's Rivers. Sites that were most frequently in violation of water quality standards were Garrard (at Brooklyn Rd.) and Stearns (at Pleasant Valley) Creeks and the Newaukum River (Figure 6).

Compliance with Washington State standards for fecal coliform varied slightly depending on the specific standard used to evaluate water quality. When using 50 colonies/100 mL as the standard, ~7% of the samples did not meet State standards (Figure 6). When using 100 colonies/100 mL as the standard, ~4% of the samples did not meet State standards (Figure 6). For data reported in this study, the 100 mg/L standard is the most appropriate to directly evaluate water quality for the majority of the Chehalis Basin; this standard is intended to project primary human contact. The 50 colonies/100mL is most appropriate to evaluate the health of the estuary and its direct tributaries; the goal of this standard is to protect waters that require extraordinary quality (e.g., water supporting shellfish culture). However, given the potential for downstream transport of pollutants, it is important to consider the cumulative downstream effects of fecal coliform pollution that may occur in upstream reaches.

Turbidity

The average turbidity observed throughout all months of sampling was 4.14 NTU. Turbidity ranged from 0.3 to 413 NTU. Turbidity was highest in November and lowest during June

(Figure 7). Sites where turbidity was most commonly in compliance with Washington State standards (i.e., "healthy" sites) were China and Cloquallum Creeks. Sites that were most frequently in violation of water quality standards were the Black (at 110th Ave.) and the M. Fork of the Satsop Rivers (Figure 8).

Compliance with Washington State standards for turbidity varied slightly depending on the specific standard used to evaluate water quality. When using a 5 NTU increase as the standard, ~18% of the samples did not meet State standards (Figure 8). When using a 10 NTU increase as the standard, ~8% of the samples did not meet State standards (Figure 8). For the data reported in this study, the standard of a 5 NTU increase is likely most appropriate in reaches that support salmon spawning and oyster rearing; this standard is intended to protect spawning substrate. The 10 NTU standard is likely most appropriate for all other stream reaches throughout the Chehalis; this standard is intended to protect salmon migration and rearing habitat.

Temperature

The average temperature observed throughout all months of sampling was 8.04 ^{o}C. Temperature ranged from 0.85 to 16.28 ^{o}C. Temperatures were highest in June 2007 and lowest during January 2007 (Figure 9). Sites where temperature was most commonly in compliance with Washington State standards (i.e., "healthy" sites) were the Black (at 110th Ave.) and the S. Fork of the Newaukum Rivers. Sites that were most frequently in violation of water quality standards were the Skookumchuck (at mouth) and Elk Rivers (Figure 10). **Note that Hannaford Creek appears to have the lowest average temperatures, but this site is highly influenced by two outlier values.*

Compliance with Washington State standards for temperature varied considerably depending on the specific standard used to evaluate water quality. When using 9 ^{o}C, ~30% of the samples did not meet State standards (Figure 10). When using 13 ^{o}C, ~6% of the samples did not meet State standards. For the data reported in this study, the 13 ^{o}C standard is most appropriate to evaluate the health of the majority of the waters in the Chehalis Basin (particularly the upper Basin) during winter months; this standard is intended to protect salmon spawning, rearing and migration (Figure 10). The 9 ^{o}C standard is more appropriate to evaluate the health of direct tributaries to the Grays Harbor estuary; this standard is intended to protect char spawning (e.g., bull trout). However, since use of the Grays Harbor estuary by bull trout is thought to be for purposes of foraging and migration, a standard of 12 ^{o}C may be more appropriate. There are also several additional less restrictive standards described by the WDOE (2006) to protect different salmonid life-stage (e.g., 16 ^{o}C to protect salmonid core summer habitat).

pH

The average pH observed throughout all months of sampling was 6.59. pH throughout the Chehalis Basin ranged from 4.16 to 12.05. pH was highest in November 2006 and lowest during January 2007 (Figure 11). Sites where pH was most commonly in compliance with Washington State standards (i.e., "healthy" sites) were Beaver Creek and the M. Fork of the Satsop River. Sites that were most frequently in violation of water quality standards were the Chehalis River at Hwy 107 and Borst Park (Figure 12).

Because the State water quality standard for pH does not change across water bodies, there is only one set of standards for comparison. Using the 6.5 to 8.5 standard, ~72% of the samples did not meet this benchmark (Figure 12). The majority of these violations occurred when pH dropped below the 6.5 value (i.e., became more acidic). However, two events in November and February caused a non-compliance that exceeded the 8.5 upper limit. The only variation for compliance to the 6.5 to 8.5 standard is the acceptable size of a human-induced change (0.2 for water supporting Char and 0.5 for water supporting salmon). However, a more inclusive data set would be necessary to effectively assess these relative, human-induced changes.

Specific Conductivity

The average specific conductivity observed throughout all months of sampling was 88.5 υS/cm. Specific conductivity throughout the Chehalis Basin ranged from 2.2 to 8.55 υS/cm. Specific conductivity was highest in October 2006 and lowest during January 2007 (Figure 13). Throughout the study, sites that had the highest conductivity were Hannaford Creek and the Skookumchuck River (Figure 14). Sites that exhibited the lowest specific conductivity were the Newaukum, E. Fork of the Wishkah and Hoquiam Rivers. Washington State standards for conductivity do not exist and thus, were not analyzed for compliance. **Note that all tidally influenced sites (Elk River, Johns River, Winter Creek, Hoquiam River and Humptulips River) were excluded from analysis given the variable influence of the salt water.*

Relative Rankings

Descriptions of the relative site rankings are broken up based on the standards used to assess compliance (most restrictive and least restrictive) and the relative contribution of individual parameters to cumulative water quality violations.

Most Restrictive Standards

Throughout the Chehalis Basin, the percentage of time that samples did not comply with Washington State standards (using the standards characterized as most restrictive in Table 2) ranged from 19 % to 56 % (Figure 15). In general, sites were most commonly in violation of State standards during November and least commonly in violation of standards during March (Figure 16). Based on a relative rank, sites that were most commonly in compliance with Washington State standards (i.e., "healthy" sites) were Waddell Creek and the Skookumchuck River. Sites that were most frequently in violation of water quality standards were Salzar Creek (at Salzar Cr. Rd.) and Hannaford Creek (at Schaefer Rd.).

Least Restrictive Standards

Throughout the Chehalis Basin, the percentage of time that samples indicated that a given site was in violation of Washington State standards (using the standards characterized as least restrictive in Table 2) ranged from 12 % to 34 % (Figure 17). In general, sites were most commonly in violation of State standards during November and least commonly in violation of standards during October (Figure 16). Based on a relative rank, sites that were most commonly in compliance with Washington State standards (i.e., "healthy" sites) were the Skookumchuck (at hatchery) and Chehalis River (at SR 6) and Deep Creek. Sites that were most frequently in violation of water quality standards were Winter Creek and the Black River (at 110th Ave.).

Relative Contribution of Individual Parameters
Throughout the Chehalis Basin, the relative importance of the individual parameters as a source of pollution varied widely (Figure 18). pH was the parameter that accounted for the highest percentage of water quality violations and fecal coliform accounted for the lowest. The relative importance of each parameter as a source of water quality violations was relatively consistent regardless of which level of standard was used (except for temperature, which varied by over 16% between standard sets).

Site Location
Throughout the Basin, several broad geographic trends in water quality appear to exist (Figure 2). In general, larger and more frequent deviations from State standards occurred in the upper Chehalis Basin (WRIA 23). However, in any given tributary (and in the mainstem of the Chehalis), water quality was generally higher further upstream. Water quality was generally lower in downstream reaches of primary tributaries and the mainstem of the Chehalis.

Potential for Invertebrate Monitoring
To date, relatively little invertebrate-based water quality/ecosystem monitoring has been conducted in the Chehalis Basin. Two studies were conducted in the Chehalis Basin by Washington Department of Fish and Wildlife (WDFW; 2002) and WDOE (1999). These two studies utilized invertebrate community monitoring to assess ecosystem health/productivity at specific sites. Results from these studies support the conclusions from ongoing water quality monitoring using physical-chemical parameters (described in the Introduction).

Given the breadth of the Chehalis Basin and it biogeographic diversity, routine monitoring at all 83 sites would likely be cost prohibitive (given the time/labor intensity and taxonomic expertise necessary to conduct detailed invertebrate-community monitoring). That being said, invertebrate-community monitoring could provide valuable insight about water quality on a site-specific basis. In particular, invertebrate-community monitoring, would be useful to confirm the presence of healthy and/or degraded waters and to provide additional information regarding TMDL (or general mitigation project) effectiveness. One experimental design that has been effective for determining site-specific changes in biological community structure is the upstream-downstream, before-after, control, treatment (UDBACT) technique.

To utilize the UDBACT technique, invertebrate communities are measured upstream and downstream of a specific treatment site (e.g., a TMDL site) and compared to an appropriate control site (or sites) at some point before and after site manipulation (e.g., buffer planting). However, for this technique to be successful, it is necessary to identify (1) site-specific baseline conditions and (2) appropriate reference sites. Data collected in the aforementioned studies, could provide potential baseline and/or reference data in future studies, however, this data is likely to be very site-specific and may not directly correlate to all sites of interest within the Chehalis Basin. To effectively utilize invertebrate monitoring in the Chehalis Basin, it will be necessary to identify select priority sites (and the appropriate controls) where invertebrate monitoring would have the largest potential impact. Based on the current water quality goals for the Basin (described in detail in the corresponding QAPP), potential priority sites may include current TMDL sites, potential high quality waters and potential future restoration sites.

Summary/Conclusions

In general, results from this study suggest that there is wide range of water quality in the Chehalis Basin (during this specific sampling season), ranging from relatively undisturbed to severely degraded. This conclusion is consistent with previous water quality studies within the Basin. However, unlike previous studies, this study also suggests that the determination of water quality health is highly dependent on the specific standard used (particularly for DO and temperature). Among the parameters measured, pH (followed by DO and temperature) accounted for the majority of the water quality standard violations and as such, restoration efforts that address these issues may be more appropriate across a wider range of sites. However, there is likely a need to develop site-specific restoration and preservation goals for water quality throughout the Basin. Throughout the course of the year, major flooding events appeared to have a significant impact on all parameters; however, this impact was not consistent across parameters. For DO, turbidity and fecal coliform, November and February (the months with the largest flooding events of the sampling season) had the highest occurrences of water quality violations. However, water quality violations for temperature and pH during November and February were relatively few (most pH and temperature violations occurred in months with lower instream flows). These results also suggest that water quality violations are more frequent and larger in the upper Basin than in the lower Basin, and within a given stream system, water quality decreased downstream. Although this sampling season covered a wide range of instream conditions, it did not capture water quality during the months with the historically lowest flows (and potentially lowest water quality). To accurately gauge water quality in the Chehalis, it will be important to continue this work into the drier summer months.

