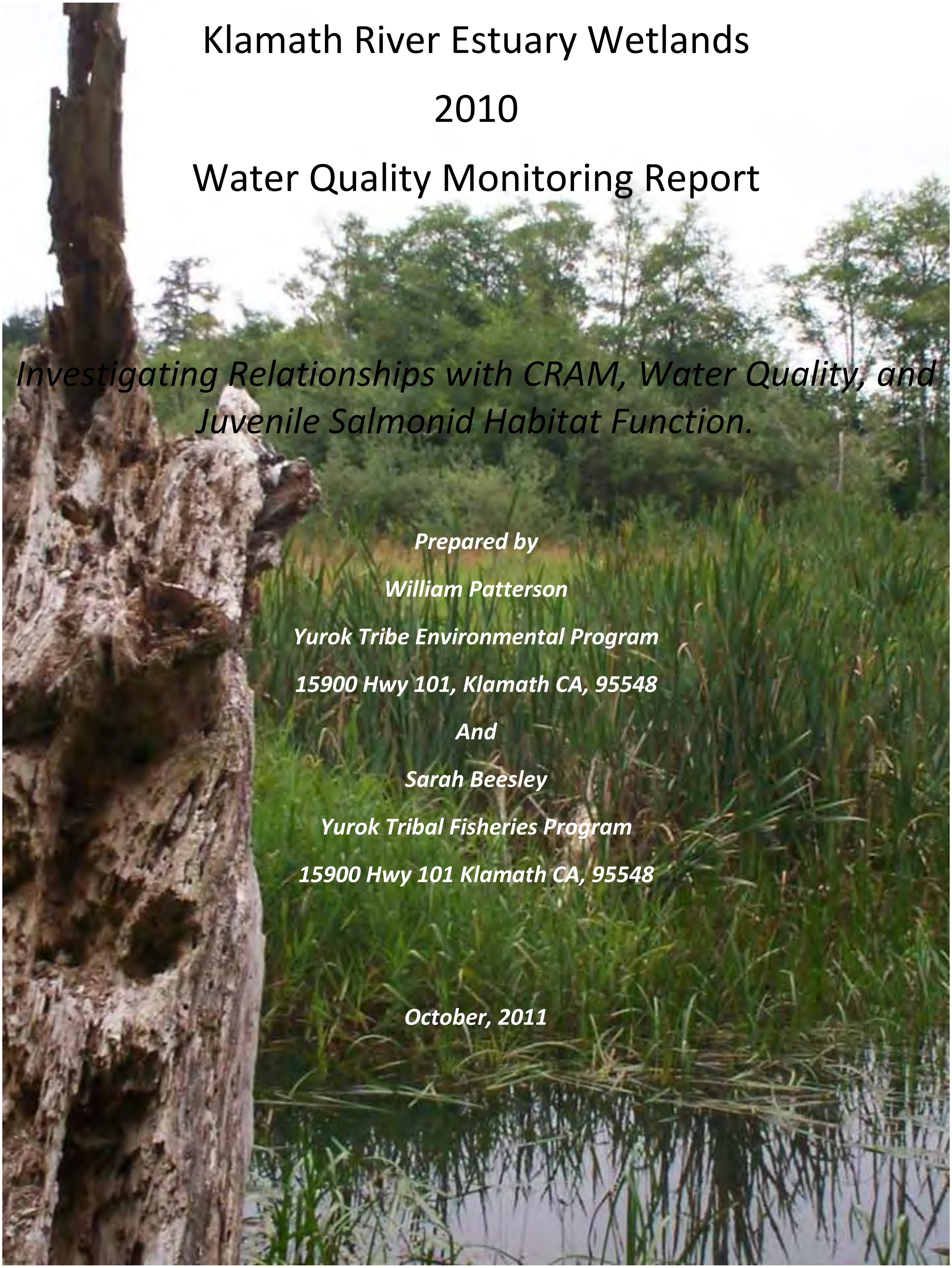

Klamath River Estuary Wetlands

2010

Water Quality Monitoring Report

Investigating Relationships with CRAM, Water Quality, and Juvenile Salmonid Habitat Function.

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1.0 Introduction

This report summarizes the Klamath River Estuary (KRE) wetlands monitoring project undertaken by the Yurok Tribe Environmental Program (YTEP) in 2010 under a Wetlands Program grant from USEPA. Continuous water quality data was collected over the course of twelve months to further characterize the current ambient condition of KRE wetlands. In 2008 and 2009, YTEP employed the California Rapid Assessment Method (CRAM) to assess the current condition of KRE wetlands. This information was used to prioritize sites for wetland restoration for compensatory mitigation planning purposes (Patterson, 2009). Due to the importance of wetlands to juvenile salmonids, YTEP supplemented existing CRAM data with a water quality study to determine if relationships between the two existed. Concurrently, the Yurok Tribal Fisheries Program (YTFP) has been monitoring juvenile salmonids in many of the KRE wetlands complexes. For this report, YTFP conducted an initial assessment of the functionality of the KRE wetlands as juvenile salmonid rearing habitat based on a set of developed parameters. Together the three data sets, CRAM, water quality, and the fish habitat evaluation, provided for a more in-depth characterization of the current condition of KRE wetlands. Exploring how wetland condition relates to salmonid productivity is useful when prioritizing and justifying wetland mitigation, protection, and restoration.

1.1 Background

1.1.2 Yurok Indian Reservation

The Yurok Indian Reservation (YIR) consists of a 59,000-acre corridor extending for one mile from each side of the Klamath River from just upstream of the Trinity River confluence to the Pacific Ocean, including the channel and the bed of the river (Figure 1). There are approximately two dozen major anadromous tributaries within that area. The mountains defining the river valley are as much as 3,000 feet high. Along most of the river, the valley is quite narrow with steep slopes. The vegetation is principally redwood and Douglas fir forests with a diverse deciduous understory. Historically, prevalent open prairies provided complex and diverse habitat.

Figure 1: The Yurok Indian Reservation, Lower Klamath Watershed, and Yurok Ancestral Territory

1.1.3 Klamath River

The health of the Klamath River and associated fisheries has been central to the life of the Yurok Tribe since time immemorial fulfilling subsistence, commercial, cultural, and ceremonial needs. Yurok oral tradition documents this way of life. The Yurok did not use terms for north or east, but rather spoke of direction in terms of the flow of Klamath River (Kroeber, 1925). The Yurok word for salmon, *nepuy*, refers to "that which is eaten". Likewise, the local waterways and watershed divides have traditionally defined Yurok aboriginal territories. Yurok ancestral land covers about 360,000 acres and is defined by the Klamath and Trinity Rivers, their surrounding lands, and the Pacific Coast extending from Little River to Damnation Creek. Fisheries resources continue to be vital to the Yurok today (Figure 1). Yurok lands are within the Lower Klamath Sub-Basin of the Klamath River Watershed (Figure 2). The September 2002 Klamath River fish kill, where a conservative estimate of 33,000 adult salmonids died in the Lower Klamath before reaching their natal streams to spawn, was a major tragedy for the Yurok people and the local communities.

Figure 2: The Klamath River Basin Map

1.1.4 KRE Wetlands

The KRE is located in Southern Del Norte County. The Klamath River is within the Columbian province, which extends along the Northern Pacific coast from Cape Mendocino to Vancouver Island. Mountainous shorelines with rocky foreshores are prevalent. Estuaries in this province are strongly influenced by freshwater runoff and the tidal range is large to moderate. The KRE is short and small even though the Klamath drainage ranks second in size of all California Rivers (Bricker et al., 2007). The estuary provides habitat and a migration corridor for anadromous fish but lacks extensive tidal flats and tidal marshes which normally occur in larger estuaries (Wallace, 1995). Surrounding the larger brackish or mainstem section of the KRE are several freshwater wetland complexes (WCs) which are fed by tributary streams (Figure 3). Due to size constraints offered by the local topography, complete functioning of the estuary is vital, and off–estuary wetlands have an increasingly local significance of natural resource value. Aerial photographs dating back to the early 1900’s reveal that these freshwater WCs no longer maintain the hydrologic relationships they once had with the estuary due to severe man made manipulations to the landscape (Hiner and Brown, 2004; Beesley and Fiori, 2004). The large WC formerly known as Hunter Slough, which historically consisted of anatomizing slough, ponds, and wetland marsh features is no longer in existence (Hiner and Brown, 2004; Beesley and Fiori, 2004; Beesley and Fiori, 2008; Patterson, 2009).

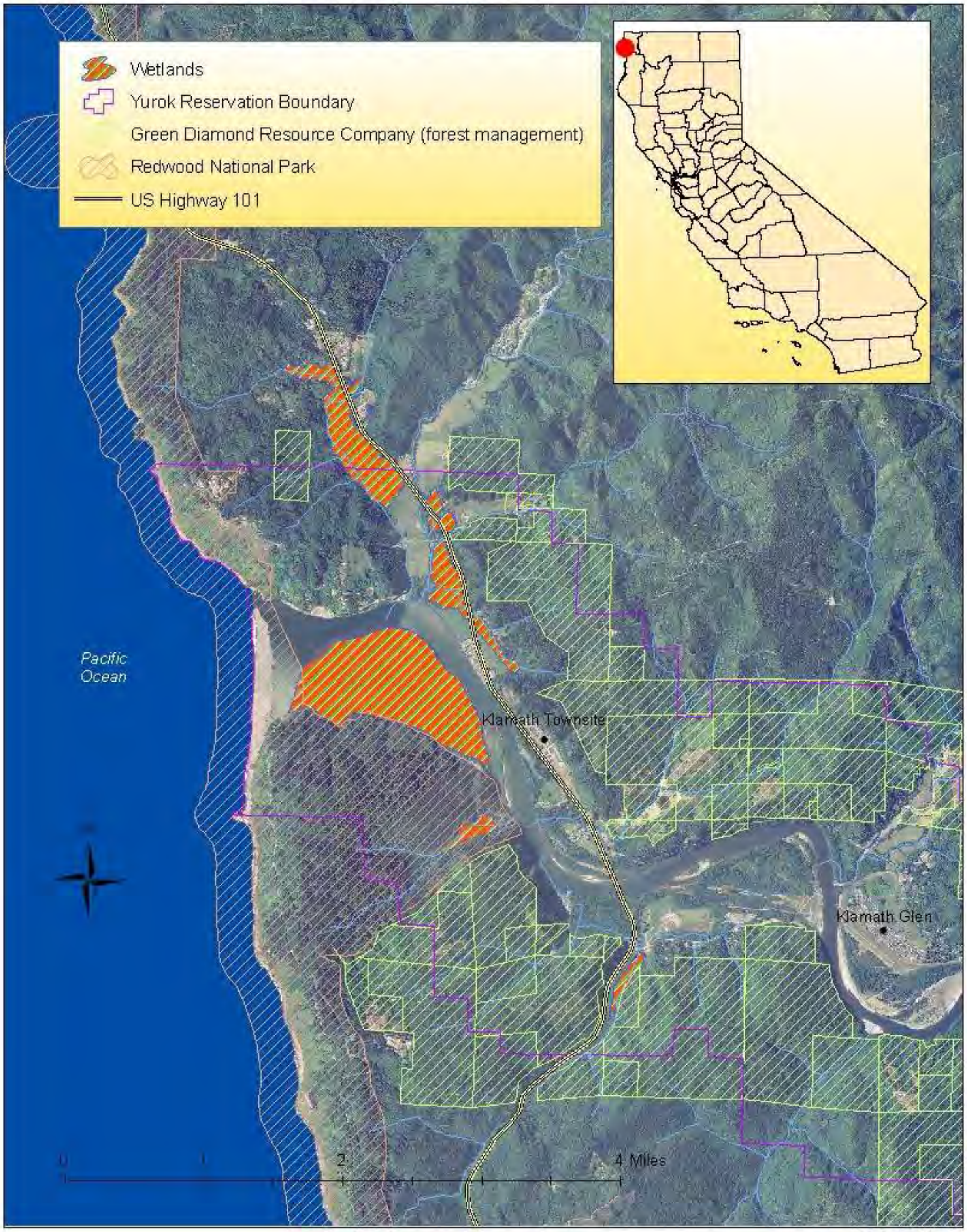

Figure 3: KRE Wetlands and surrounding land use.

1.1.5 Klamath River Fisheries

The health of the Klamath River fishery is vital to the survival of the Yurok people and Yurok way of life. Since time immemorial, the Yurok people have subsisted on the resources readily available in the Klamath River basin; the primary protein source for Yurok people is fish, which formerly filled the river in regular seasonal runs. Anthropogenic activities over the past century have resulted in substantial declines to Klamath River fish runs and drastically altered or degraded associated habitats. Man-made dams and water diversions in the upper basin and diversions in several major tributaries have significantly reduced Klamath River flows and drastically altered its natural hydrograph. The combination of altered flows, increased sediment delivery rates, and reduced water quality has greatly impacted the productivity of the mainstem KRE, while anthropogenic development has severely degraded associated freshwater WCs surrounding the KRE (Hiner and Brown, 2004; Beesley and Fiori, 2004; Beesley and Fiori, 2008; Patterson, 2009; Silloway, 2010).

Off-estuary tributary and wetland habitats are critical to juvenile salmonid populations from throughout the Klamath Basin. YTFP initiated historic and baseline hydrologic and geomorphic assessments to characterize conditions limiting salmonid populations in these critical habitats. Salmonid population research conducted in off-estuary tributaries and wetlands of the Klamath River has documented consistent use of these habitats by juvenile and adult salmonids (Wallace, 2001; Hiner and Brown, 2004; Beesley and Fiori, 2004; Silloway, 2010; Silloway and Beesley, 2011). In addition to providing high quality habitat for Tribal Trust fish and wildlife populations, off-estuary wetlands serve as critical water storage areas during flood events and greatly influence sediment retention and delivery rates in the lower river. Unfortunately, a majority of coastal wetlands in the Klamath River have been lost or severely degraded from land and water management activities (Hiner and Brown, 2004; Beesley and Fiori, 2004; Beesley and Fiori, 2008; Patterson, 2009).

1.1.6 Yurok Tribe Environmental Program – Wetlands Program

In 1998, YTEP was created to protect and restore tribal natural resources through high quality scientific practices. YTEP is dedicated to improving and protecting the natural and cultural resources of the Yurok Tribe through collaboration and cooperation with local, private, state, tribal, and federal entities such as YTFP, US Fish and Wildlife Service (USFWS), the United States Environmental Protection Agency (USEPA), Green Diamond Resource Company, the North Coast Regional Water Quality Control Board (NCRWQCB), and the United States Geological Survey (USGS). USEPA funding allocated under the Clean Water Act Section 106 and funding from PacifiCorp primarily fund YTEP's ongoing water quality monitoring and assessment activities.

In 2007, YTEP was a recipient of the USEPA Wetland Program Development Grant (WPDG) and began identifying and assessing wetlands in the YIR. Under the Yurok Tribe Wetlands Compensatory Mitigation Enhancement Program (YTWCMEP) [a USEPA approved Quality Assurance Project Plan (QAPP)], YTEP has collected sound scientific data regarding the current location and condition of KRE wetlands. YTEP assessed KRE wetlands using CRAM, a standardized procedure for scoring wetland condition, based on four attributes: Buffer and Landscape Connectivity, Hydrology, Physical Structure, and Biotic Structure. Using these attribute scores, YTEP was able to determine the restoration potential for each WC and have used the information to develop the KRE Wetlands Restoration Prioritization Plan (KREWRPP) (Patterson, 2009) which is one approach to guiding wetland mitigation and restoration efforts in the Lower Klamath River.

In 2009, YTEP further developed its Wetlands Program by expanding monitoring and assessment activities utilizing a two year WPDG. In an effort to supplement previously collected wetland assessment data, YTEP monitored water quality using continuous monitors in KRE wetlands complexes in 2010. YTEP has a goal of thoroughly monitoring and assessing the condition of KRE wetlands. This information will aid in the development of a thorough understanding of the relationships between wetland condition and function, as well as allow for a science-based decision making approach to guide wetland mitigation and restoration efforts. Although YTEP does not implement restoration projects at this time, the Yurok Tribe Watershed Restoration Department (YTWRD) has been implementing upslope restoration projects in the Lower Klamath River Sub-basin since 2000. In addition, YTFP has a robust Lower Klamath restoration division which has implemented multiple fisheries restoration projects in Lower Klamath tributaries, including three coastal wetland restoration projects in summer 2010 (Fiori et al., 2011a & 2011b; Hiner et al., 2011). YTEP works with YTWRD and YTFP to provide scientifically valid and useful information in support of these restoration efforts.

1.1.7 Yurok Tribal Fisheries Program – Lower Klamath Division

In the Klamath River, all runs of chinook salmon (*Oncorhynchus tshawytscha*), green sturgeon (*Acipenser medirostris*), and Pacific lamprey (*Lampetra tridentata*) are on the decline and coho salmon (*O. kisutch*) are listed as "threatened" under the Endangered Species Act (ESA). YTFP is dedicated to rehabilitating degraded habitats to levels that support robust, self-sustaining populations of native anadromous fish. YTFP currently consists of four different divisions: Harvest Management, Lower Klamath, Klamath River, and Trinity River (http://www.yuroktribe.org/departments/fisheries/FisheriesHome.htm). The Lower Klamath Division (YTFP-LKD) focuses on fisheries assessment, monitoring, research, and restoration within the Lower Klamath River Sub-basin. Since 2000, YTFP-LKD has been conducting fisheries related studies in the KRE and associated off-estuary habitats (Hiner and Brown 2004, Beesley and Fiori 2004, 2007, & 2008, Hiner 2006, YTFP 2008, Soto et al., 2008, Hillemeier et al., 2009, Hiner 2009, Silloway 2010, Silloway and Beesley 2011). Study goals have included assessing fish use within this unique area, documenting historic and existing habitat conditions, identifying factors currently limiting fish production and survival, and using our research to guide development and implementation of comprehensive, process-based fisheries habitat enhancement plans.

Since 2006, YTFP and the Karuk Tribe have been partnering with the U.S. Bureau of Reclamation, U.S. Geological Society, and coho experts to conduct the Klamath River Coho Ecology Study (Soto et al., 2008; Hillemeier et al., 2009; Soto et al., in Progress). Study objectives include documenting use of mainstem Klamath River and off-channel habitats by juvenile coho and using the information to inform coho recovery efforts in the Klamath River and California. The Coho Ecology Study has documented significant use of KRE and coastal wetlands, beaver ponds, and off-channel habitats by juvenile coho salmon from spawning populations emanating from throughout the Klamath Basin. These habitats are especially important to juvenile coho during winter and just prior to ocean entry; however, some of the KRE and coastal wetlands also serve as critically valuable summer habitat for both young of the year and age 1+ salmonids (Soto et al., 2008; Hillemeier et al., 2009; Silloway, 2010; Silloway and Beesley, 2011).

Winter growth and survival of juvenile salmonids using slow velocity habitats, such as wetlands and off-channel features, tends to be greater than for fish residing in mainstem tributary and river habitats (Nickelson et al., 1992; Lestelle, 2007; Soto et al., 2008; Hillemeier et al., 2009; Hiner et al., 2011). Growth and survival of juvenile salmonids is very important since it is well understood that ocean survival of juvenile salmonids is positively correlated to their size at ocean entry (Scrivener and Brown, 1993; Quinn and Petersen, 1994). Studies conducted in Oregon indicate that ocean survival of juvenile chinook was greatly increased when fish entered the ocean at sizes greater than 120 mm fork length (Nicholas and Hankin, 1989). Therefore, increasing the quantity and quality of slow velocity habitats in the Lower Klamath River Sub-basin is a priority restoration measure for YTFP-LKD. In summer 2010, YTFP-LKD and our restoration consultant Rocco Fiori (Fiori GeoSciences (FGS)) constructed three off-channel wetlands in two coastal tributaries of the Lower Klamath River (Fiori et al., 2011a & 2011b; Hiner et al., 2011). YTFP-LKD and FGS are currently working with partners and stakeholders to design and implement large-scale wetland restoration in Salt Creek and Waukell Creek.

2.0 Methods

This report analyzes historic and current data collected by YTFP and YTEP. Historic data was collected by YTEP using CRAM in 2008 and 2009. Water Quality data summarized in this report was collected in 2010. YTFP's juvenile salmonid rearing habitat evaluation was developed based on investigations conducted since 2000.

2.1 CRAM Methods

CRAM data is reported in detail in "*The Klamath Estuary Wetlands Restoration Prioritization Plan*" (Patterson, 2009). The CRAM data previously collected is briefly summarized in this report, for an in-depth characterization of this data please see the above referenced report at: http://www.yuroktribe.org/departments/ytep/documents/FinalKREWetlandRestorationPrioritizationPlan102009_000.pdf. Methods for collecting CRAM data were developed in conjunction with YTEP staff and the USEPA Region 9 Quality Assurance (QA) Office, and are presented in the QAPP – *"Yurok Tribe Wetlands Compensatory Mitigation Enhancement Program"* (Patterson, 2008). The complete methods for carrying out CRAM can be best obtained from the *"CRAM User's Manual version 5.0.2"* (Collins et al., 2008).

2.1.1 CRAM Site Selection:

Locations for CRAM assessments included the following KRE WCs: Salt Creek, Panther Creek, Spruce Creek, South Slough, Richardson Creek, and Waukell Creek (Figures 4 – 9). YTEP assessed KRE WCs in part due to their vital function as salmonid habitat (Wallace, 2001; Soto et al., 2008; Silloway, 2010; Silloway and Beesley, 2011) and because of the cultural significance healthy salmonid populations have to the Yurok Tribe. In addition, the largest concentration of wetlands within the YIR occurs in and around the KRE. Due to the severe anthropogenic degradation of KRE wetlands over time, the KRE WCs were also studied to develop a plan which could prioritize and guide wetland mitigation and/or restoration efforts (Patterson, 2008 & 2009).The ultimate goal of YTEP in this process is to provide useful information to partnering Tribal departments and agencies involved in restoration and mitigation, and to support these efforts.

Within each WC CRAM scores from representative assessment areas (AA) (1 hectare each) were averaged to determine the overall CRAM score for each WC. The number of AAs coincided with the relative size of the wetland, the larger the WC the more AAs there were.

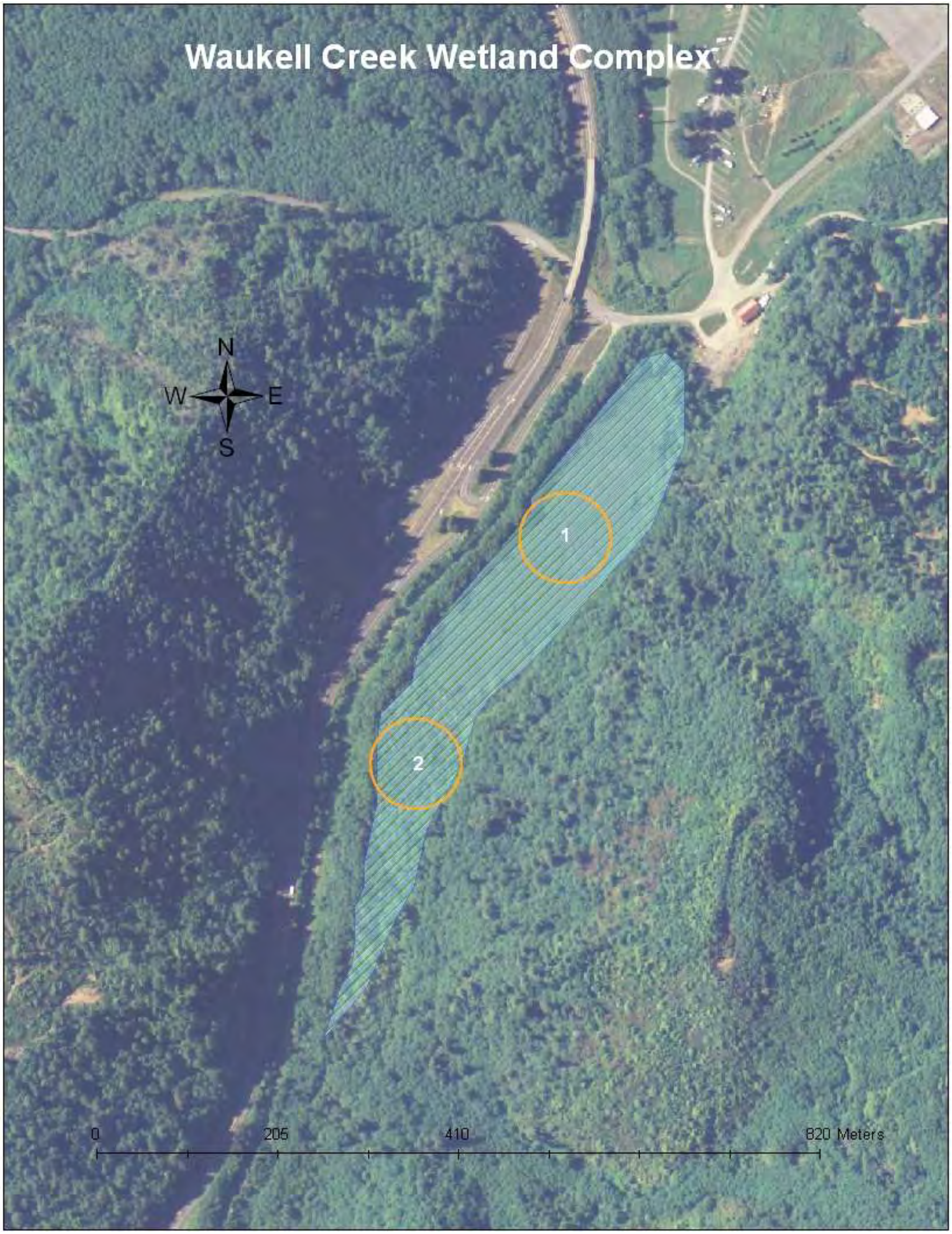

Figure 4: Waukell Creek WC CRAM assessment area locations.

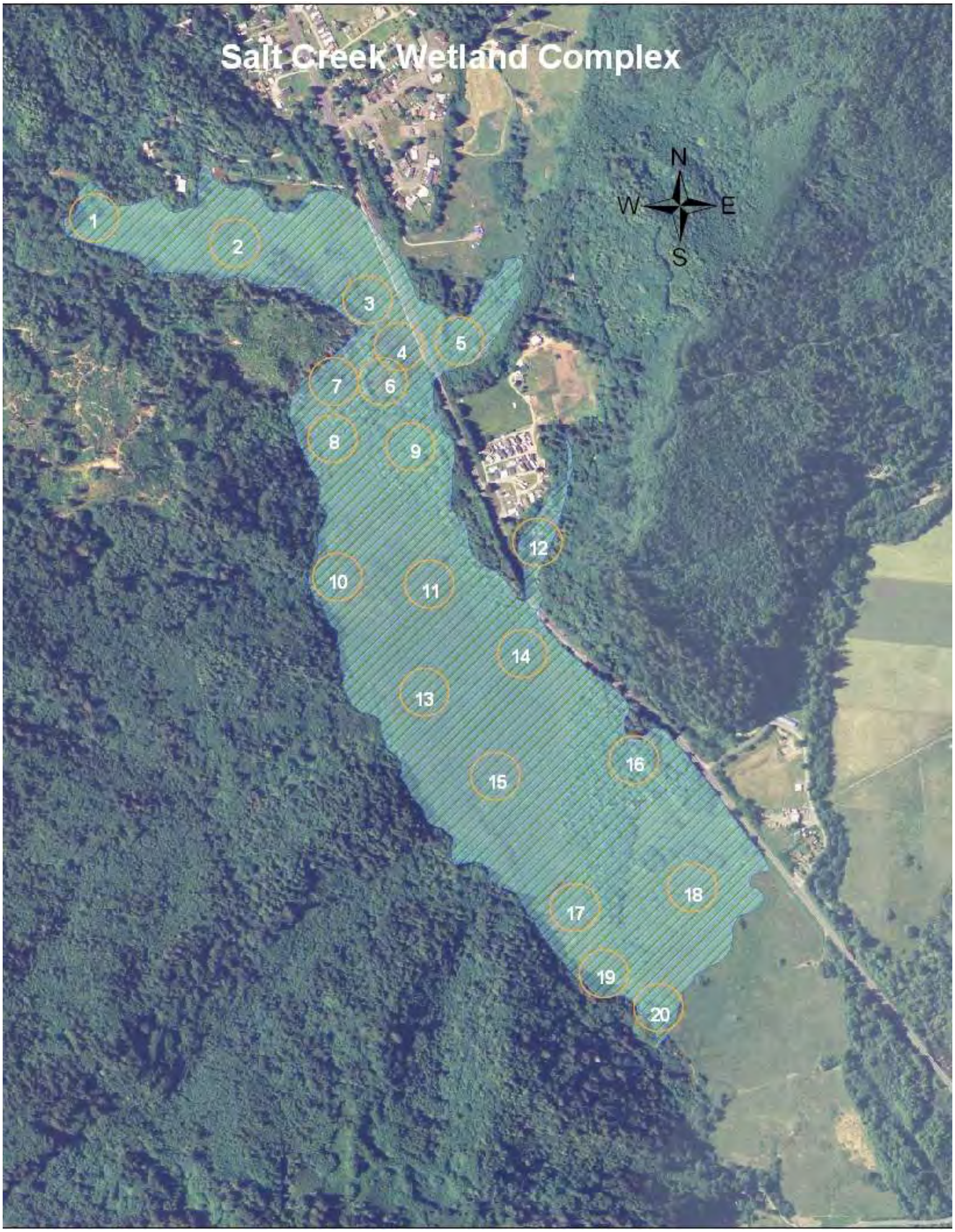

Figure 5: Salt Creek WC CRAM assessment area locations.

Figure 6: Spruce Creek WC CRAM assessment area locations.

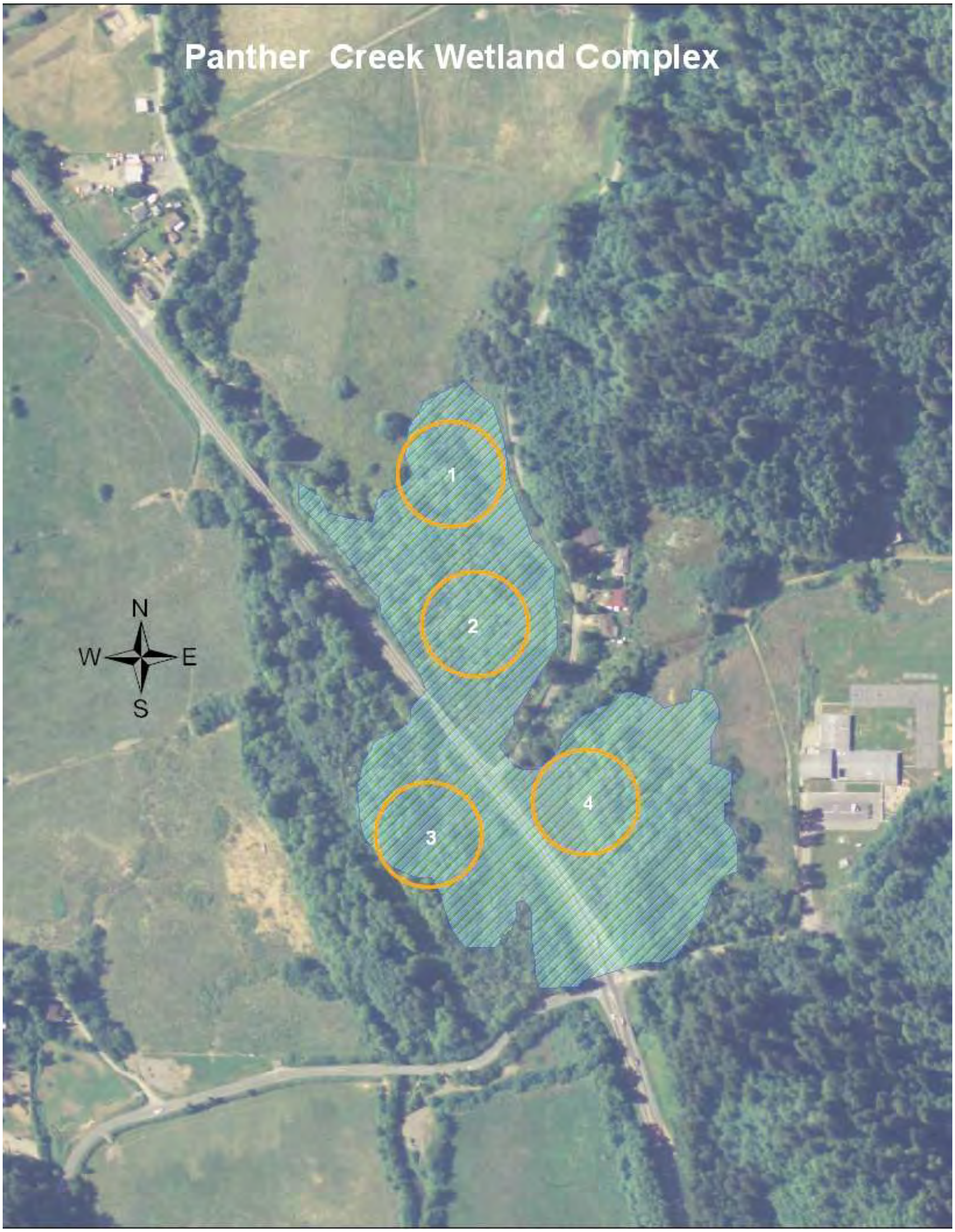

Figure 7: Panther WC CRAM assessment area locations.