Recommendations

Observations throughout this study have led to a series of recommendations to improved water quality and water quality monitoring in the Chehalis Basin:

1) Develop community-based water quality goals that relate the frequency and magnitude of water quality violations with a desired state of the river.
2) Continue sampling throughout the summer low-flow months.
3) Expand the coverage of the monitoring site locations to obtain a more representative profile of the Basin. New potential monitoring sites could include: upper Humptulips River; upper Satsop River; and Grays Harbor estuary.
4) Potentially utilize the *Enterococcus* endpoint instead of fecal coliform for tidally influenced sites (including potential new sites in the estuary).
5) Identify the presence and magnitude of variations in water quality between monthly sampling events. This variation could be assessed using long-term deployment monitoring probes.
6) Identify quantitative relationships between land use, stream order and water quality.
7) Add instream flows as a criteria used to rank water quality at a given site.
8) Develop a reach-specific ranking protocol that accounts for site/season-specific application of specific water quality standards.
9) Develop reach-specific restoration and preservation priorities that account for the differential contribution of different parameters to water quality.
10) Investigate the relationship between flood events and ambient pH.

Chehalis Basin WRIA 22 and 23

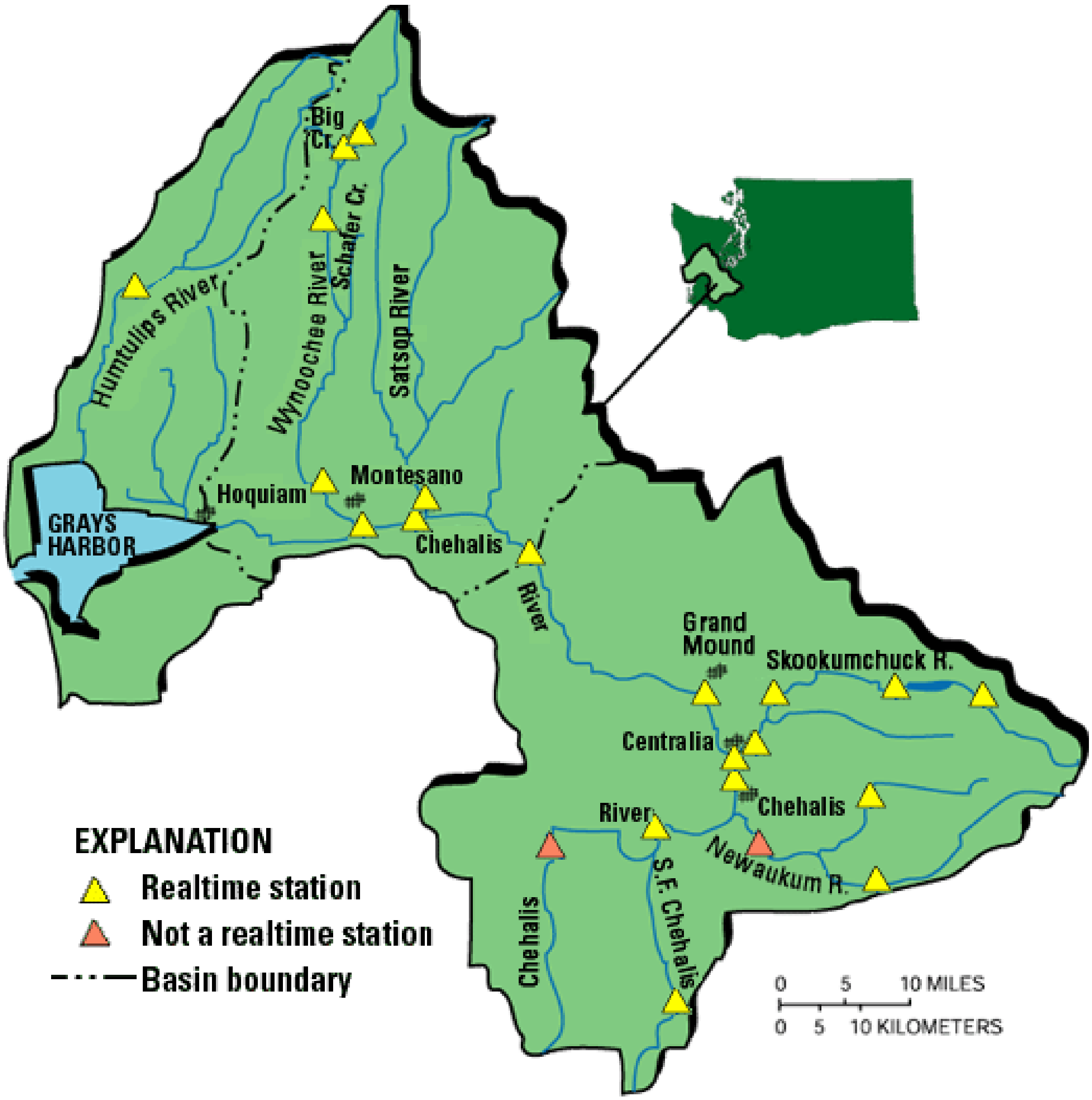

Figure 1. Location of the Chehalis Basin (WRIA 22 and 23) and select long-term flow monitoring sites. (USGS, 2006)

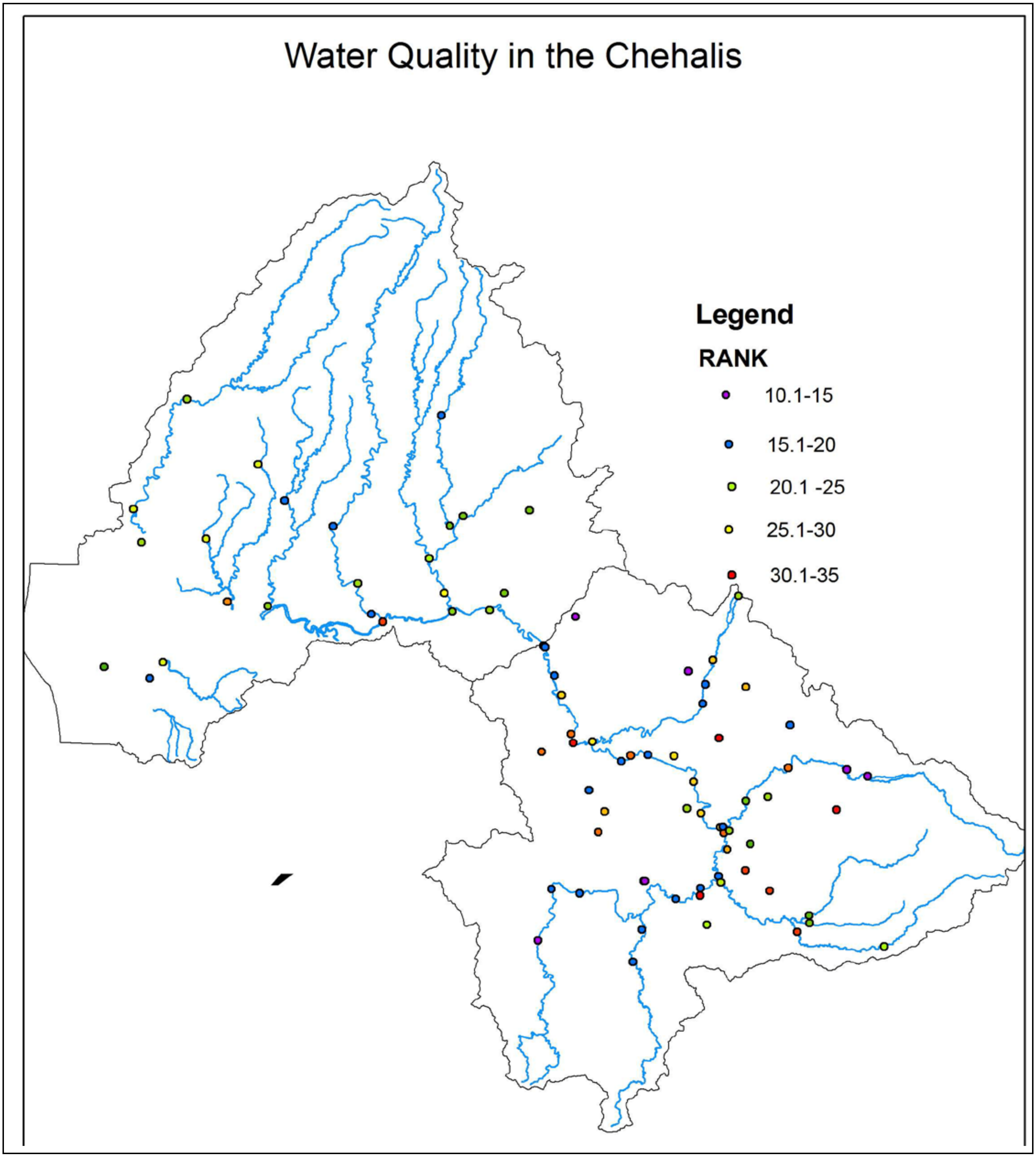

Figure 2. Represents the location of all sample sites throughout the Chehalis Basin. Each site is color coded based on the frequency (as a percentage) of water quality violations (most impacted sites in red, least impacted in blue).