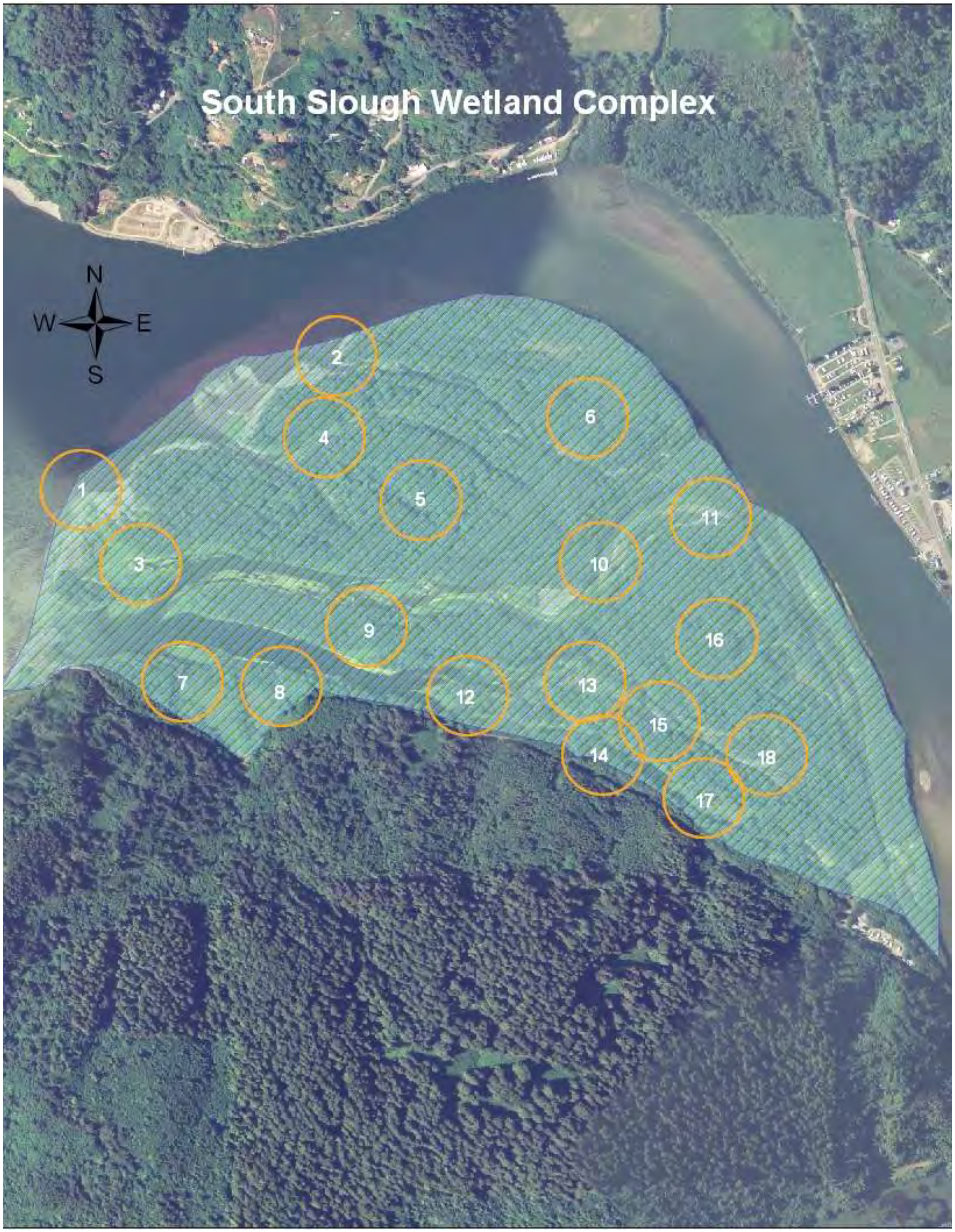

Figure 8: South Slough WC CRAM assessment area locations

Figure 9: Richardson Creek WC CRAM assessment area locations.

2.2 Water Quality Monitoring Methods

YTEP worked with the USEPA Region 9 QA office to develop a QAPP – *"KRE Wetlands Water Quality Monitoring"* (Patterson, 2010). The QAPP was developed following USGS protocols outlined in the document: *"Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting"* (Wagner et al., 2006). Water quality data presented in this report was collected from January 2010 to January 2011. Data was collected to assess water quality conditions at times of high use by juvenile salmonids in their redistribution and emigration life stage (Lestelle, 2007), as well as to assess the potential for year-round use by salmonids (Silloway, 2010). Continuous water quality information was collected using YSI 6600EDS multi-parameter data sondes equipped with specific conductivity/temperature, pH, dissolved oxygen (DO), and turbidity probes. Data sonde calibration methods were developed to follow manufacturer guidelines for proper use of the equipment and accurate readings. During this study, many QA/QC measures were undertaken to ensure the data collected with the data sondes was of the highest quality. Calibration drift and bio-fouling errors were closely tracked and accounted for in the data computation process. YTEP used Aquarius computer software to manage and report the water quality data.

Due to a limited number of data sondes (4), YTEP rotated data sondes weekly to evenly distribute water quality monitoring to all of the 12 wetland sites throughout the year, and track general trends. Each wetland site was monitored for a week at a time and had a two week span before monitoring occurred again in that WC. All data sondes under went calibration and QA/QC procedures upon extraction and deployment. Measurements were taken at 15 minute intervals.

2.2.1 Criteria for Evaluation

Data for each of the water quality parameters was evaluated based on a synthesis of previously established criteria set forth by NCRWQCB and is drawn from several documents (Table 1). The established criteria are used to assess the deviance from optimal conditions and assign an overall water quality score for each WC.

Table 1: Threshold criteria used to evaluate each parameter including citations for the source of established criteria.

Parameter:	Threshold Criteria	Citation
Temperature (C°)	10 to 16	Carter, 2008
Dissolved Oxygen (mg/L)	8	Carter, 2008; NCRWQCB 2010
Dissolved Oxygen (%)	85	NCRWQCB, 2010
pH	6.5 to 8.5	NCRWQCB,2011
Specific Conductivity (µS/cm²)	120-200	NCRWQCB, 2011
Turbidity (NTU)	25	NCRWQCB, 2006

Currently, numeric standards for wetlands do not exist in the state of California. Using the Klamath River TMDL to assess water quality conditions in associated WCs not directly within the mainstem Klamath River can be problematic. Given the unique characteristics and differing hydrologic regimes of each wetland utilizing values developed for streams can also be problematic in evaluating wetland water quality, However until numeric wetland water quality standards have been fully developed, current established guidelines for rivers and streams give the current “best available science” in defining numeric targets. Given the importance of wetlands’ water quality in their functionality as salmonid habitats, salmonid life stage requirements for water quality was given emphasis. The documents relied upon in this study to develop water quality criteria all underwent literature review of salmonid life stage water quality requirements. Although some of the reviewed literatures differ on what is “optimal” the documents are a synthesis of the available information and provide a professional, science based judgment of what defines optimum conditions for salmonids. Wetland habitats are primarily used by juvenile salmonids as opposed to adults, therefore in cases where optimum conditions are available for different life stages the juvenile life stage was used.

2.2.2 Water Quality Scores

Each WC was rated for overall water quality conditions based on the established criteria. A percent exceedance metric was calculated for each parameter, which represents the amount of time the parameter was outside optimal range over the course of 1 year. The percent exceedance (decimal form) was then multiplied by a weighting factor to arrive at a parameter score. The summation of parameters scores gives the overall water quality score (Table 2). The overall water quality score was based on a scale of 100 points, with a score of 100 representing 100 percent exceedance of all parameters, and poor water quality conditions. Not all parameters were given equal weight, with some being more important to salmonids than others based upon the current conditions in the wetlands related to the criteria. Weighted parameters were assigned more points of the total 100 points available. It should be noted that developing a water quality score or similar types of indices ratings are subjective. YTEP investigations into water quality indices revealed different methods but subjectivity remained in all of them. However, in order to make a relationship between a WC overall CRAM score and water quality, a scoring system for water quality similar to CRAM was necessary.

Table 2: Parameters, threshold criteria and weighting factors for evaluating water quality conditions.

Parameter:	Threshold Criteria	Weighting Factor
Temperature (C°)	10 to 16	40
Dissolved Oxygen (mg/L)	8	40
Dissolved Oxygen (%)	85	0
pH	6.5 to 8.5	10
Specific Conductivity (µS/cm²)	120-200	0
Turbidity (NTU)	25	10
		Total = 100

An advantage of this water quality scoring approach is that when compared to more complex rating indices the percent exceedance is directly reflected in the final score and allows for the differentiating of locations on a finer scale as opposed to grouping the scores by class or grade. Objective decision making requires the use of the continuous data, annual trends, and overall water quality score. In the future as conditions change in the Klamath system, weighting factors may change as an emphasis is placed on the current conditions.

2.2.3 Data Calculations

Data was collected for a 7 day periods in each of the WC’s then data sondes were rotated to the next WC. This resulted in certain WCs being monitored while others were not during that same time period. A 14 day gap exists between continuous data sets for a given WC. This made the comparability of data sets difficult based solely on the continuous data. To overcome this problem several steps were taken. First, the daily maximums or minimums (depending on the parameter) were calculated and averaged. This is widely accepted method of evaluating water quality data (Carter, 2008). Second, an interpolation was calculated to produce an annual trend line representing the continuous data without gaps, allowing for comparability between locations. The last data calculation involved capturing temporal and spatial changes in water quality in the WC and eliminating the bias that may exist in a single monitoring location. The two annual trend lines (one from the upper location, and one from the lower location) were averaged to represent conditions within the wetland. This composite trend line is used in calculating the percent exceedance for each parameter in a given WC and the subsequent water quality score.

2.2.4 Parameters

2.2.4.1 Temperature

Water temperature plays a critical role in dissolved oxygen (DO) saturation levels as well the solubility of other constituents (pH, conductivity, etc.) It can also affect the survival of fish, aquatic organisms, and vegetation. The criteria for temperature used in scoring this parameter was based on an appendix document of the Klamath River TMDL- Appendix 4 Effects of Temperature, DO/Total Dissolved Gas, Ammonia, and pH on Salmonids (Carter, 2008). The document specifically outlines 16 degrees Celsius as the upper threshold for optimal conditions for juvenile salmonid rearing. Based on the lethality of high water temperatures the annual trend that is calculated based on continuous data is derived from daily maximum temperatures.

The lower limit is not specifically defined, however the decreased feeding and metabolism associated with extremely cold water is recognized in several sources within the document. From the literature reviewed, 10 degrees Celsius is the value that has been identified as the lower limit of the preferred range in juvenile rearing (Carter, 2008). Because absolute values for the lower end of the optimum temperature range differ depending on literature some subjectivity will undoubtedly remain, however YTEP has adopted this value for the purposes of this report and will keep this value in “adaptable” status into the future.

2.2.4.2 Dissolved Oxygen

DO plays a critical role in the function of wetlands as fisheries habitat as well as the survival of aquatic organisms. The amount of oxygen in the water can vary depending on many interrelated variables, including stream temperature, salinity, atmospheric pressure, turbulence, respiration, photosynthesis, and biological and chemical oxygen demanding reactions. Similar to temperature, the criteria for DO concentration evaluation and scoring are based on Appendix 4 of the Klamath River TMDL (Carter, 2008). 8 mg/L has been identified in this document as the level at which there is “no impairment to production”. Similarly, this value exists in the North Coast Basin Plan water quality objectives for Lower Klamath HA streams (NCRWQCB, 2011). Concentration of DO is used in evaluating the WCs as opposed to the Klamath River TMDL which focuses on percent saturation. According to the Oregon Department of Environmental Quality and the Dissolved Oxygen Technical Advisory Committee, when evaluating DO levels, concentration criteria should be used rather than percent saturation when evaluating conditions other than those for early salmonid life stages (ODEQ, 1995). The Klamath River TMDL focuses entirely on percent saturation in regards to water quality objectives for the Klamath River, due to the fact that differences in elevation (atmospheric pressure), temperature and salinity vary throughout the Klamath River basin, making previous numeric targets for dissolved oxygen concentration unattainable at certain locations even under ideal conditions. WCs in this report all share similar elevations, temperature and salinity (South Slough is the exception) and differences are likely attributed to those factors independent of affecting water's oxygen holding capacity (photosynthesis, turbulence, respiration, organic decomposition, and oxygen demanding biological and chemical reactions).

Percent saturation is reported in this report but was not used in the determination of an overall water quality score. The criteria that was selected for this parameter is based on the North Coast Basin Plan objective for Lower Klamath HA streams and has a value of 85% (NCRWQCB, 2010). Under theoretical conditions this value would achieve a "no impairment to production" and also according to NCRWQCB,

"…85% saturation is the minimum percent saturation occurring in a healthy, free-flowing stream with moderate nutrient and organic loading" (NCRWQCB, 2010).

For the purposes of evaluating continuous DO data the daily minimum values have been used to derive an annual trend. Daily minimum values represent the extreme conditions that may trigger changes in fish behavior and metabolism, and in turn affect the site productivity for rearing. Daily minimum values are widely accepted as a way to evaluate continuous DO data (Carter, 2008).

2.2.4.3 pH

pH plays a critical role in the survival of fish at moderately high or low levels and can also affect aquatic organisms and vegetation. Changes in pH may be a result of dissolved gases such as carbon dioxide, hydrogen sulfide, and ammonia (indicators of pollution). pH also influences ammonia toxicity which has a direct effect on fish equilibrium hyperexciteability, increased breathing, cardiac output, oxygen uptake, and in extreme cases coma, convulsions and death (USEPA, 1986). Early life stages are more susceptible to threats of low pH than adults (Jordan and Benson, 1987). High pH levels can also interact with high water temperatures to create lethal conditions (Wagner et al., 1997). Appendix 4 of the Klamath River TMDL cites sources of information that indicate fish can tolerate levels from 6.0-9.0 and maintain normal activity (Carter, 2008). The pH conditions reported here are typically within the conservative range of 6.5-8.5, set forth in the North Coast Basin Plan specific to Lower Klamath HA streams. Therefore, pH parameter scores were given less weight in the overall water quality score.

2.2.4.4. Turbidity

Turbidity plays a critical role the survival of fish, and aquatic organisms. Turbidity can also be related to the amount of sediment suspended in the water column. Sediment is typically detrimental to successful spawning as the eggs have a decrease chance of survival as fine sediment increases (NCRWQCB, 2006). Often overlooked, sediment can also have detrimental effects on older juvenile salmonids. Detrimental effects of turbidity include avoidance response, reduced feeding rates, reduced growth rates, damage to fish gills, and fatality (MacDonald et al., 1991). In addition, increased sediment can lead to decreased populations of benthic macroinvertebrates, a food source for fish. Small amounts of turbidity can be beneficial to juvenile salmonids as it serves as cover in hiding from predators (MacDonald et al., 1991). Turbidity is dependent on many influences including intrinsic differences in a watershed's attributes (e.g., geology, soils, stream and slope gradient) that affect erosion. In addition, the relationship between suspended sediment and turbidity is variable (NCRWQCB, 2006). Criteria for evaluation and the subsequent water quality score are based upon values extracted from *Desired Salmonid Freshwater Habitat Conditions For Sediment-Related Indices* (NCRWQCB, 2006). This document review literature pertaining to research done on turbidity and sediment affects on salmonids. The current value of 25 NTU has been extracted from this document and applied in the water quality score but carries little weight due to the conditions found in the study and that fact that projecting annual trends for turbidity appears less representative of actual conditions and the exponential nature of “pulse” turbidity values.

2.2.4.5 Specific Conductivity

Specific conductivity plays a critical role in the determination between salt water and freshwater influence on wetland hydrology. Specific conductivity also helps determine the validity of other water quality parameters collected in tandem with the data sonde. Very little literature exists which pertains to specific conductivity levels and the effects on salmonids. Compared to high specific conductivity levels tolerated by salmonids in the ocean, freshwater ranges are relatively small and insignificant. This parameter is reported in this report but does not play a role in determining the overall water quality score in a WC. The criteria for evaluating this parameter is based on the NCRWQCB Basin Plan values for Lower Klamath HA streams of 120-200 $\mu S/cm^2$. The criteria was developed to protect water quality in general for beneficial uses as a part of anti-degradation laws, but is not specific to water quality requirements for salmonids.

2.2.5 WQ Monitoring Sites:

Site locations for water quality monitoring include two sites in each WC (Figure 10). One data sonde was located at the top of the WC where flow enters, and one data sonde was located at the bottom, where flow coalesces into a stream. The two data sets together will capture changes to water quality occurring within the wetland and allow for a more accurate characterization of water quality conditions as compared to one representative data set from one location within the WC. Where possible locations were selected based on the existence of previously collected data. In 2007 and 2008, YTEP and YTFP collected data in off-estuary tributary WCs, as a part of a fisheries habitat monitoring effort. Although the previous data was not collected with the same frequencies, equipment and procedures; the previous collected data sets can give another layer of confidence in characterizing wetland water quality, which can vary from year to year with annual fluctuations in seasonal air temperature and rainfall.

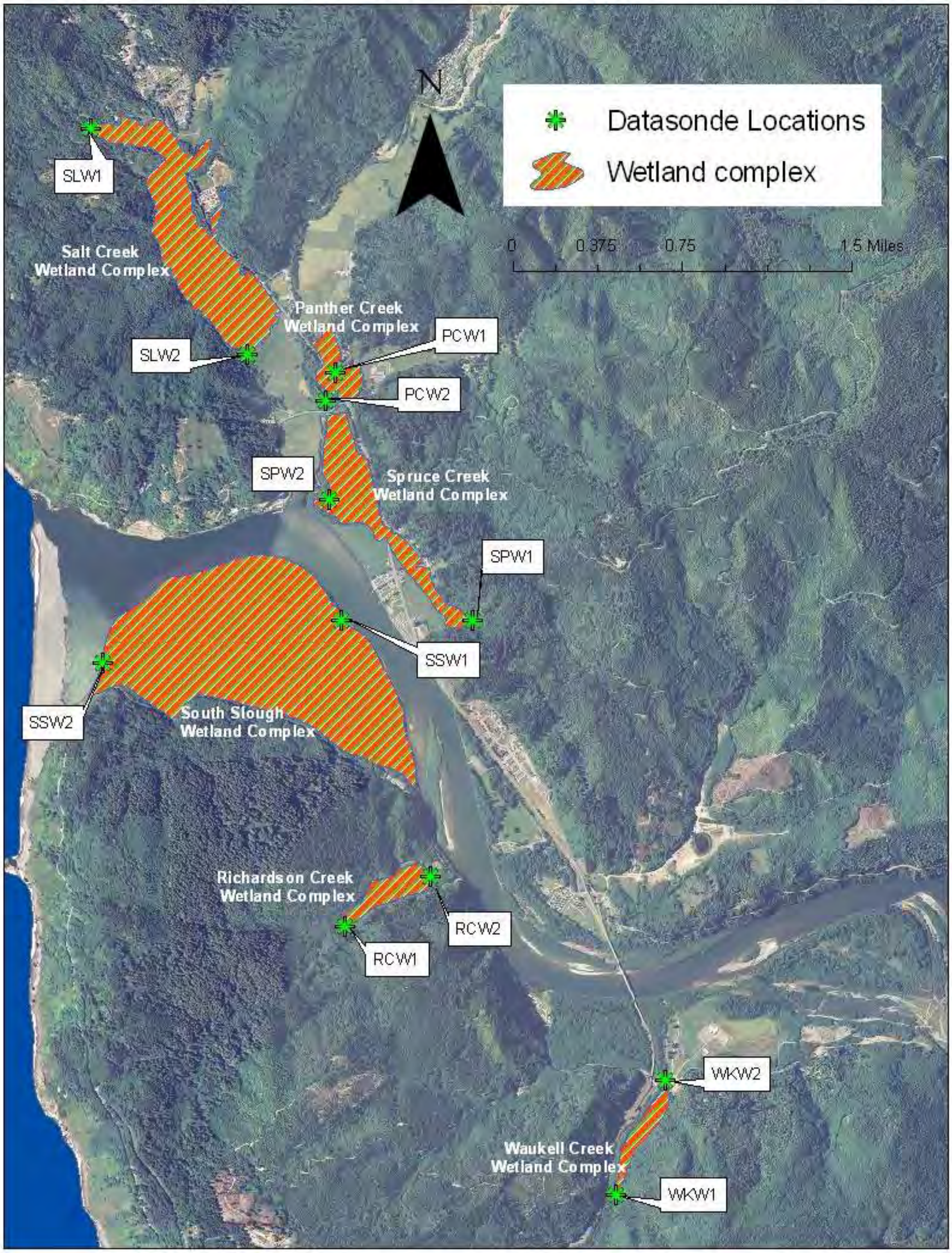

Figure 10: Water quality monitoring locations (data sonde) in each WC, with site IDs.

2.3 Fisheries Methods

2.3.1 Evaluating Juvenile Salmonid Rearing Habitat

YTFP used previously collected fisheries and physical habitat data, site condition assessments and observations, and professional judgment to develop a set of ten parameters to allow for an initial assessment of the functionality of the KRE wetlands as juvenile salmonid rearing areas (Table 3). Although YTFP-LKD has been conducting fisheries research and habitat assessments in the KRE and in off-estuary tributaries since 2000, this data was collected as part of separate projects with different but related objectives than those addressed by this current study. YTFP-LKD has conducted fisheries and habitat assessments in each of the KRE wetlands; however, we have more extensive data for some of the sites than we do for other sites. Therefore, YTFP-LKD only included parameters in which data and/or information existed for all of the KRE wetlands. The set of parameters and assigned point values should be considered a working draft that YTFP-LKD will continue to refine and expand as more study-specific data is collected in subsequent phases of YTEP's wetland program.

Juvenile salmonid rearing habitat parameters were assessed and the resulting scores were recorded for all of the KRE study wetlands. Assigned point totals were then summed for each KRE wetland to obtain an overall score. A total of 35 points were possible with the higher point totals representing the wetlands with the highest functional juvenile salmonid rearing habitat (Table 3). Not all fish habitat parameters were given equal weight and some of the parameters incorporated a certain degree of subjectivity (e.g. high, medium or moderate, and low) (Table 3). The parameters given the highest point values were considered the most beneficial to juvenile salmonid rearing habitat productivity; whereas zero or negative values related to conditions perceived the most detrimental to juvenile salmonid rearing habitat productivity (Table 3).

2.3.2 Juvenile Salmonid Rearing Habitat Parameters

Parameters used to assess the functionality of the KRE wetlands as juvenile salmonid rearing habitats focused on five categories: 1) native fish species diversity, 2) rearing habitat availability, 3) rearing habitat complexity, 4) rearing habitat impairment, and 5) proximity to large water bodies (Table 3).

2.3.2.1 Native Fish Species Diversity

Native fish diversity is critically important to the Yurok Tribe. Habitats that support multiple native salmonid species for part or all of their lives were valued more than areas with low native salmonid diversity. Parameters in this category included: Natal Salmonid Populations, and Non-Natal Coho Use (Table 3). The total number of points possible for native salmonid diversity was five (Table 3).

2.3.2.2 Rearing Habitat Availability

Availability and access to high quality juvenile salmonid rearing habitat is one of the most important factors influencing salmonid survival in the Klamath Basin. The availability of complex, slow velocity habitats in the Lower Klamath River are especially important to ESA listed Klamath Basin coho populations; however, YTFP-LKD has documented use of these types of habitats by all of the other native salmonid species (Soto et al., 2008; Hillemeier et al., 2009; Silloway, 2010; Silloway and Beesley, 2011; Hiner et al., 2011). Parameters in this category included: Rearing Habitat Availability, and Low Flow Access (Table 3). The total number of points possible for this category was ten and comprised nearly 29% of the overall score based on the importance of rearing habitat availability to native salmonids.

Table 3: Parameters used to assess juvenile salmonid rearing habitat functionality of Klamath River wetland complexes, California.

Parameter	Criteria	Points	Definition
Natal Salmonid Populations	High	3	Located in a watershed that supports spawning populations of chinook, coho, steelhead, and coastal cutthroat
	Med	2	Located in a watershed that supports spawning populations of coho, steelhead, and coastal cutthroat
	Low	1	Located in a watershed that only supports spawning populations of trout (steelhead and coastal cutthroat)
	No	0	Located in a watershed that does not support spawning populations of salmon or trout
Non-Natal Coho Use	Yes	2	YTFP has documented use of the wetland complex by non-natal juvenile coho salmon
	No	0	YTFP has not documented use of the wetland complex by non-natal juvenile coho salmon
Rearing Habitat Availability	Yes	5	Wetland complex supports juvenile salmonid winter-spring and summer rearing
	Partial	3	Wetland complex supports juvenile salmonid winter-spring rearing only
	No	0	Wetland complex does not support juvenile salmonid rearing
Low Flow Fish Access	Yes	5	Unimpeded access to wetland complex during low flow periods
	Partial	2	Partial or limited access to wetland complex during low flow periods
	No	0	No access to wetland complex during low flow periods
Non-Native Fish Species	Yes	0	YTFP has documented use of the wetland complex by non-native fish species
	No	2	YTFP has not documented use of the wetland complex by non-native fish species
Bull Frogs	Yes	0	YTFP has documented use of the wetland complex by bull frogs
	No	2	YTFP has not documented use of the wetland complex by bull frogs
Invasive Plant Impairment	High	-5	Current level of impairment prohibits salmonid rearing
	Med	0	Current level of impairment greatly inhibits salmonid rearing habitat capacity and productivity
	Low	2	Current level of impairment is low to moderate
	No	5	Invasive plants do not currently impair salmonid rearing habitat capacity and productivity
Rearing Habitat Complexity	High	5	High diversity and quantity of cover elements, shallow and deep water habitat, high potential for allochthonous input
	Med	2	Moderate diversity and quantity of cover elements, moderate diversity of depth, moderate allochthonous input potential
	Low	0	Minimal to no cover elements, low to no diversity of depth, low to no allochthonous input potential
Distance from Ocean	High	1	Wetland complex is 16.0 - 44.0 river miles upstream of the Pacific Ocean
	Med	2	Wetland complex is 4.0 - 16.0 river miles upstream of the Pacific Ocean
	Low	3	Wetland complex is 0.0 - 2.0 river miles upstream of the Pacific Ocean
Distance from Klamath River	High	1	Wetland complex is > 2.0 river miles upstream of the Klamath River
	Med	2	Wetland complex is 0.5 - 2.0 river miles upstream of the Klamath River
	Low	3	Wetland complex is 0.0 - 0.5 river miles upstream of the Klamath River

2.3.2.3 Rearing Habitat Impairment

Parameters that characterized factors currently limiting juvenile salmonid rearing included: Non-Native Fish Species, Bull Frogs, and Invasive Plant Impairment (Table 3). The number of points possible for this category ranged from nine to negative five and comprised nearly 26% of the overall score (Table 3). Non-native fish and bull frogs impact native fish and amphibian populations by increasing competition for food and space, and reducing survival due to increased predation. Invasive plants, especially reed canary grass (*Phalaris arundinacea*), can greatly reduce the functionality of juvenile salmonid rearing habitat by decreasing dissolved oxygen levels through respiration and decomposition, decreasing the amount of habitat available, limiting access to rearing areas, and reducing habitat diversity (Beesley and Fiori 2007 & 2008; Silloway, 2010; Silloway and Beesley, 2011). Therefore, the point range for the Invasive Plant Impairment parameter ranged from five to negative five (Table 3).

2.3.2.4 Rearing Habitat Complexity

In general, complexity of freshwater habitats is positively correlated to juvenile salmonid use and productivity (Cederholm et al., 1997; Koning and Keeley, 1997; Lestelle, 2007; Jeffres et al., 2008; Bisson et al., 2009). The only parameter in this category was Rearing Habitat Complexity and the total number of points possible was five (Table 3). Rearing habitat complexity was assessed based on the quantity and quality of cover elements available, the range of depths available, and the seasonal input of the allocthonous materials perceived beneficial to juvenile salmonids (e.g. terrestrial invertebrates, leaves and small woody materials that facilitate increased aquatic macroinvertebrate production) (Table 3).

2.3.2.5 Proximity to Major Water Bodies

As previously stated, mainstem and off-channel wetlands located in the Lower Klamath River Sub-basin provide critically valuable juvenile salmonid rearing habitat (Beesley and Fiori, 2004; Soto et al., 2008; Hillemeier et al., 2009; YTFP 2009; Silloway, 2010; Silloway and Beesley, 2011; Hiner et al., 2011). However, the proximity of an individual wetland to the Pacific Ocean or the mainstem river influences the number and diversity of juvenile salmonid use of these areas. Wetlands located within close proximity to the Pacific Ocean or the Klamath River have the ability to benefit multiple, non-natal salmonid populations (Soto et al., 2008; Hillemeier et al., 2009; YTFP, 2009; Silloway and Beesley, 2011; Hiner et al., 2011). Whereas wetlands located upstream of the coastal zone or miles upstream of the mainstem river receive less non-natal salmonid use relative to those habitats located within close proximity of the ocean and river.

2.4 Quality Assurance

2.4.1 CRAM

CRAM data used in this report was collected according to an USEPA approved QAPP developed in 2008 (Patterson, 2008). Staff collecting data were trained on the CRAM methodology at several practitioner-level trainings offered by the developers of CRAM. In addition, YTEP contracted with CRAM practitioners from Moss Landing Laboratories to perform QA on the CRAM assessments that YTEP performed. The scores were very similar and within the accepted range allowed considering the inherent variability of scores produced with the method (CWMW, 2009).

2.4.2 Water Quality

During this study, many QA/QC measures were undertaken to ensure that the continuous water quality data collected was of the highest quality. All field personnel that were involved in data sonde maintenance have been trained appropriately by the Water Division Program Manager and are properly supervised to ensure proper protocol is followed consistently throughout the monitoring season. Each field visit requires that staff fill out field data sheets and follow protocols appropriately in the field.

Data is thoroughly reviewed after it is downloaded from the data sonde. YTEP is the primary organization responsible for data review. The data manager visually inspects all data sets to check for inconsistencies with original field data sheets. Where inconsistencies are encountered, data will be re-entered and re-inspected until the entered data is found to be satisfactory or results will be discarded. Any unusual values outside the range of norm will be flagged and all aspects of field data sheets will be reviewed. Outliers will be identified and removed from the dataset if deemed necessary by the QA Officer. The Project Manager will maintain field datasheets and notebooks in the event that the QA Officer needs to review any aspect of sampling for QA/QC purposes. Data is reviewed and finalized once data are merged or entered into a database.