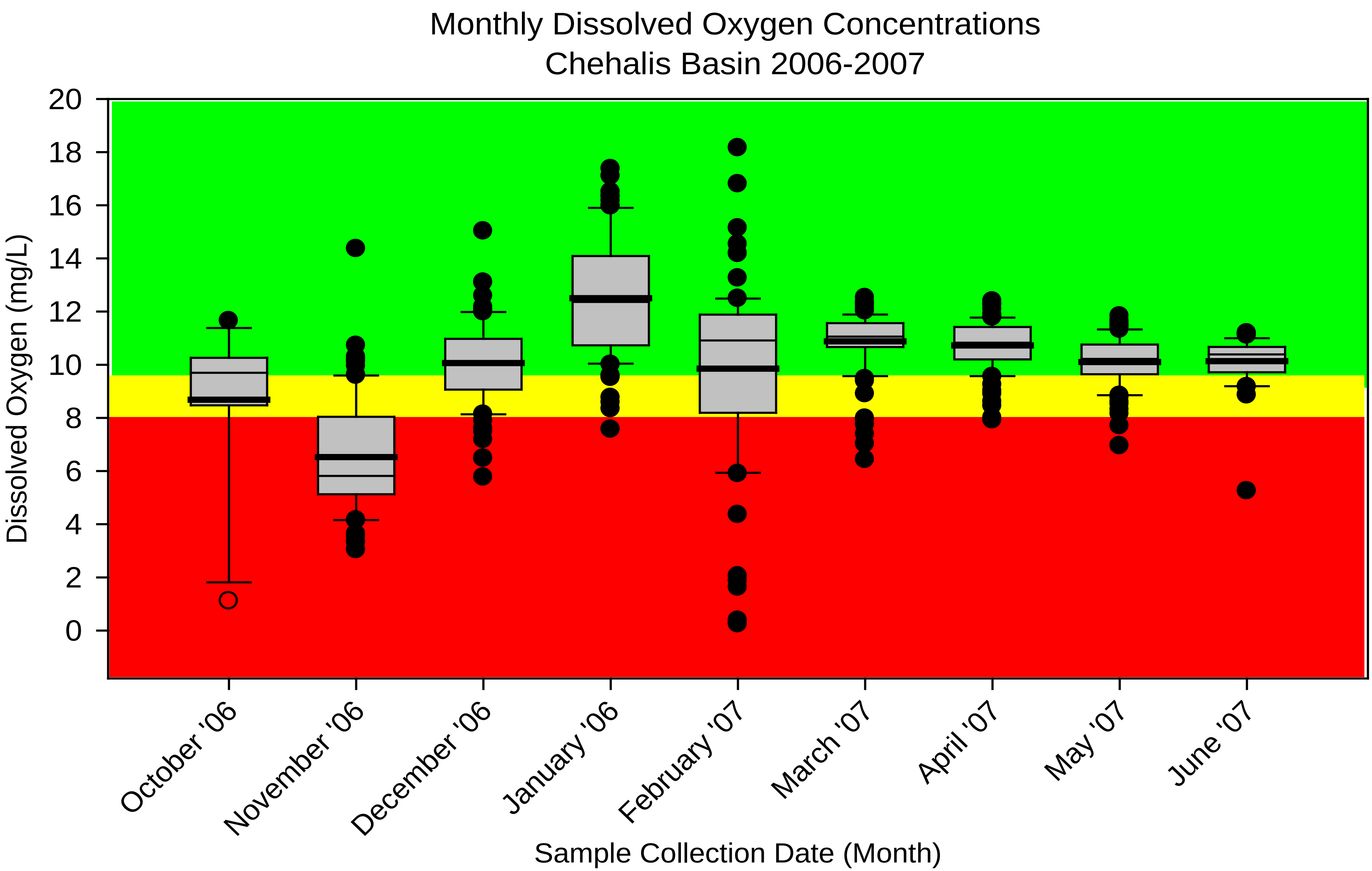

Figure 3 Represents monthly dissolved oxygen concentrations throughout the Chehalis Basin. Grays bars represent 25th and 75 percentiles. "Whiskers" represent 10^{th} and 90^{th} percentiles. Dark horizontal lines (within the vertical gray bars) represent mean concentrations and light lines represent media values.

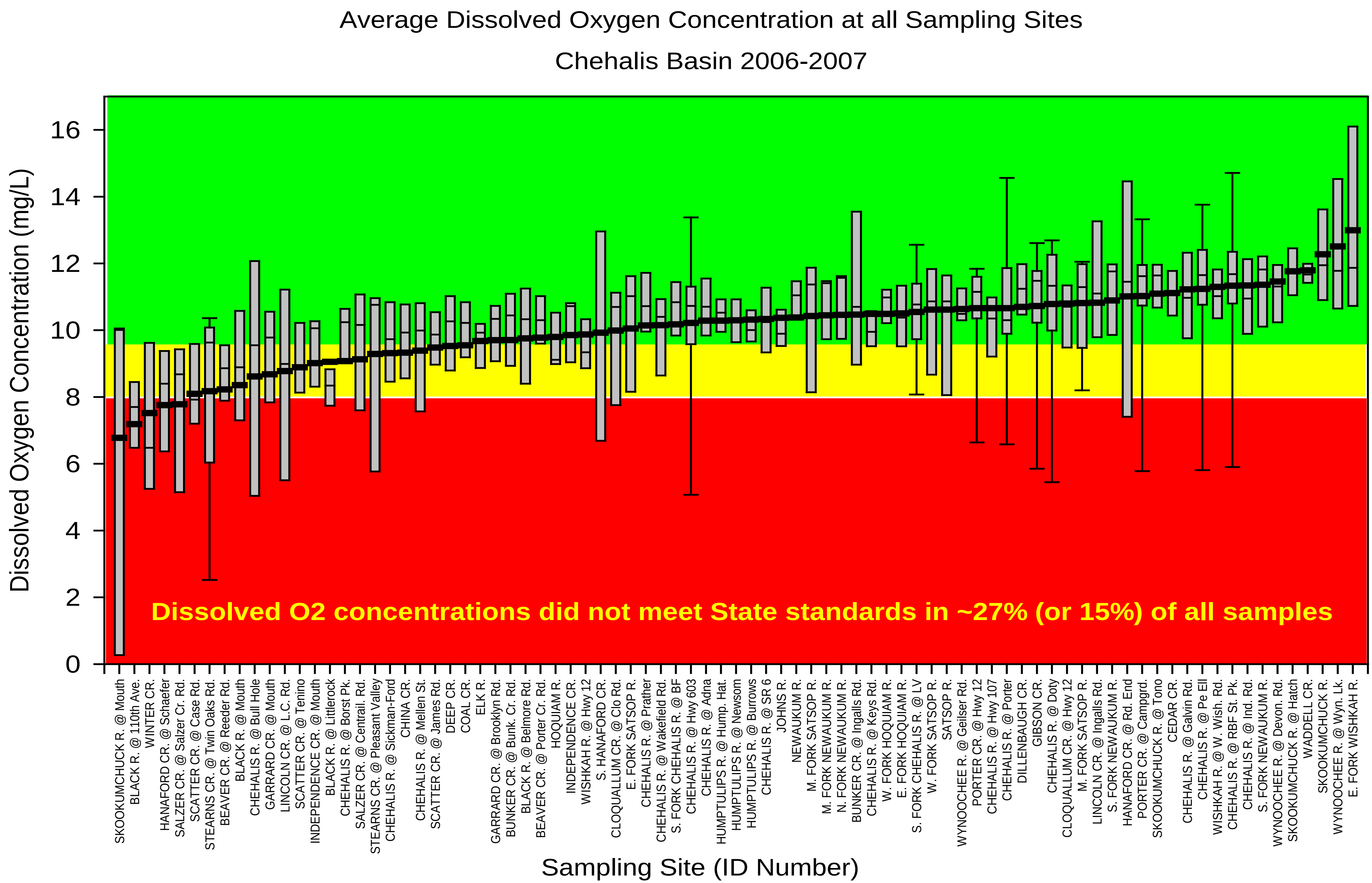

Figure 4 Represents dissolved oxygen concentrations at all sites throughout the Chehalis Basin. Grays bars represent the 25th and 75th percentiles. "Whiskers" represent the 10th and 90th percentiles. Dark horizontal lines (within the vertical gray bars) represent mean concentrations and light lines represent media values. Frequency of water quality violation (as a percentage) is calculated for the most restrictive and (least restrictive) standards.

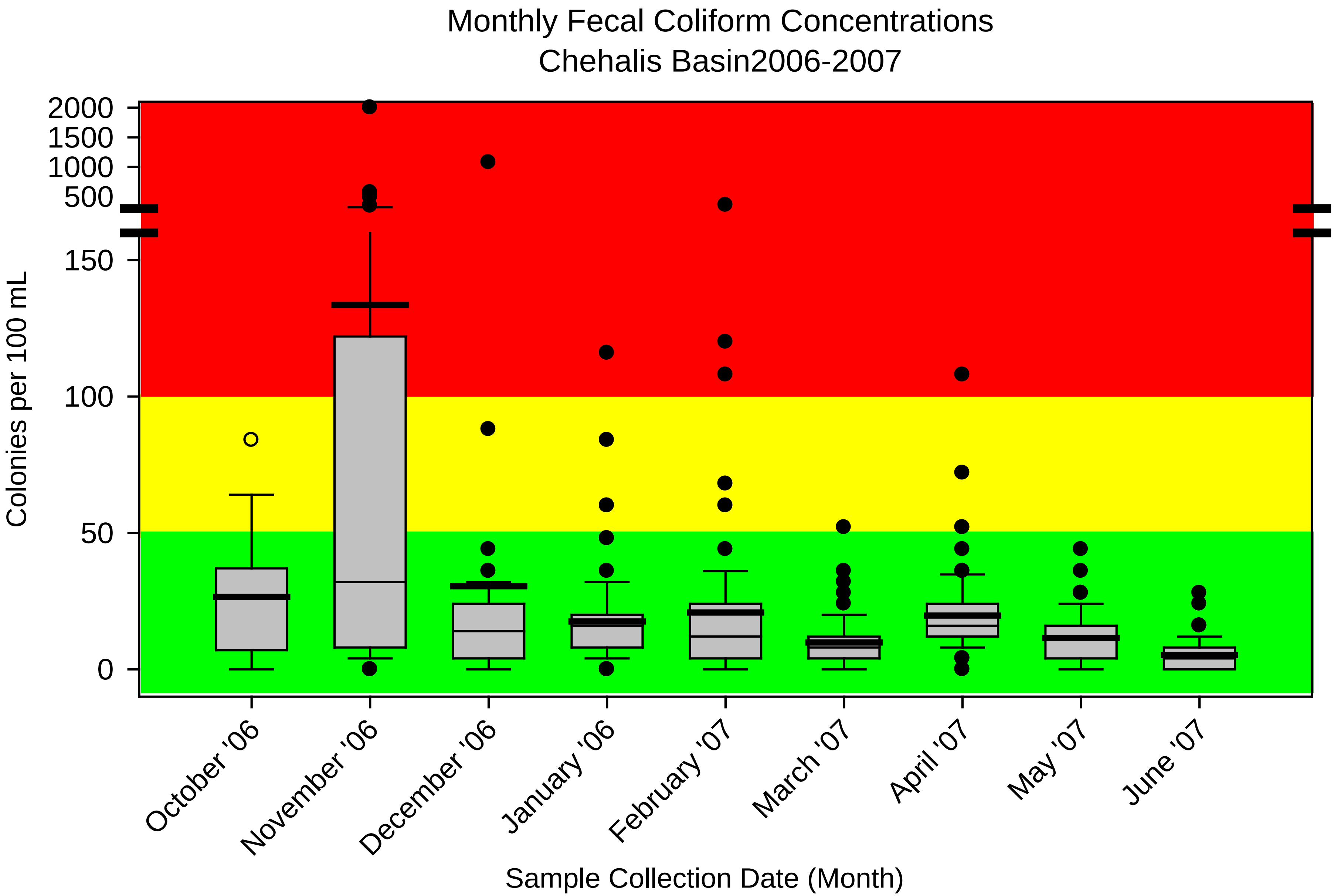

Figure 5 Represents monthly fecal coliform concentrations throughout the Chehalis Basin. Grays bars represent 25th and 75 percentiles. "Whiskers" represent 10th and 90th percentiles. Dark horizontal lines (within the vertical gray bars) represent mean concentrations and light lines represent media values.

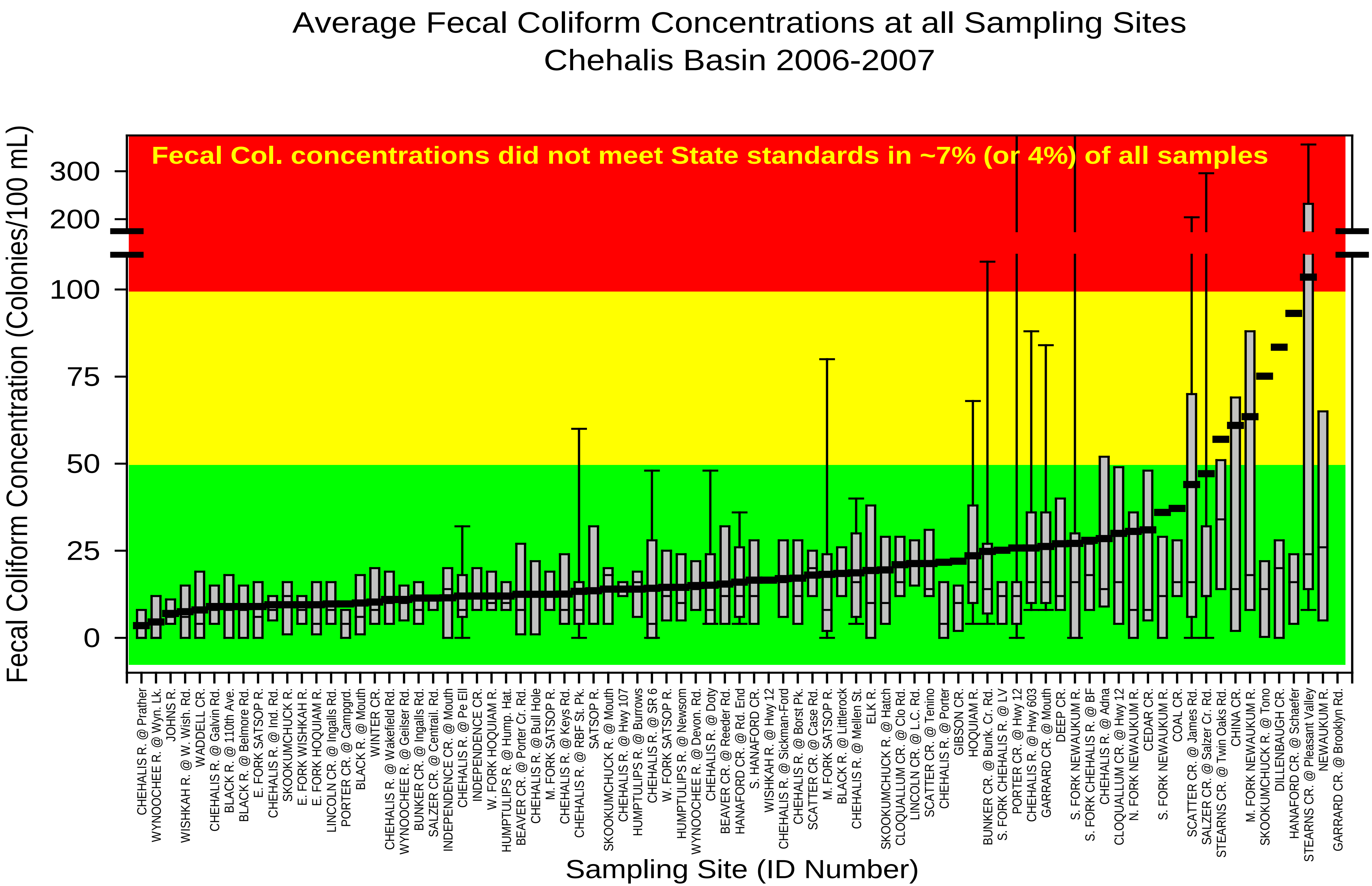

Figure 6 Represents fecal coliform concentrations at all sites throughout the Chehalis Basin. Grays bars represent the 25th and 75th percentiles. "Whiskers" represent the 10th and 90th percentiles. Dark horizontal lines (within the vertical gray bars) represent mean concentrations and light lines represent media values. Frequency of water quality violation (as a percentage) is calculated for the most restrictive and (least restrictive) standards.

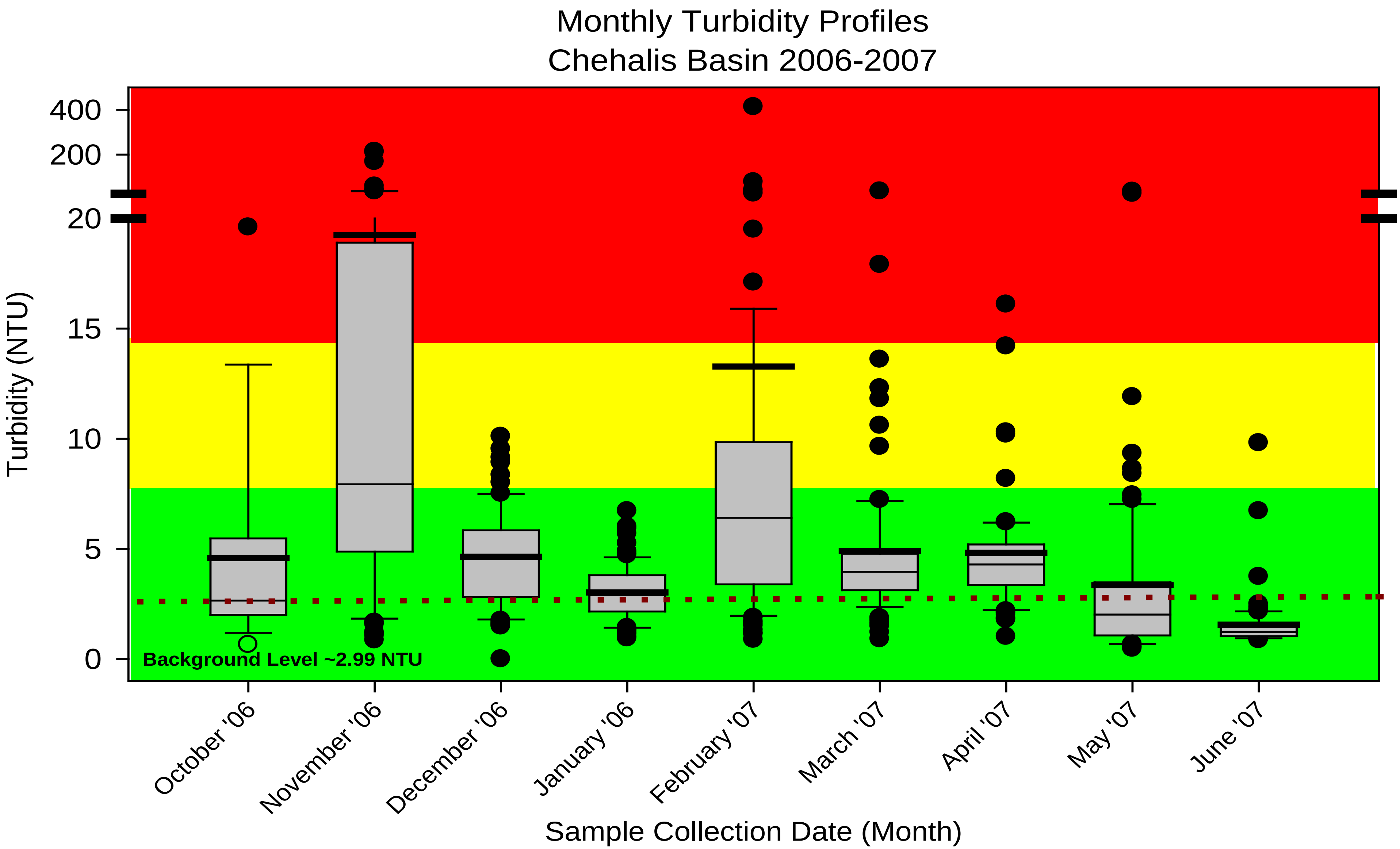

Figure 7 Represents monthly turbidity readings at all sites throughout the Chehalis Basin. Grays bars represent 25th and 75 percentiles. "Whiskers" represent 10th and 90th percentiles. Dark horizontal lines (within the vertical gray bars) represent mean concentrations and light lines represent media values.

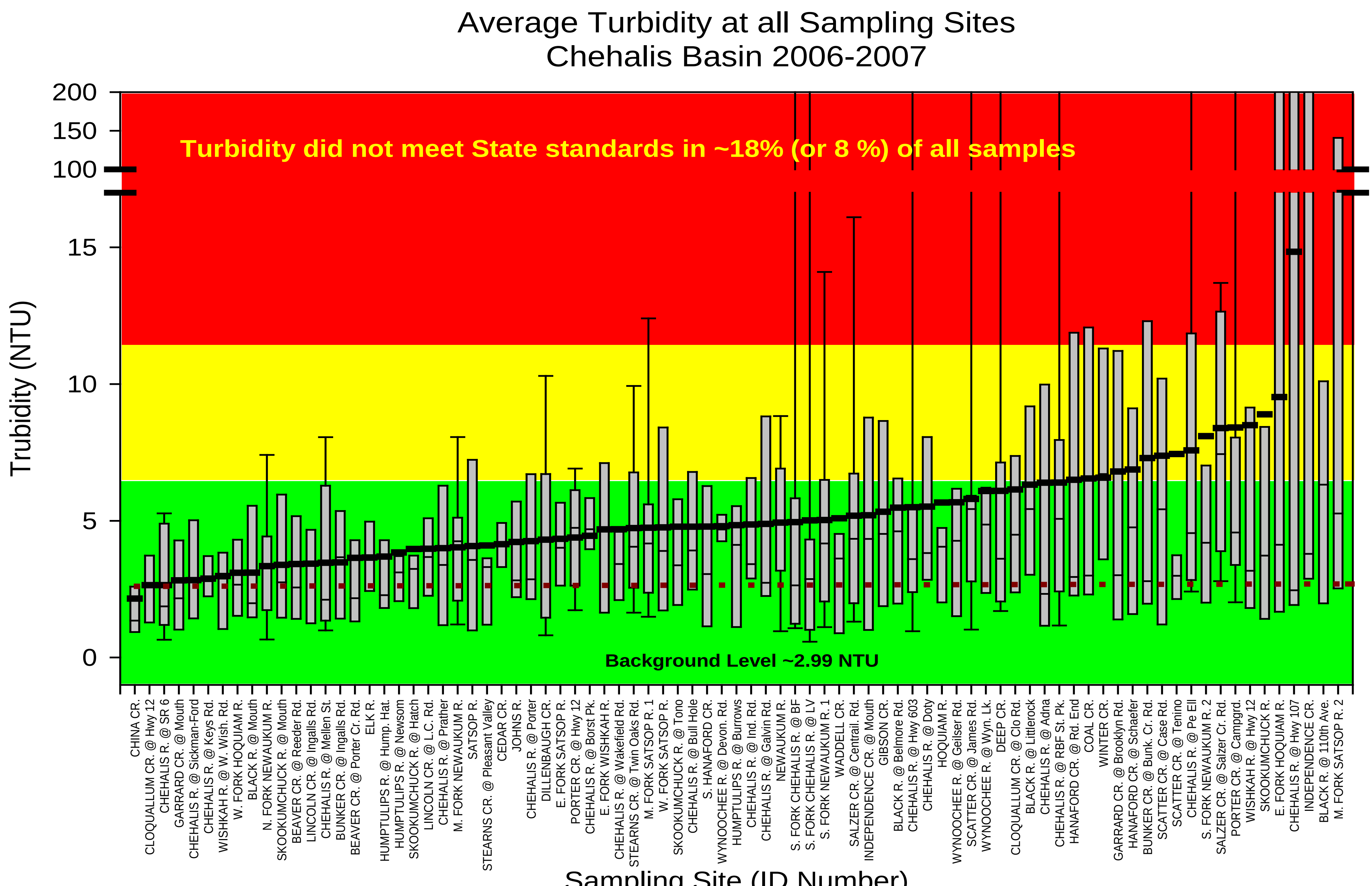

Figure 8 Represents the average turbidity (NTU) measured at all sites throughout the Chehalis Basin. Grays bars represent the 25th and 75th percentiles. "Whiskers" represent the 10th and 90th percentiles. Dark horizontal lines (within the vertical gray bars) represent mean concentrations and light lines represent media values. Frequency of water quality violation (as a percentage) is calculated for the most restrictive and (least restrictive) standards.