As per the project QAPP, YTEP graded all of the data and used the grades to determine when a correction to the data was necessary. In the QAPP for the project YTEP set a data quality objective of 90% usable data. YTEP was able to reach this goal and with the use of corrections made in Aquarius software, data was well over that mark. There were however some 7 periods of data that were lost in certain areas, for such reasons as battery failure, a sonde being temporarily stolen, and extreme tides causing the sonde to be “out of water”.

One parameter, turbidity, posed some difficult challenges due to the consistent clear water conditions found in many of the wetlands. The margin for error that exist in a fully calibrated turbidity probe, can lead to some poor grades. For example, if the probe is accurate to 2 NTU and measures 4 NTU in known liquid of 2 NTU, the error is 100%. In addition, turbidity probes operate on the absorbance of scattered light in the water sampled, and are very susceptible to interference from sunlight, and picking up free floating materials. The shallow nature of wetlands can compound these issues. In very clear water we have found that it is consistently difficult to maintain high grades for turbidity. As per USGS protocols some professional judgment should be used in determining whether a data set is valid (Wagner et al., 2006). YTEP has deemed the turbidity data useful in tracking trends in turbidity (i.e. seasonal changes in turbidity, changes in response winter storm events, etc.) regardless of the grade received and complications probes have in clear water.

2.4.3 Fisheries

YTFP is comprised of qualified and professional employees dedicated to restoring fisheries resources of the Klamath Basin. All YTFP fisheries biologists have at least a Bachelor’s Degree in Fisheries Biology or a comparable natural resource field and at least two years field experience. A majority of the fisheries technicians are Yurok Tribal members and have over five years of experience monitoring Klamath River salmonid populations. Lead biologist staff employ the following QA/QC procedures to all fisheries monitoring efforts: 1) providing proper training and oversight to staff, 2) ensuring the data is recorded accurately in the field, 3) ensuring the data is accurately entered into YTFP databases, and 4) ensuring the quality of the data analysis.

3.0 Results/Data

3.1 Water Quality

The results from the 2010 KRE Wetland Water Quality Study are presented in this section. Data is displayed in graphs and separated by WC.

3.1.1 Panther Creek WC (Figures 11 – 16, Table 4)

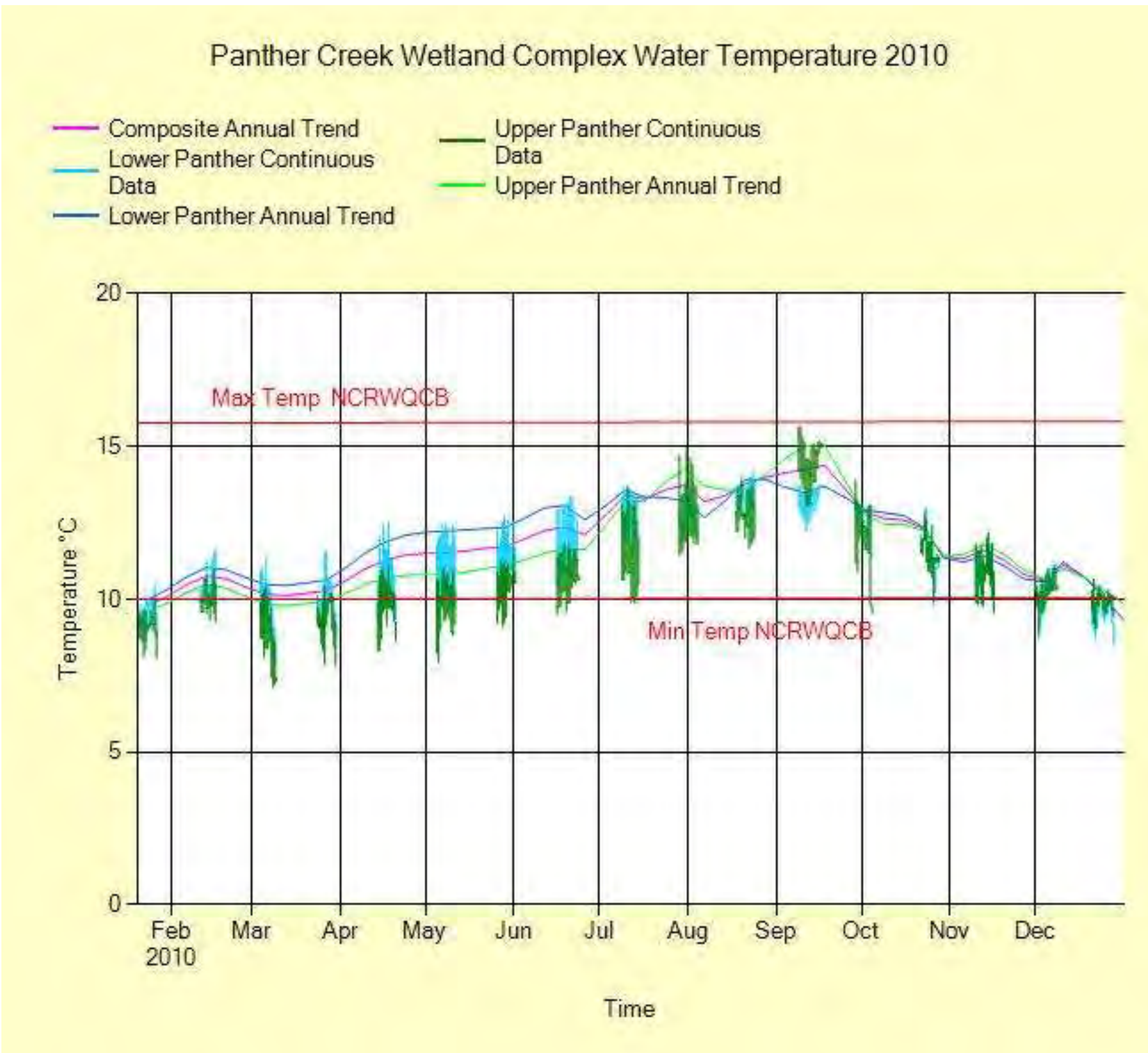

Figure 11: Panther Creek WC Water Temperature 2010, continuous data and annual trends.

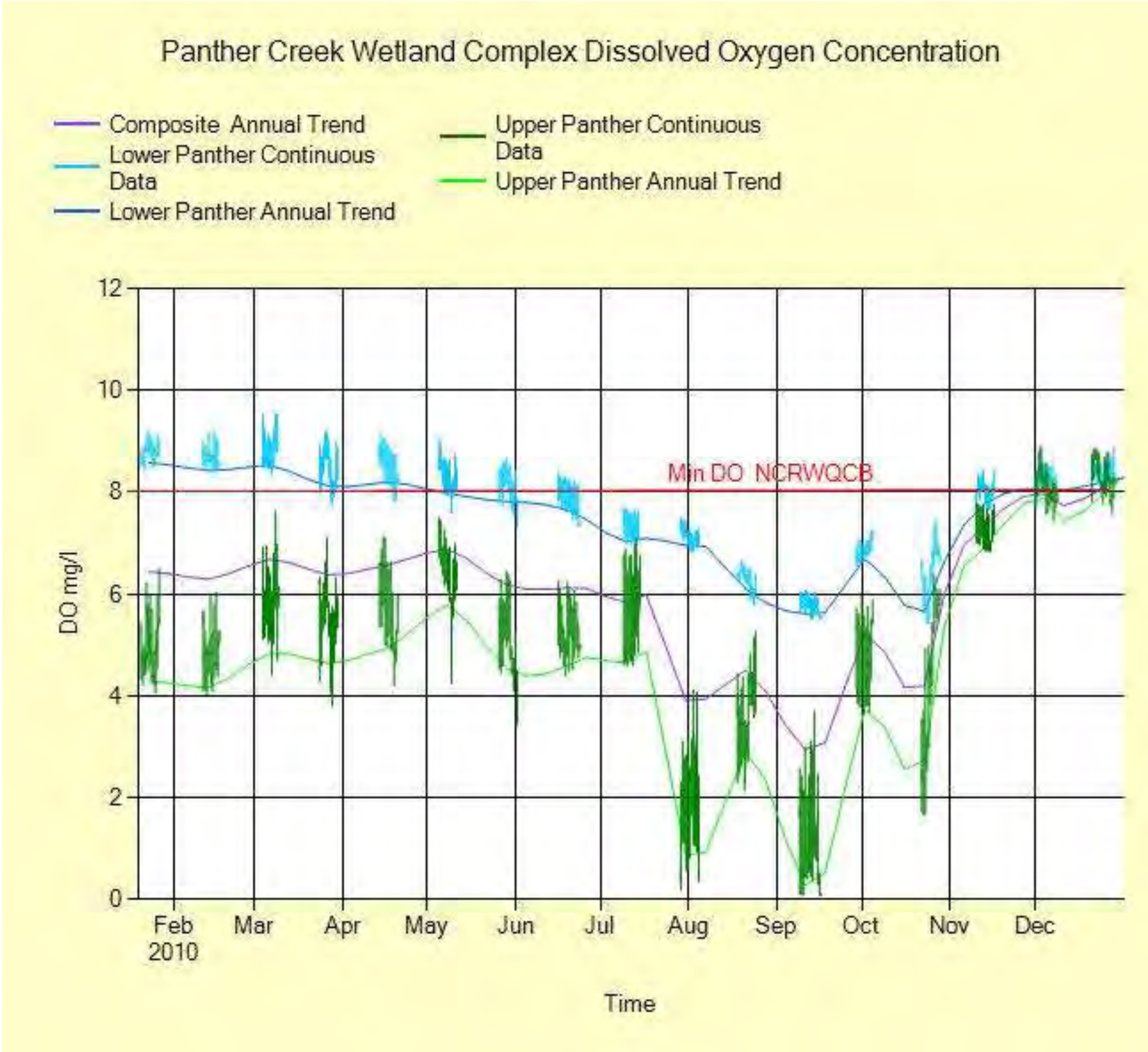

Figure 12: Panther Creek WC Dissolved Oxygen Concentration, continuous data and annual trends.

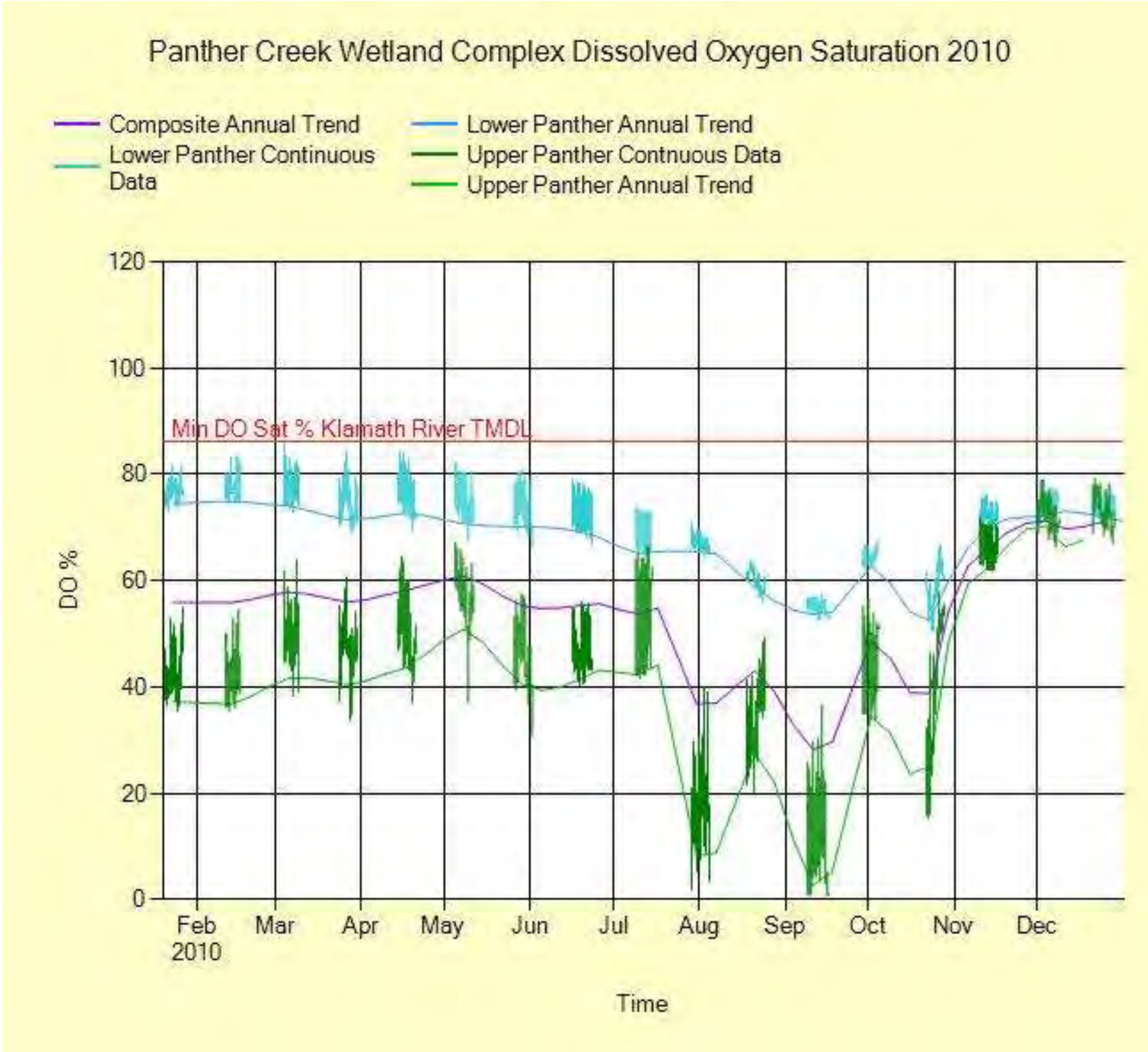

Figure 13: Panther Creek WC Dissolved Oxygen Percent Saturation, continuous data and annual trends.

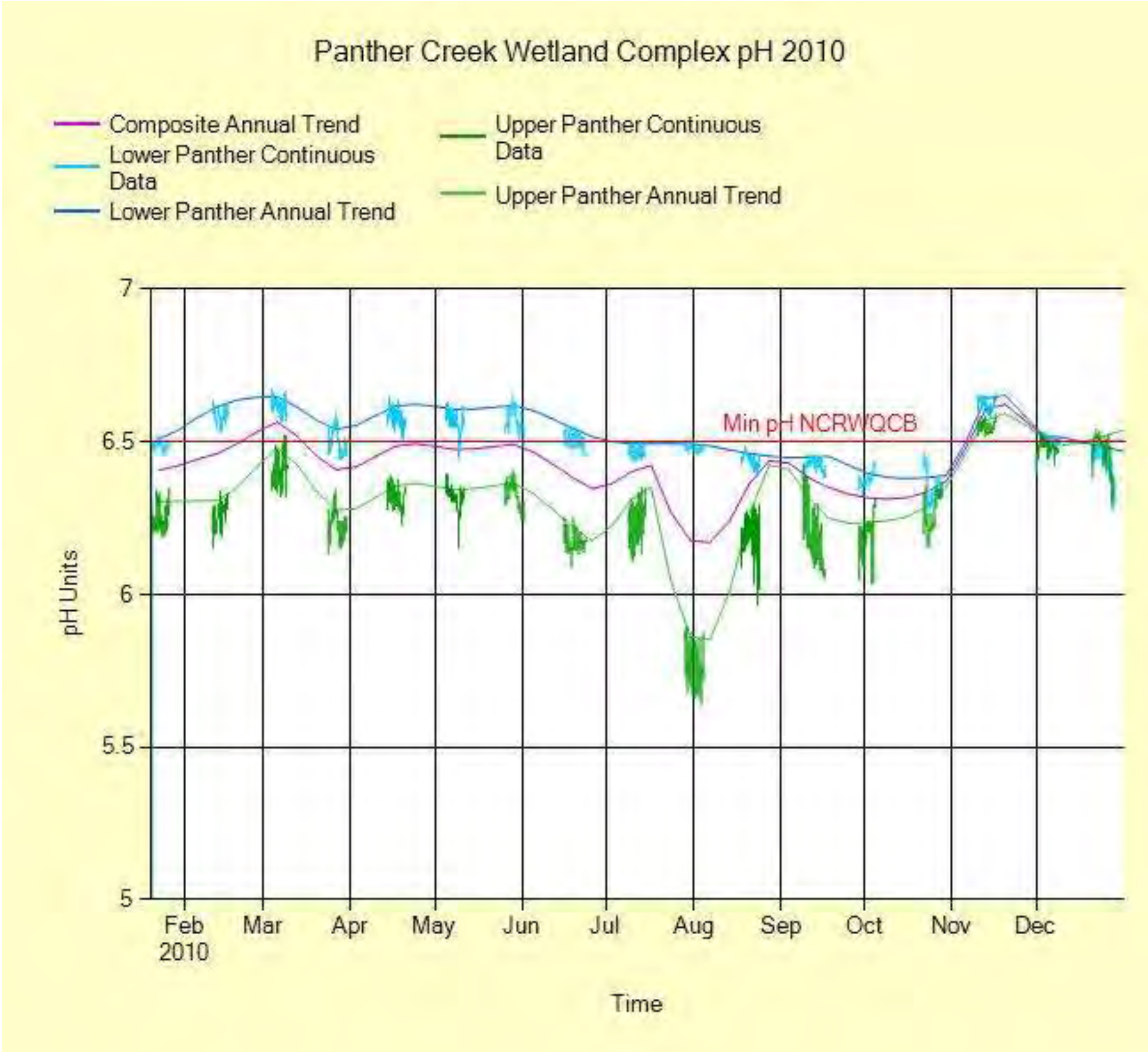

Figure 14: Panther Creek WC pH, continuous data and annual trends.

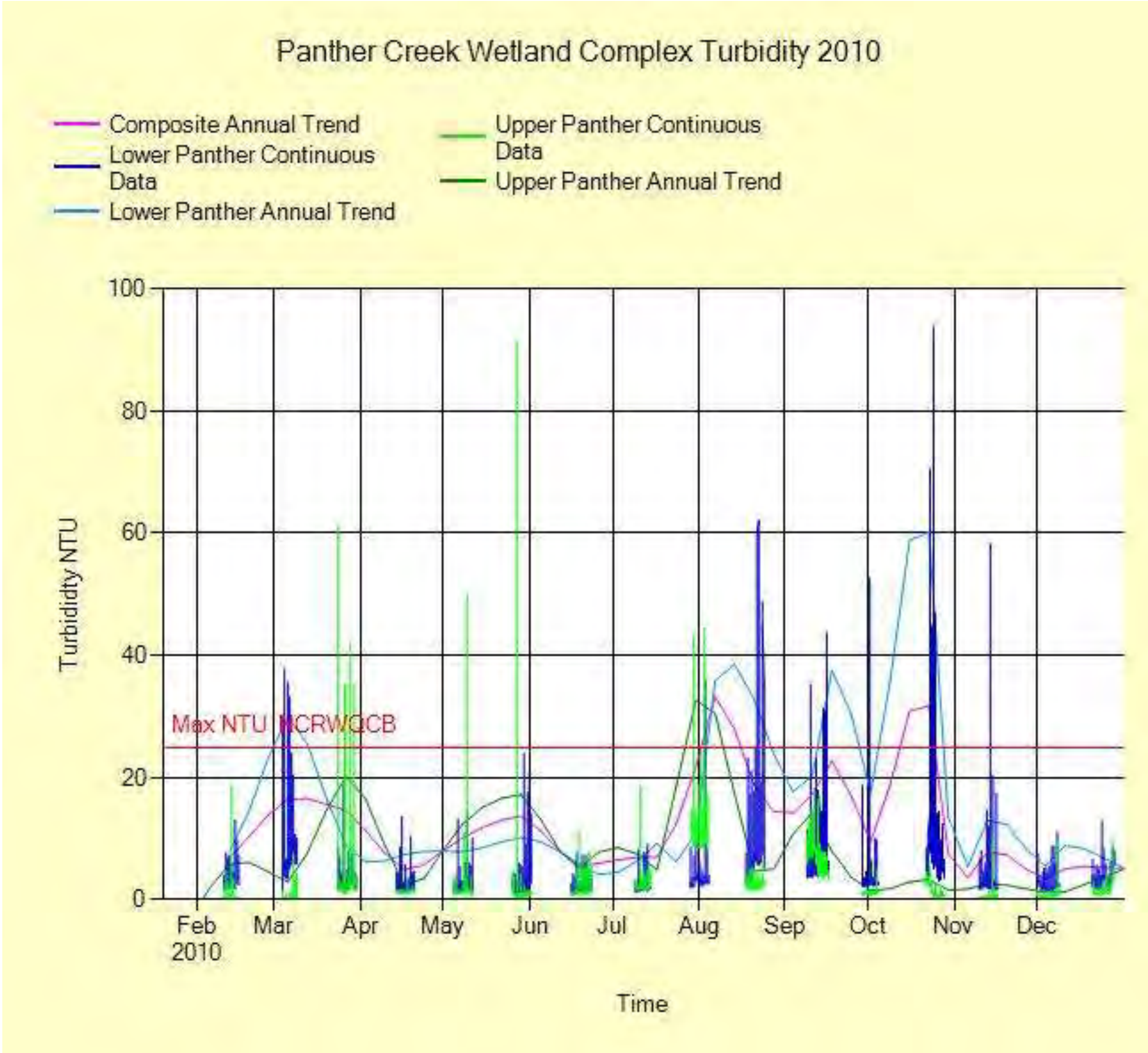

Figure 15: Panther Creek WC Turbidity, continuous data and annual trends.

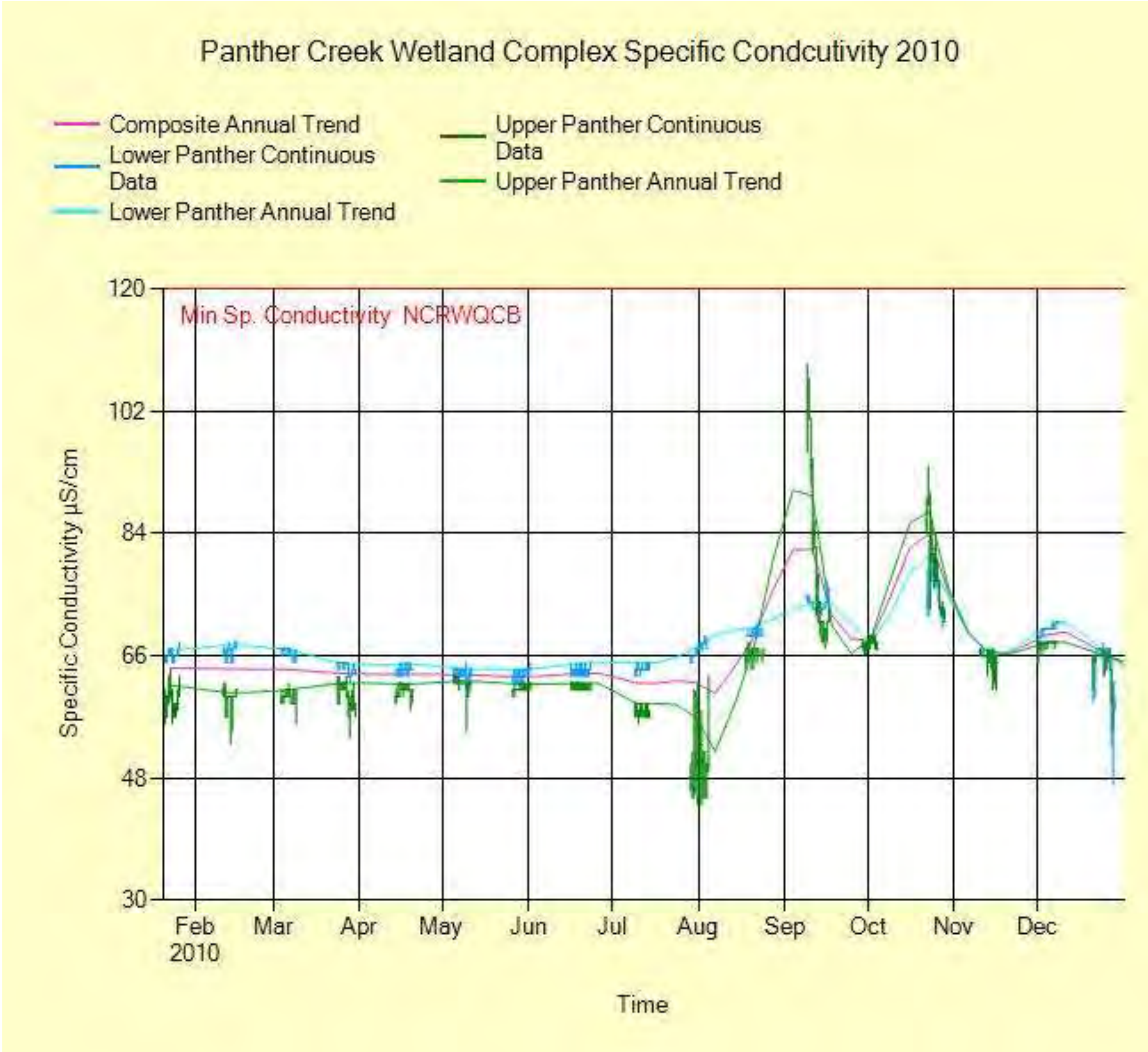

Figure 16: Panther Creek WC Specific Conductivity, continuous data and annual trends.

Table 4: Panther Creek WC water quality scoring based on percent exceedances of the parameters.

Parameter:	Threshhold	Days in Exceedance	Percent Exceedance	Weighting Factor	Parameter Score
Temperature	10 to 16	5.3	1.5	40	0.63
Dissolved Oxygen Concentration	8 mg/L	333.25	99.18	40	39.67
Dissolved Oxygen Saturation	85%	336	100	0	0
pH	6.5 to 8.5	0	0	10	0
Specific Conductivity	120 to 200	336	100	0	0
Turbidity	25	26.58	7.9	10	0.79
			Overall Water Quality Score:		41.09

Panther Creek composite minimum water temperature values exceeded the temperature criteria of 10 degrees C for 5.3 days. Composite maximum water temperature ranges reached 15 degrees C in September and minimum daily water temperatures dropped to 8 degrees C in January. Composite DO levels were nearly

100 percent exceedances for the year, both for concentration and percent saturation. Maximum DO concentration levels reached 9.5 mg/L in March, and minimum DO concentration levels dropped close to 0 mg/L in September. Maximum DO saturation levels reached 85% in March, and minimum DO saturation levels dropped close to O% in September. Maximum and minimum composite pH levels did not exceed the established pH range, with a high of 6.7 in November and a low of 5.7 in August. Maximum daily composite turbidity levels exceeded 25 NTUs for 27 days with a high of 90 NTU in November and June. The overall water quality score for Panther Creek is 41.09 which was heavily influenced by dissolved oxygen levels (Table 4).

3.1.2 Richardson Creek WC (Figures 17 – 22, Table 5)

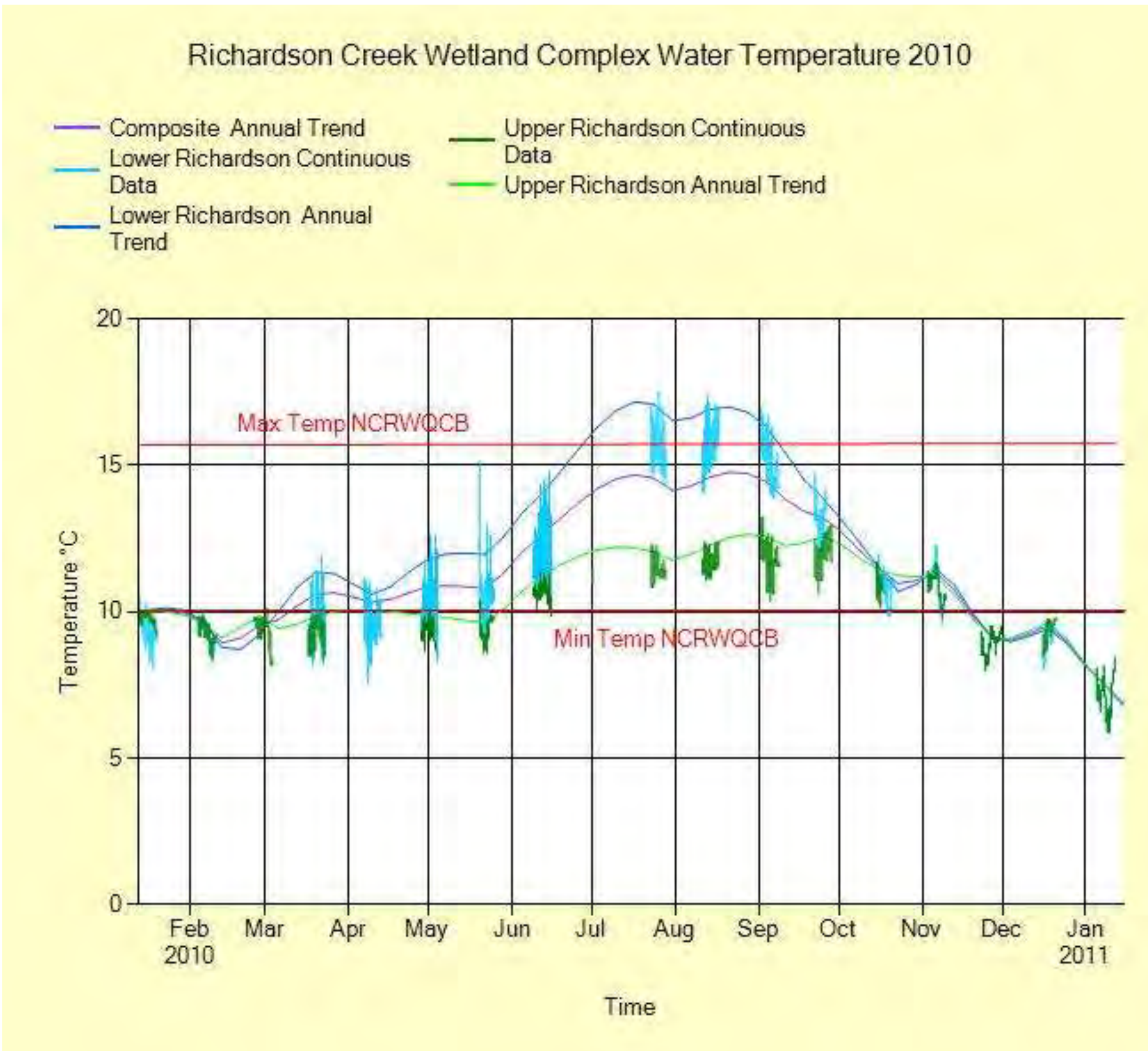

Figure 17: Richardson Creek WC Water Temperature 2010, continuous data and annual trends.