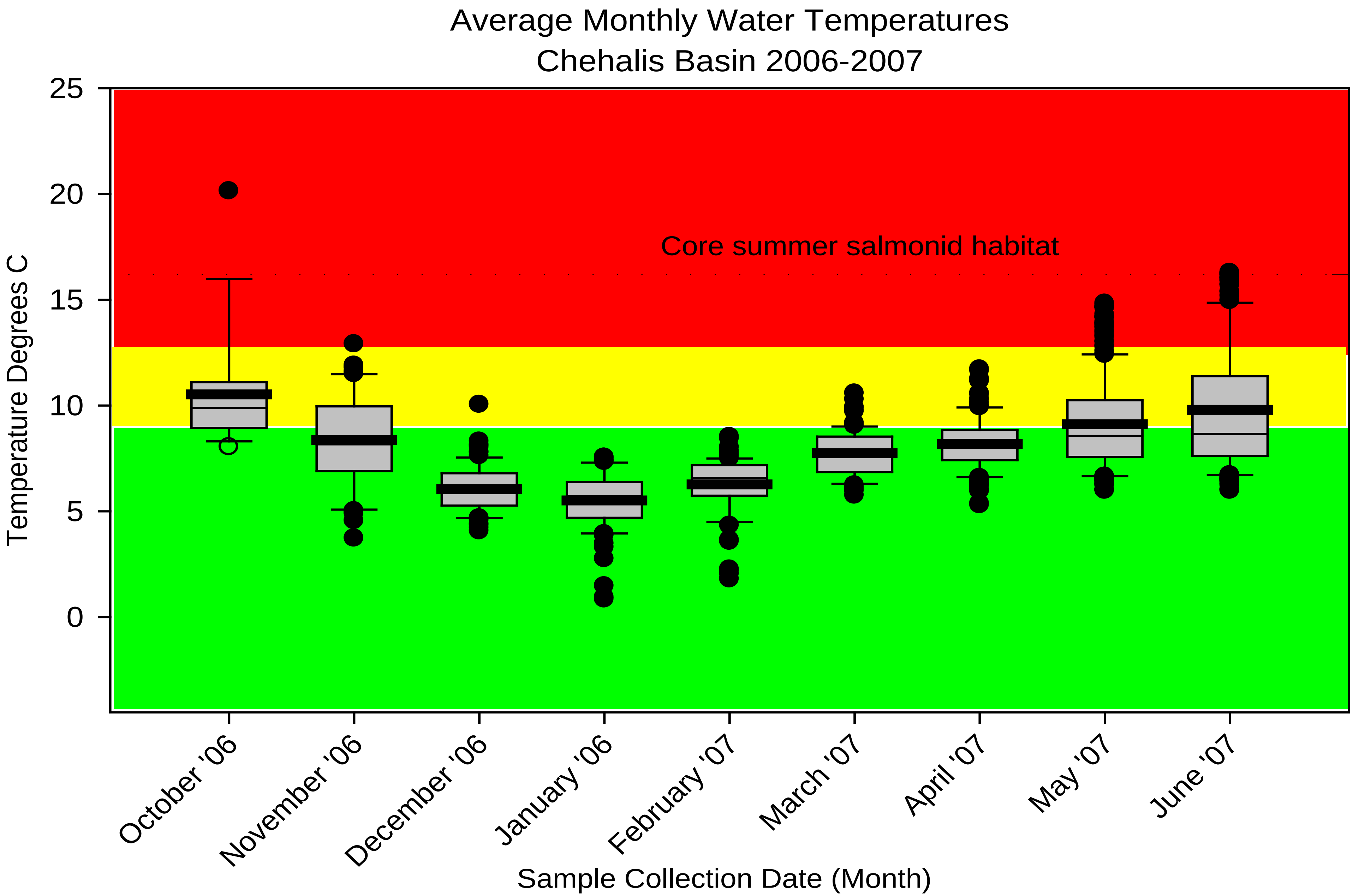

Figure 9 Represents monthly temperatures throughout the Chehalis Basin. Grays bars represent 25th and 75 percentiles. "Whiskers" represent 10th and 90th percentiles. Dark horizontal lines (within the vertical gray bars) represent mean concentrations and light lines represent media values.

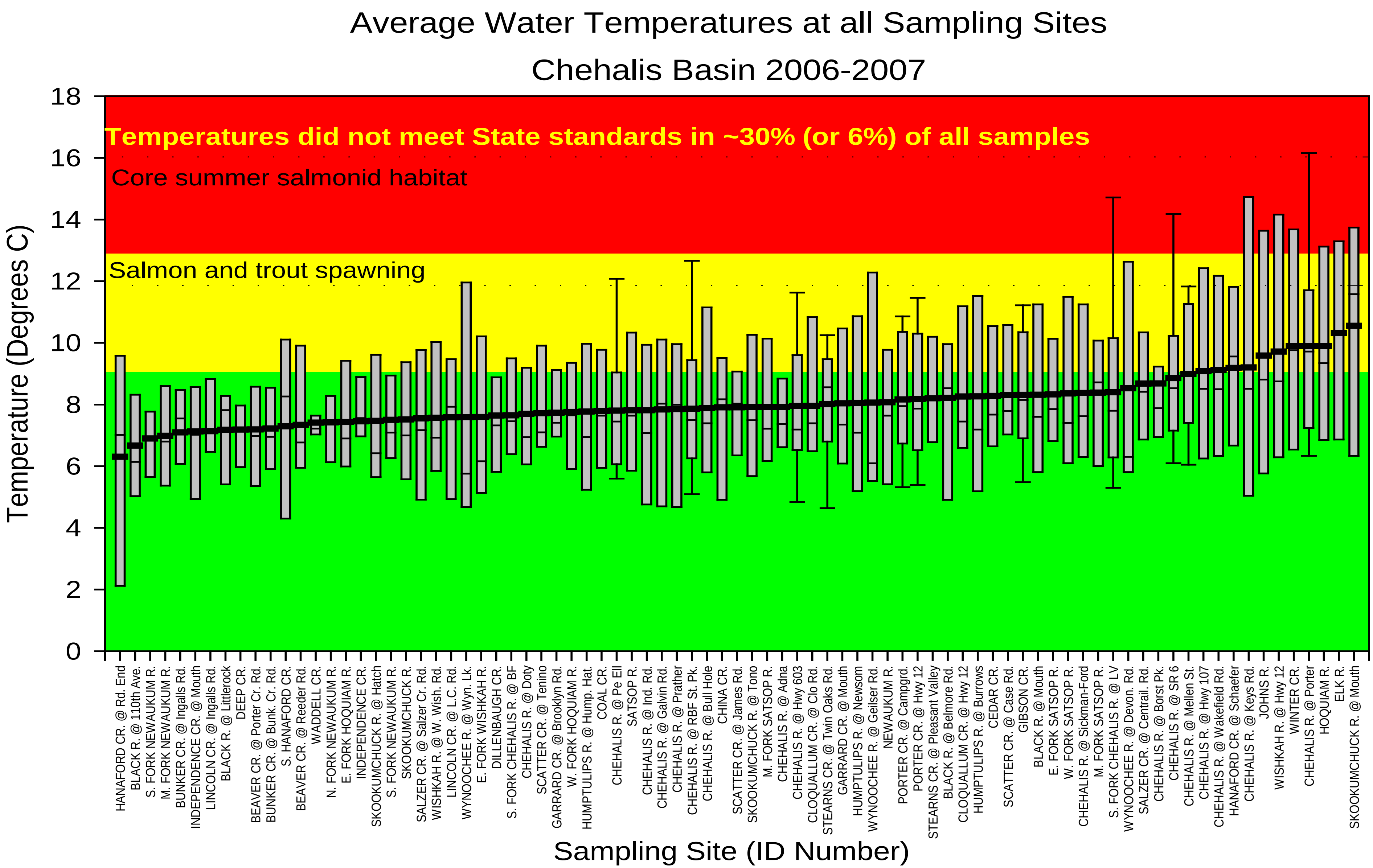

Figure 10 Represents temperatures at all sites throughout the Chehalis Basin. Grays bars represent the 25th and 75th percentiles. “Whiskers” represent the 10th and 90th percentiles. Dark horizontal lines (within the vertical gray bars) represent mean concentrations and light lines represent media values. Frequency of water quality violation (as a percentage) is calculated for the most restrictive and (least restrictive) standards.