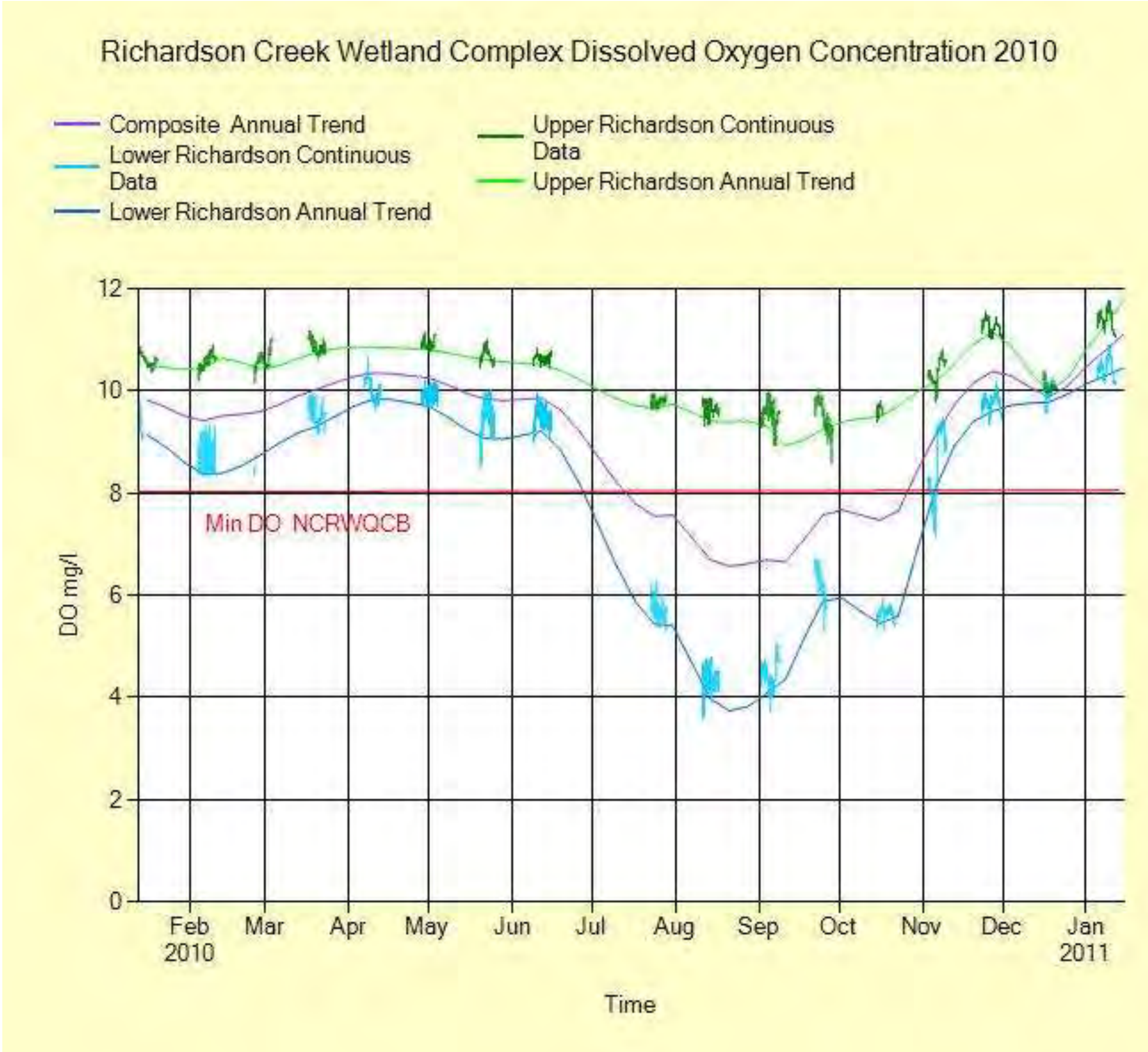

Figure 18: Richardson Creek WC Dissolved Oxygen Concentration 2010, continuous data and annual trends.

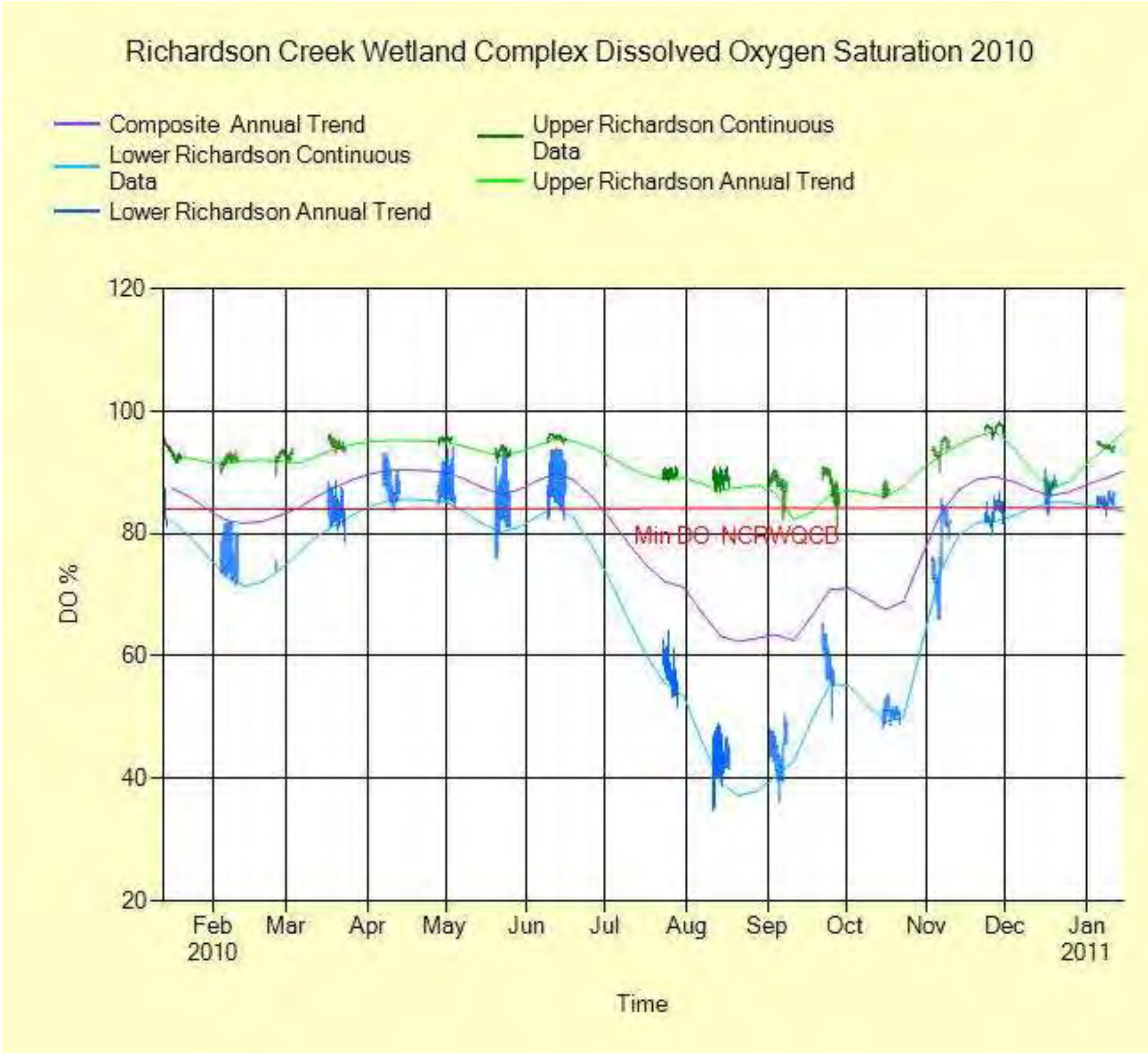

Figure 19: Richardson Creek WC Dissolved Oxygen Saturation 2010, continuous data and annual trends.

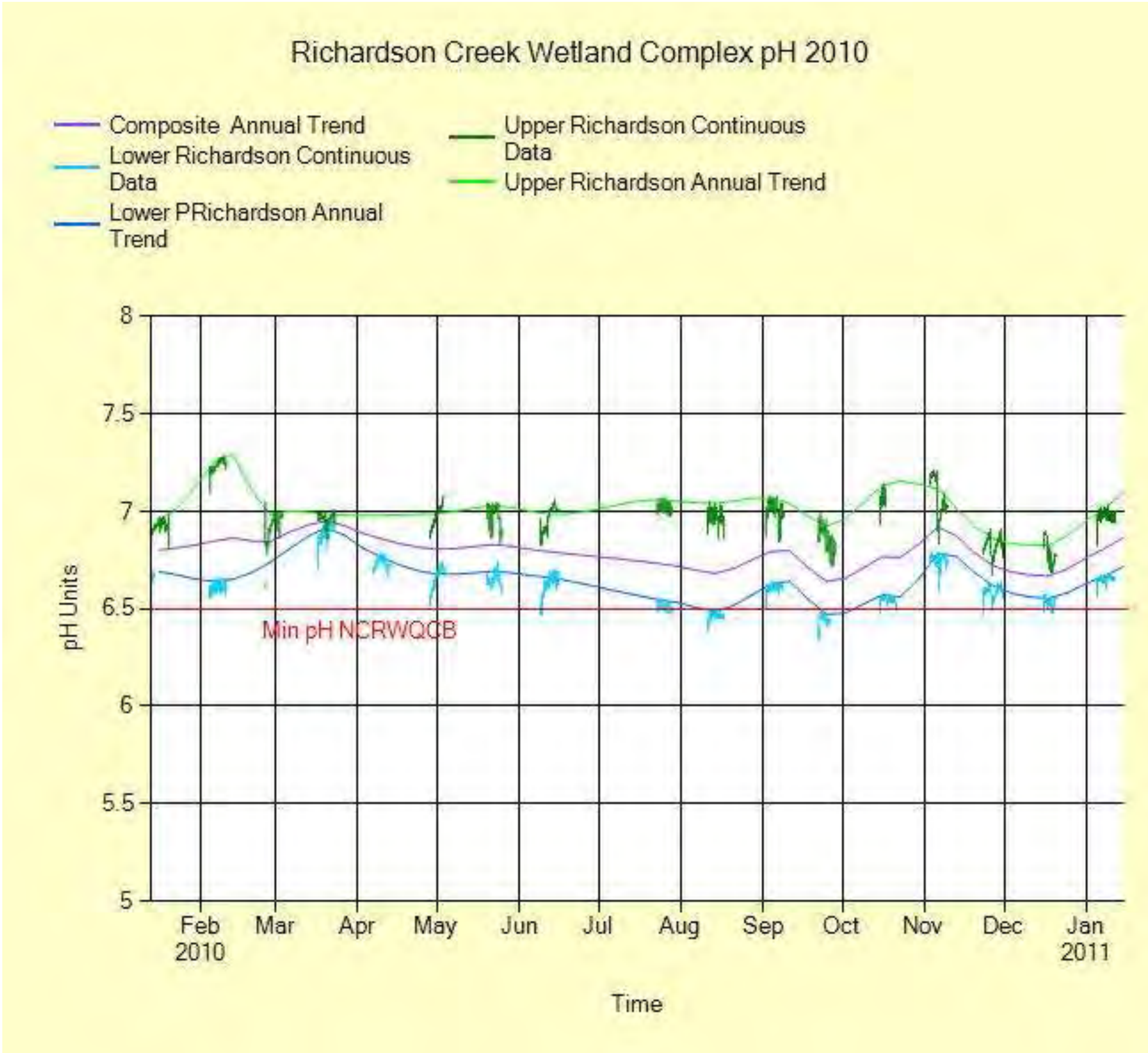

Figure 20: Richardson Creek WC pH 2010, continuous data and annual trends.

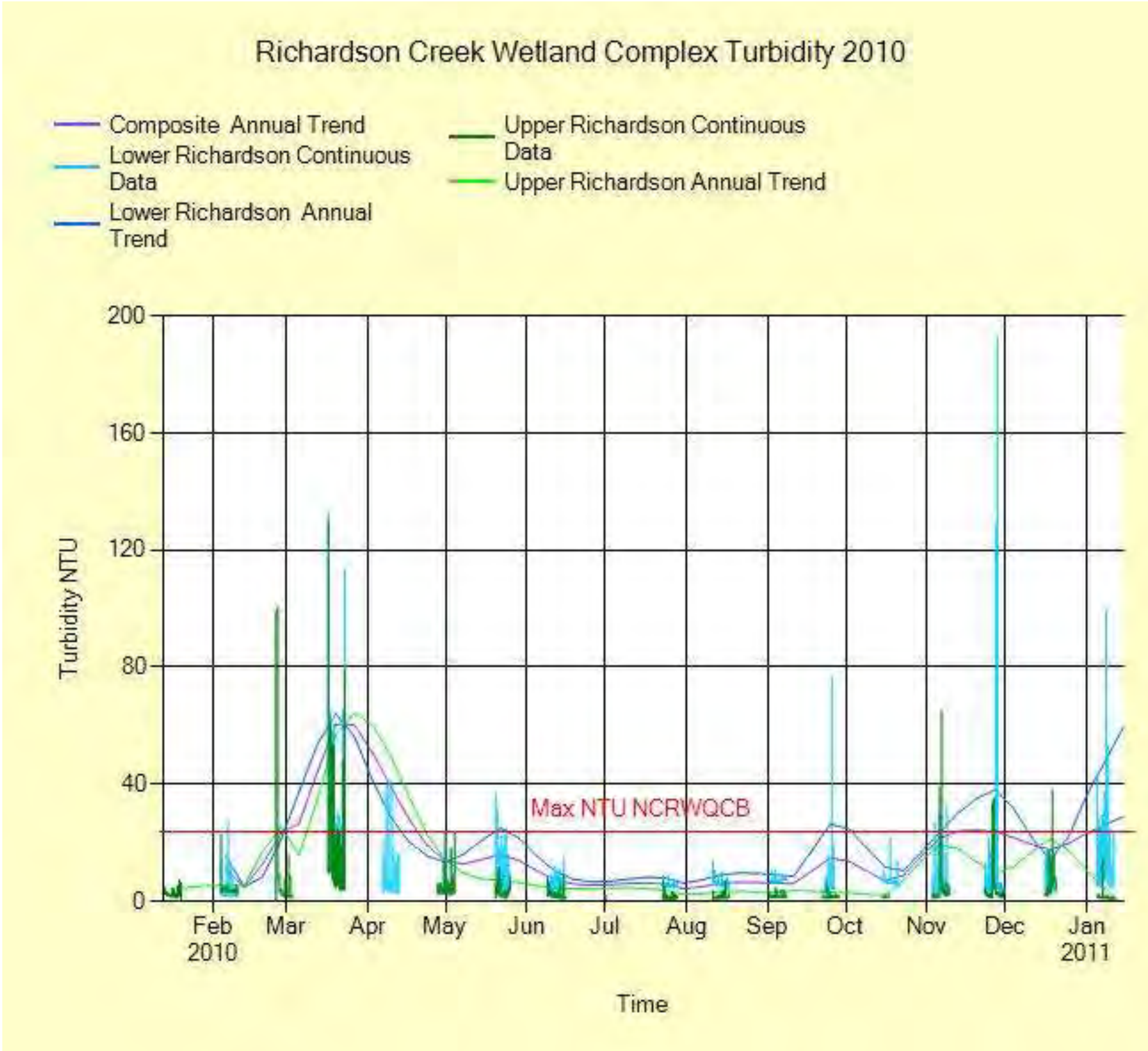

Figure 21: Richardson Creek WC Turbidity 2010, continuous data and annual trends.