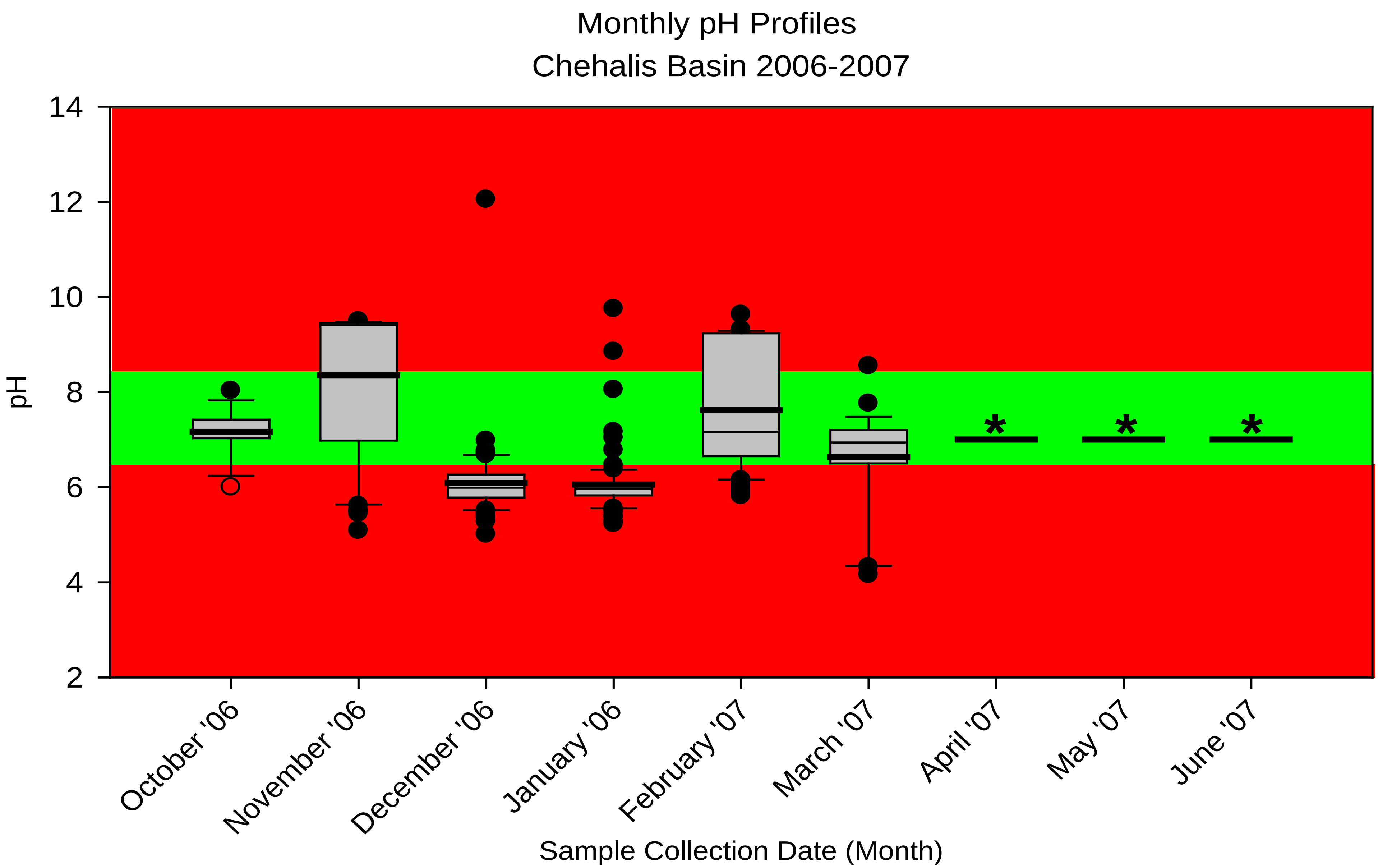

Figure 11 Represents monthly pH readings throughout the Chehalis Basin. Grays bars represent 25th and 75 percentiles. "Whiskers" represent 10th and 90th percentiles. Dark horizontal lines (within the vertical gray bars) represent mean concentrations and light lines represent media values. * represent data that was collected but excluded from analysis for quality assurance purposes.

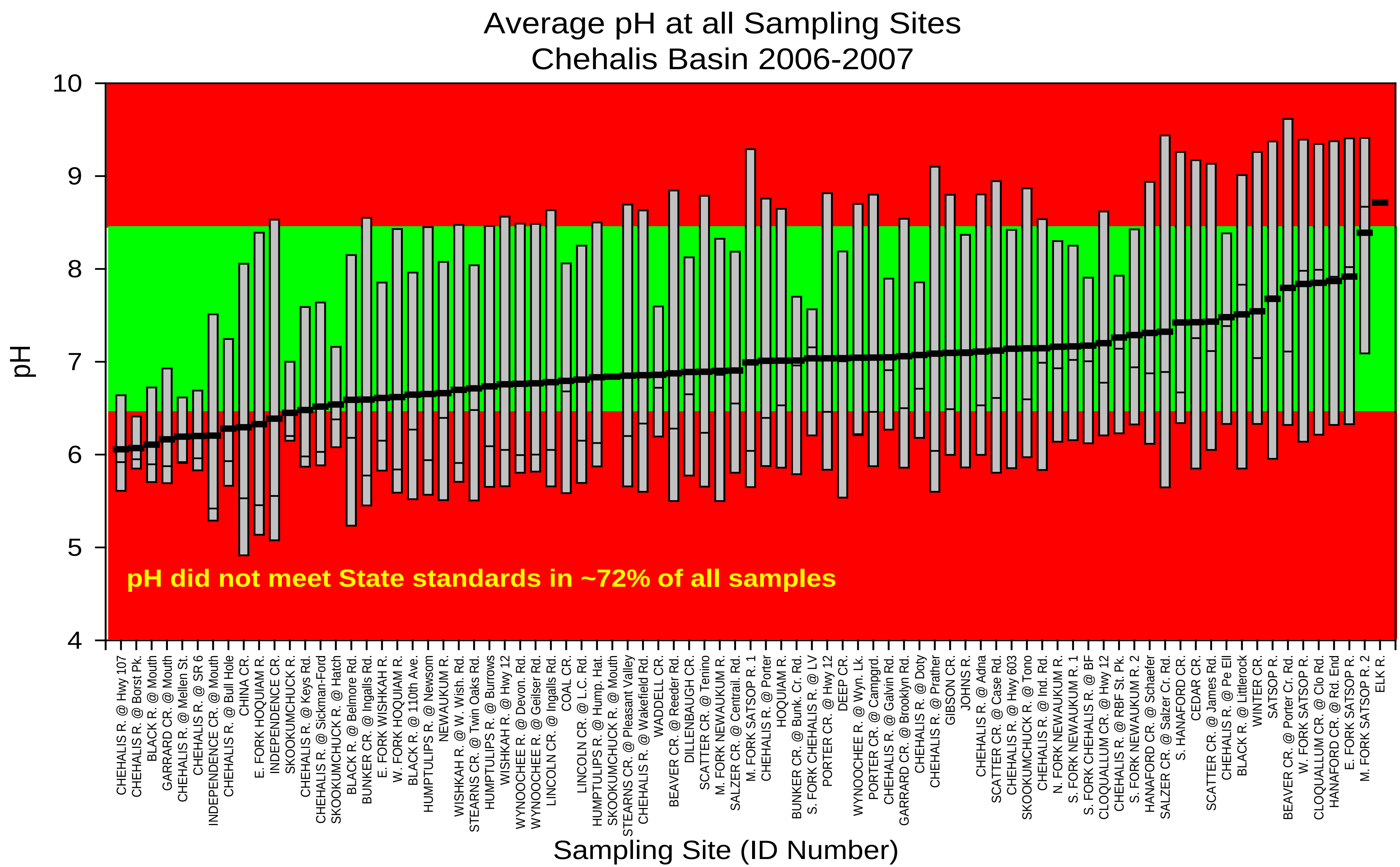

Figure 12 Represents the pH at all sites throughout the Chehalis Basin. Grays bars represent the 25th and 75th percentiles. “Whiskers” represent the 10th and 90th percentiles. Dark horizontal lines (within the vertical gray bars) represent mean concentrations and light lines represent media values. Note: data was collected for the months of April, May and June, but excluded from analysis for quality assurance purposes. Frequency of water quality violation (as a percentage) is calculated for the most restrictive and (least restrictive) standards.

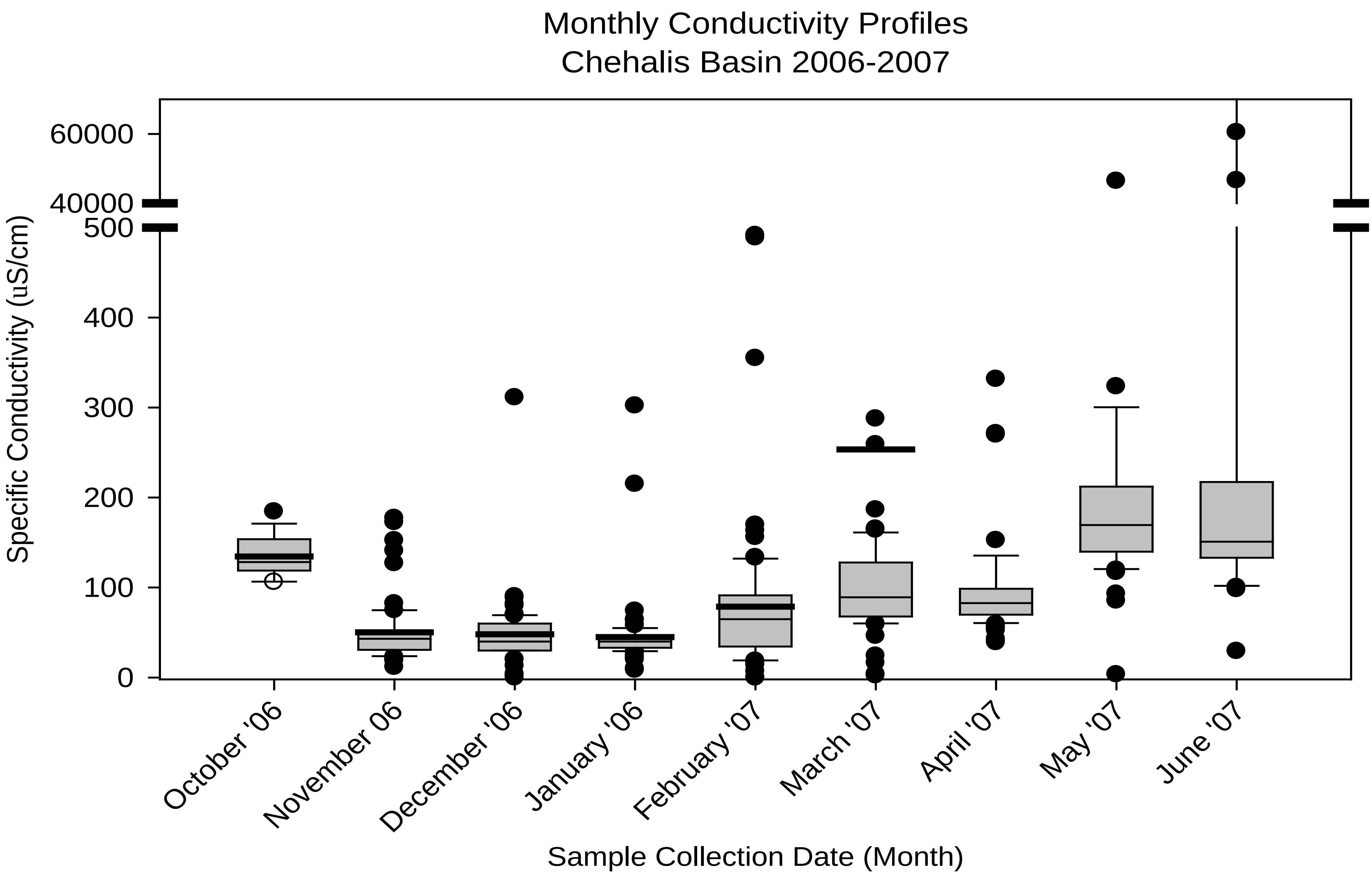

Figure 13 Represents the monthly range of conductivity readings at all sites throughout the Chehalis Basin. Grays bars represent 25th and 75 percentiles. "Whiskers" represent 10th and 90th percentiles. Dark horizontal lines (within the vertical gray bars) represent mean concentrations and light lines represent media values.

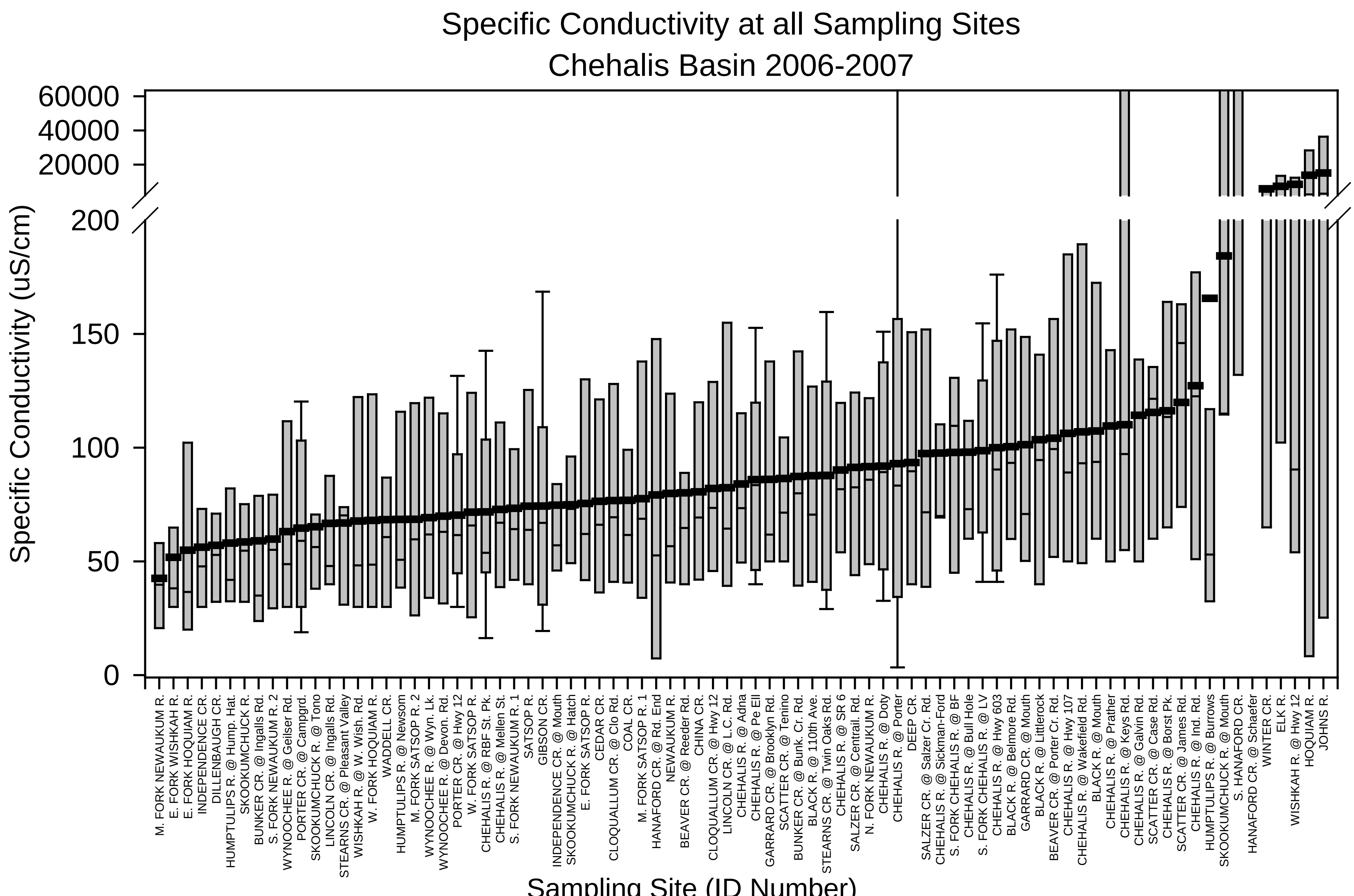

Figure 14 Represents the range of conductivity readings at all sites throughout the Chehalis Basin. Grays bars represent 25th and 75 percentiles. “Whiskers” represent 10th and 90th percentiles. Dark horizontal lines (within the vertical gray bars) represent mean concentrations and light lines represent media values.

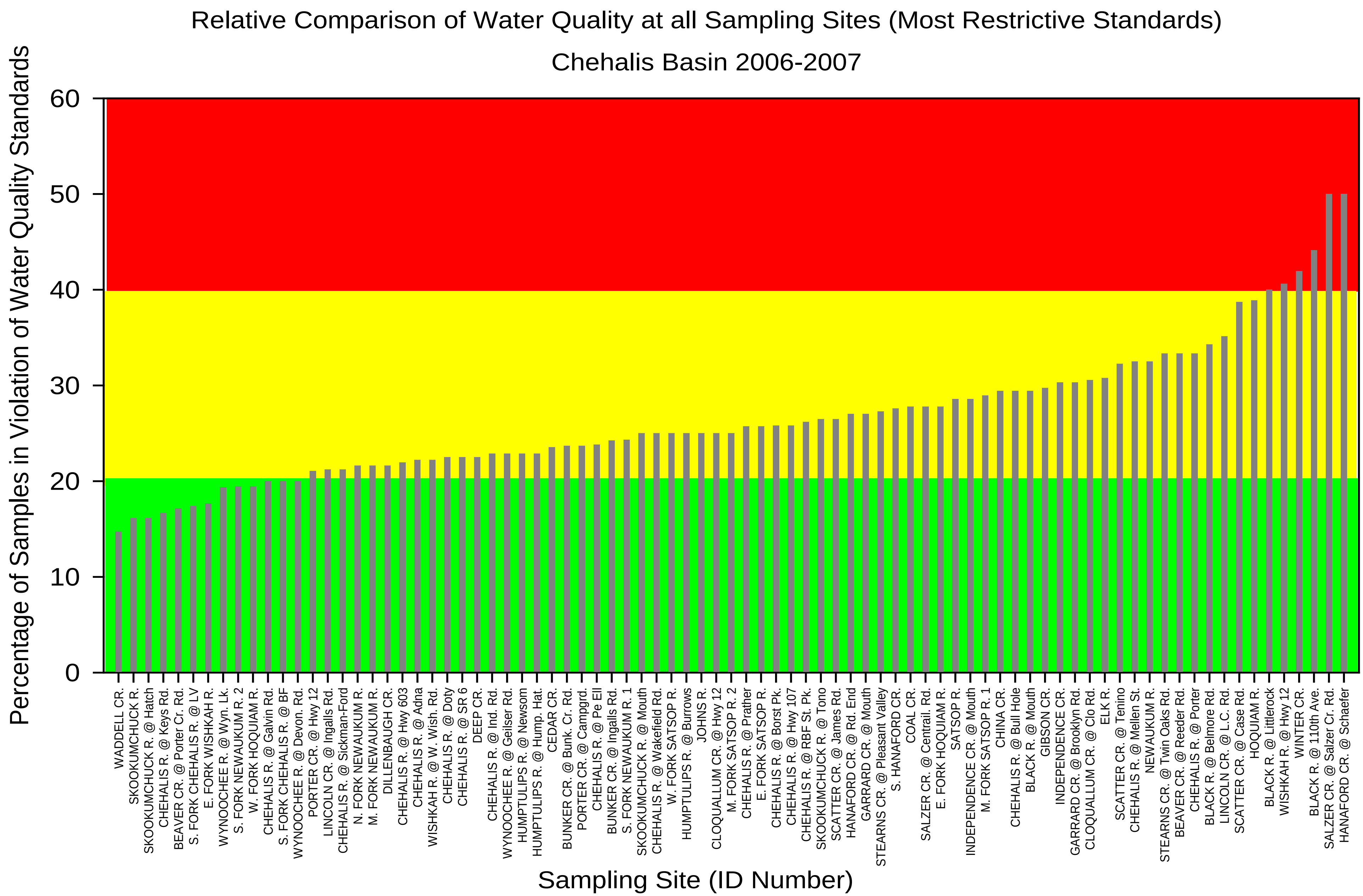

Figure 15 Depicts the relative "health" of various sites throughout the Chehalis Basin using the most restrictive water quality standards. Grays bars represent the percentage of samples (for all parameters) that exceed the Washington State water quality criteria.

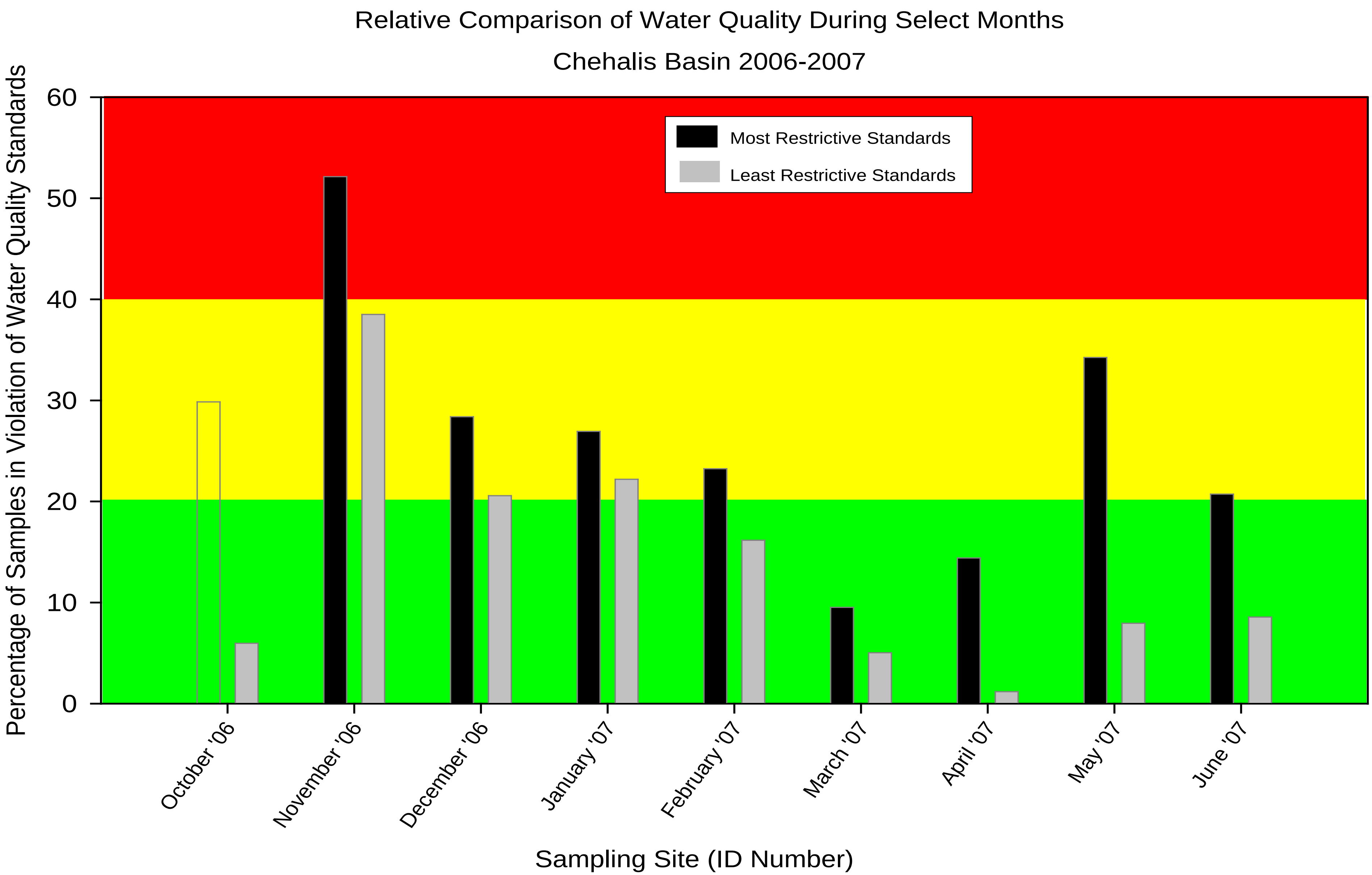

Figure 16 Depicts the relative "health" sites throughout the Chehalis Basin on a monthly basis (for two sets standards). Bars represent the percentage samples (for all parameters) that exceed the Washington State water quality criteria for any given month. Note: April, May and June pH readings were excluded for quality assurance purposes.

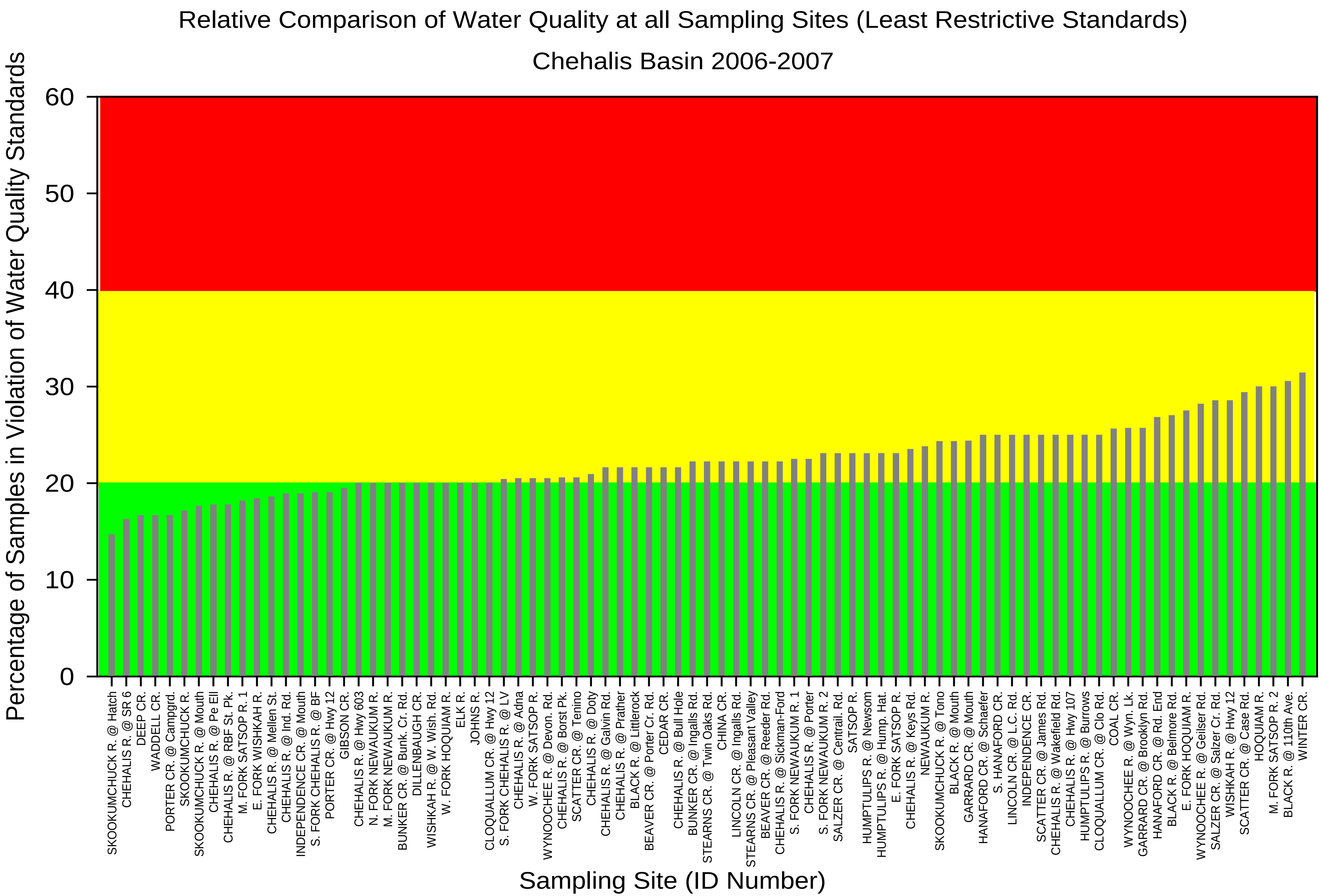

Figure 17 Depicts the relative "health" of various sites throughout the Chehalis Basin for the least restrictive standard set. Grays bars represent the percentage of samples (for all parameters) that exceed the Washington State water quality criteria.

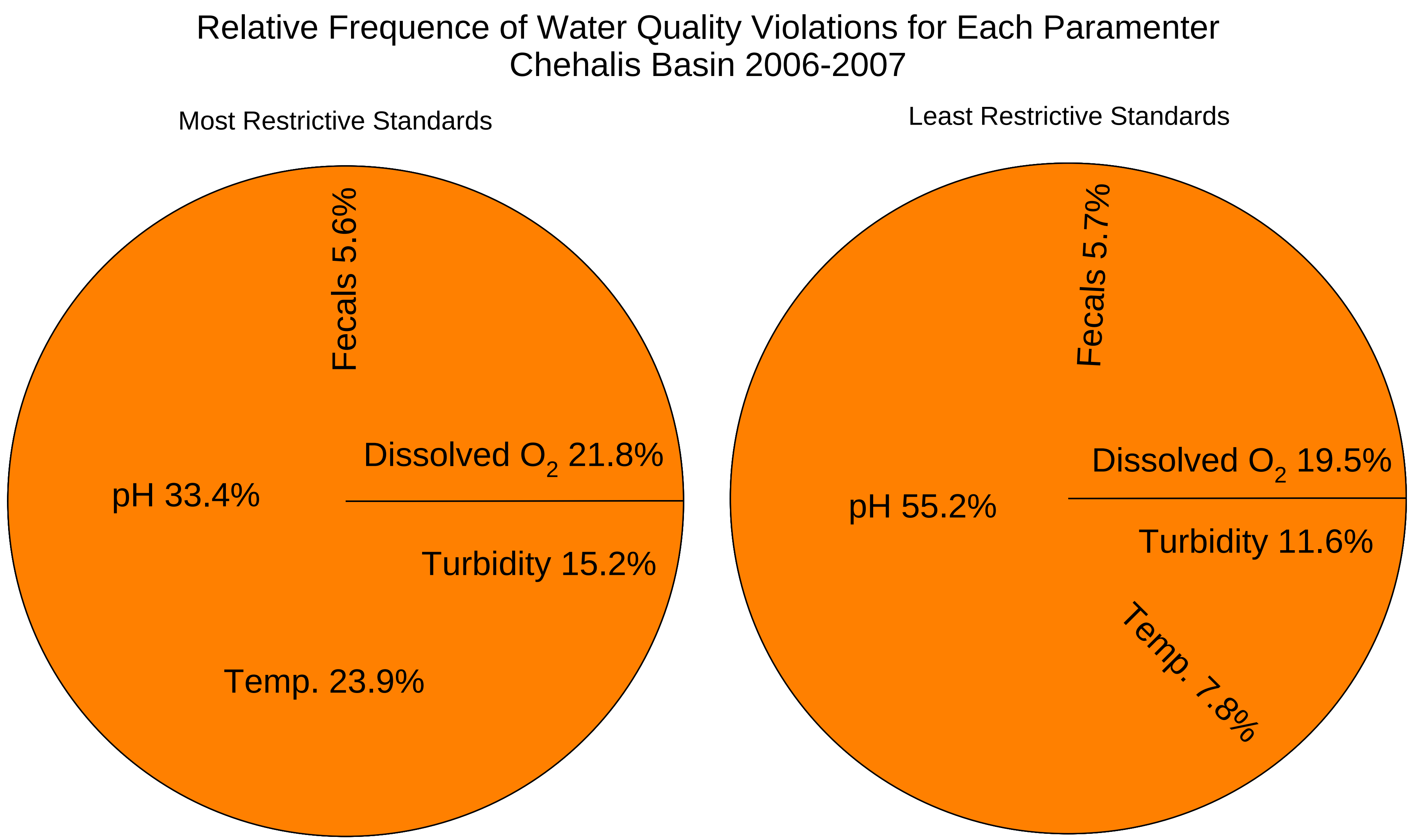

Figure 18 Represents the relative frequency (as a percentage) of water quality violations that occurred for each parameter. Relative contributions are depicted when calculated using two sets of standards (described in Table 2).

Summary of Technical Studies and Management Plans for the Chehalis Basin

Technical Studies	
7 USEPA approved TMDL studies addressing dissolved oxygen, temperature and fecal coliform throughout the upper and lower basin	WDOE, 2000; 2000; 2000; 2001; 20001; 2002; 2002
A Biological Assessment of Streams in the Coastal Range Ecoregion and Yakima Basin, Publication # 99-302	WDOE,1999
Chehalis Basin Level I Assessment	CBP, 2000
Salmon Habitat Limiting Factors in Washington State	WSCC, 2005
2002 Index Watershed Salmon Recovery Monitoring Report	WDFW, 2002
Chehalis Best Management Practices Evaluation Project: Final Report for Water Quality Sites	WDOE, 2002
Management Plans	
Chehalis Basin Detailed Implementation Plan	CBP, 2006
Chehalis Basin Watershed Management Plan	CBP, 2002
Chehalis Watershed Monitoring Plan and Quality Assurance Project Plan Framework	CBP, 2003
The Chehalis/Grays Harbor Watershed Dissolved Oxygen, Temperature, and Fecal Coliform Bacteria TMDL-Detailed Implementation (Cleanup) Plan , Publication # 04-10-065	WDOE, 2004
The Chehalis Basin Salmon Habitat Restoration and Preservation Work Plan for WRIAs 22/23	CBP, 2003

Table 1. Summarizes the technical studies and management plans for the Chehalis Basin referenced throughout the document. Studies are authored by Washington Department of Ecology (WDOE), The Chehalis Basin Partnership (CBP) and the Washington State Conservation Commission (WSCC)

Washington State Water Quality Standards

Parameter	High Standards	Description	Low Standards	Description
Temperature	**9** degrees C	7-d average to protect t char spawning	**13** degrees C	7-d average to protect salmon spawning
Dissolved Oxygen	**9.5** mg/L	7-d average to protect core summer salmon habitat	**8** mg/L	7-d average to protect salmon spawning, rearing and migration
Turbidity	**5** NTU Increase	To protect salmon spawning	**10** NTU Increase	To protect salmon migration and rearing
pH	**6.5** to **8.5**	To protect salmon spawning, rearing and migration	*same*	*same*
Fecal Coliform	**50** colonies/100 ml	To protect extraordinary uses (e.g. oyster culture)	**100** colonies/100 ml	To protect for primary contact and recreation

Table 2. Depicts a summary of Washington State standards for surface water quality. Standards are described for two levels of protection that are intended to protect waters of high or extraordinary quality. The most restrictive standards are described as "high" and the least restrictive standards as "low".