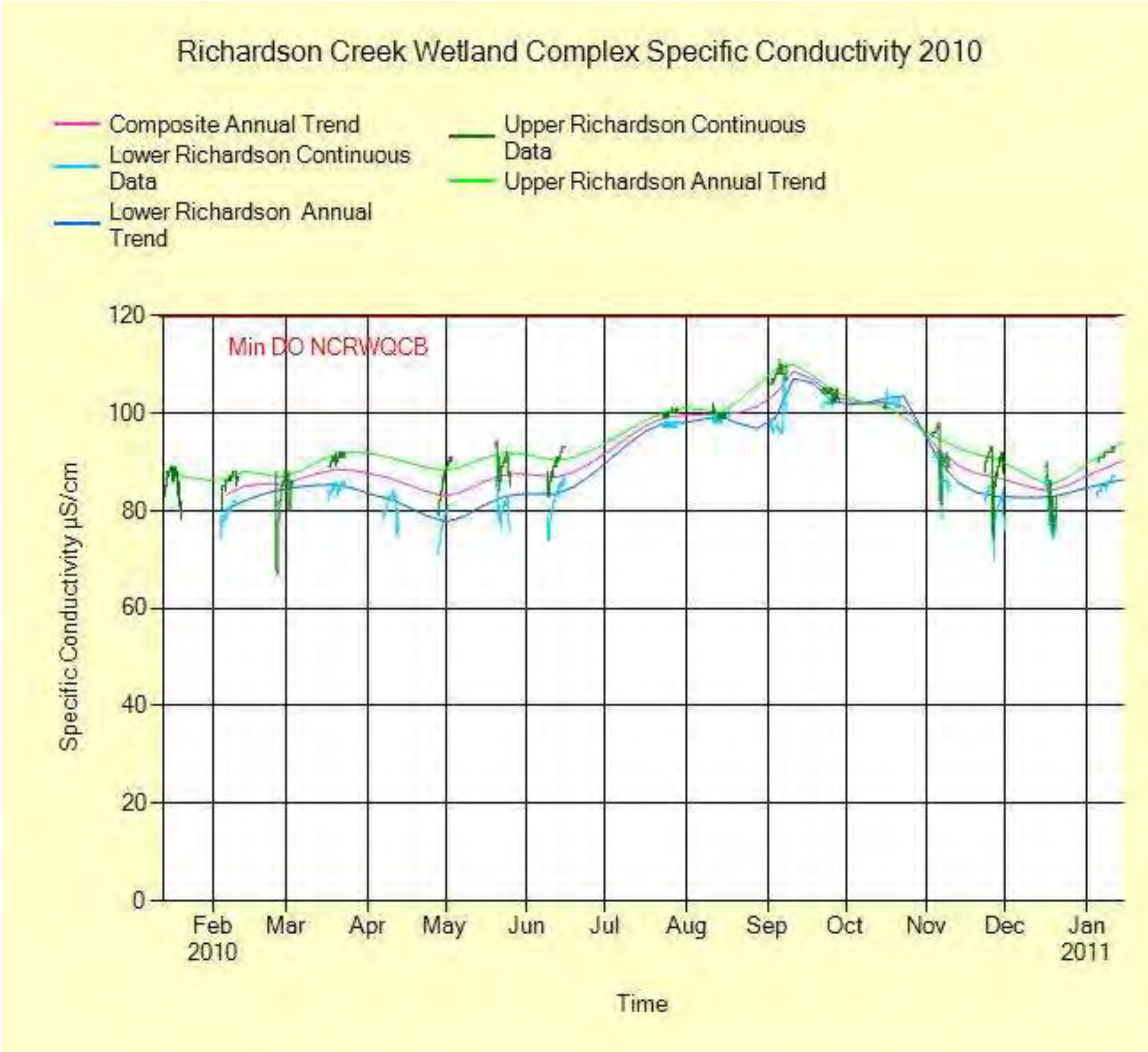

Figure 22: Richardson Creek WC Specific Conductivity 2010, continuous data and annual trends.

Table 5: Richardson Creek WC water quality scoring based on percent exceedences of the parameters.

Parameter/Units:	Threshhold	Days in Exceedance	Percent Exceedance	Weighting Factor	Parameter score
Temperature C°	10 to 16	98.99	27.20	40	10.88
Dissolved Oxygen Concentration mg/L	8 mg/L	104.5	28.71	40	11.48
Dissolved Oxygen Saturation %	85%	175.63	48.25	0	0
pH	6.5 to 8.5	0	0	10	0
Specific Conductivity µS/cm²	120-200	364	100	0	0
Turbidity NTU	25	41.57	11.42	10	1.14
			Overall Water Quality Score:		23.50

Composite minimum water temperature values fell below 10 degrees C for a total of 98.99 days in Richardson Creek WC. A high temperature of nearly 17 degrees C was observed in July, while a low temperature of approximately 7 degrees was observed in January. Composite DO levels exceeded threshold criteria for a total of 28.71 days for concentration and 48.25 days for saturation. A maximum concentration of 11.5 mg/L was observed in January, while a minimum of 3.7 mg/L was observed in August. DO saturation levels were highest in November at 90%. While low DO saturation levels near 35% were observed in August. Composite pH levels did not exceed the threshold criteria throughout the year. Maximum pH levels of 7.25 were observed in February, while minimum pH levels of 6.5 were observed in August and September. Composite maximum turbidity levels were determined to be in exceedance a total of 41.57 days, with a high turbidity value of 190 NTU in December. Composite specific conductivity levels were in exceedance for a total of 364 days, levels ranged from a low of 70 microsiemens in March to 110 microsiemens in September. The overall water quality score for Richardson Creek WC is 23.5.

<u>3.1.3 Salt Creek WC</u> (Figures 23 -28, Table 6)

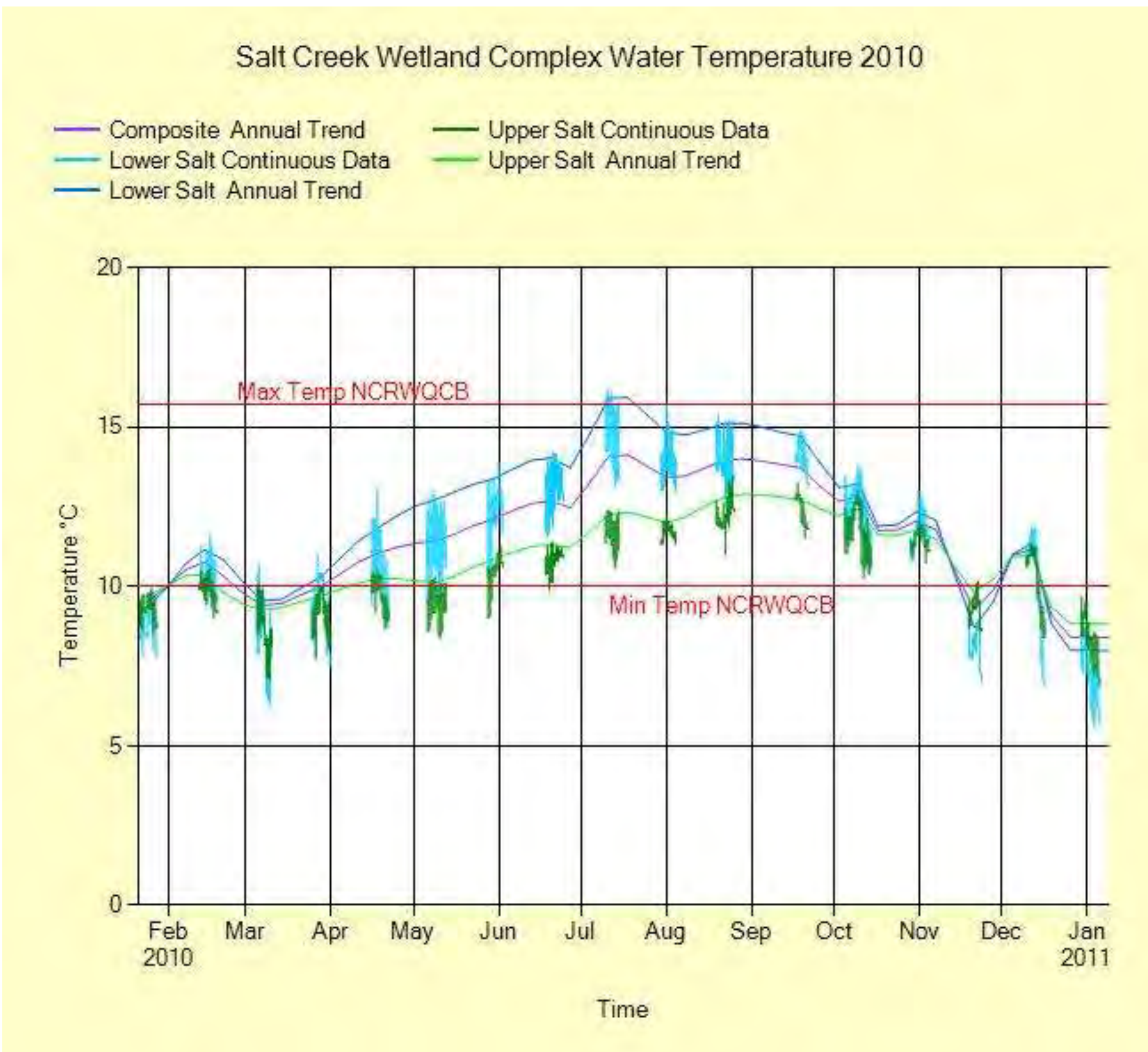

Figure 23: Salt Creek WC Water Temperature 2010, continuous data and annual trends.

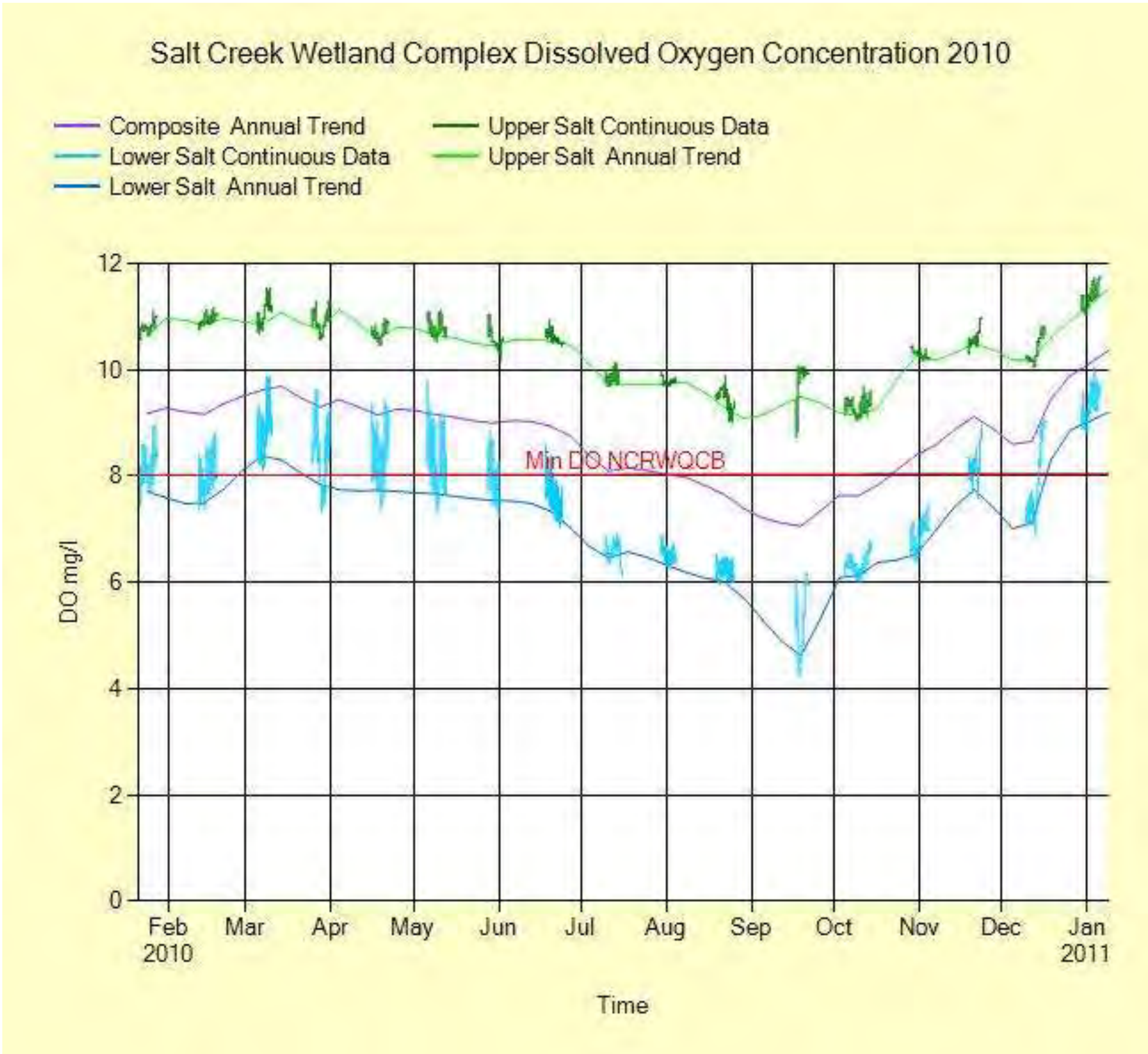

Figure 24: Salt Creek WC Dissolved Oxygen Concentration 2010, continuous data and annual trends.

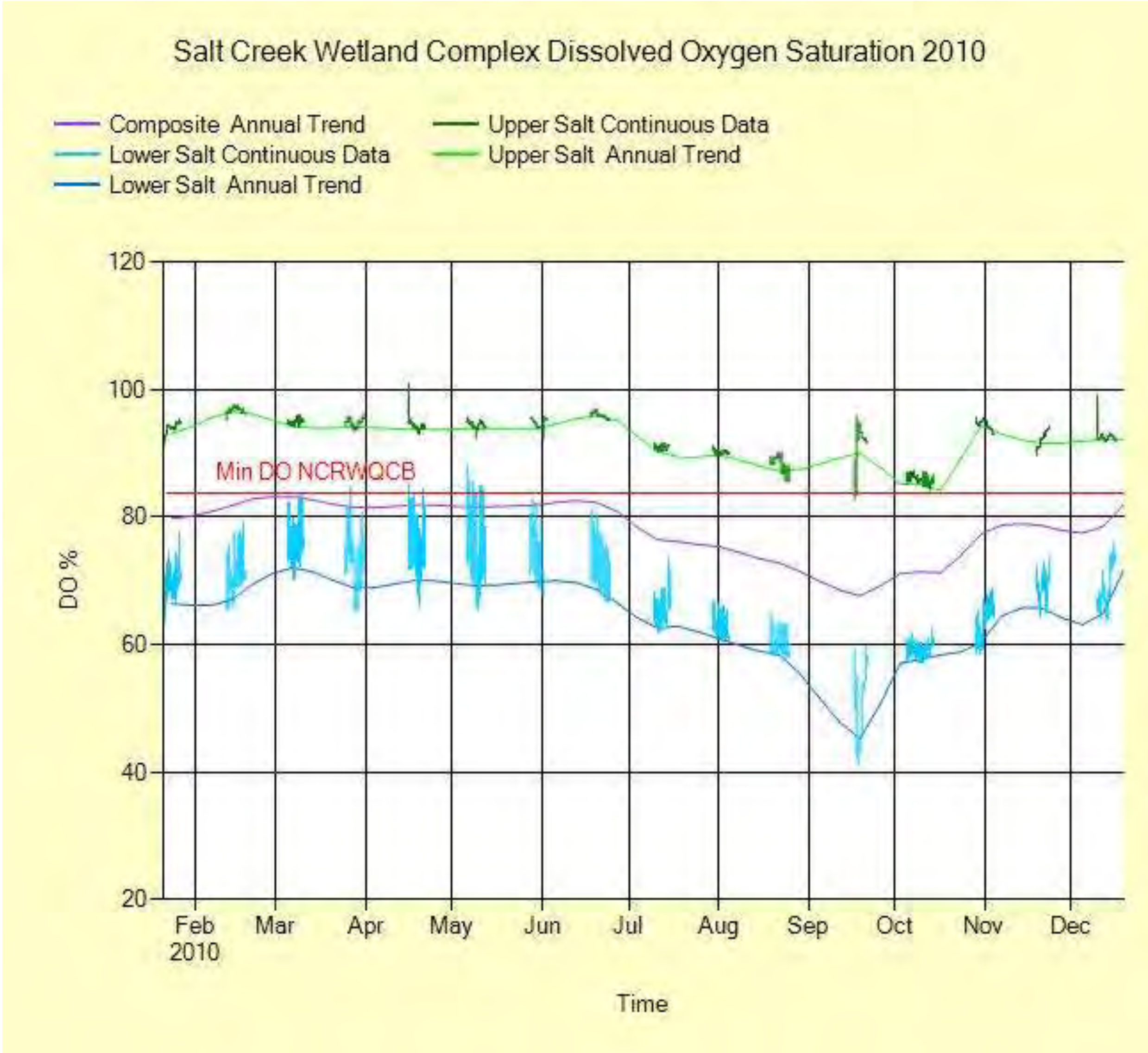

Figure 25: Salt Creek WC Dissolved Oxygen Saturation 2010, continuous data and annual trends.

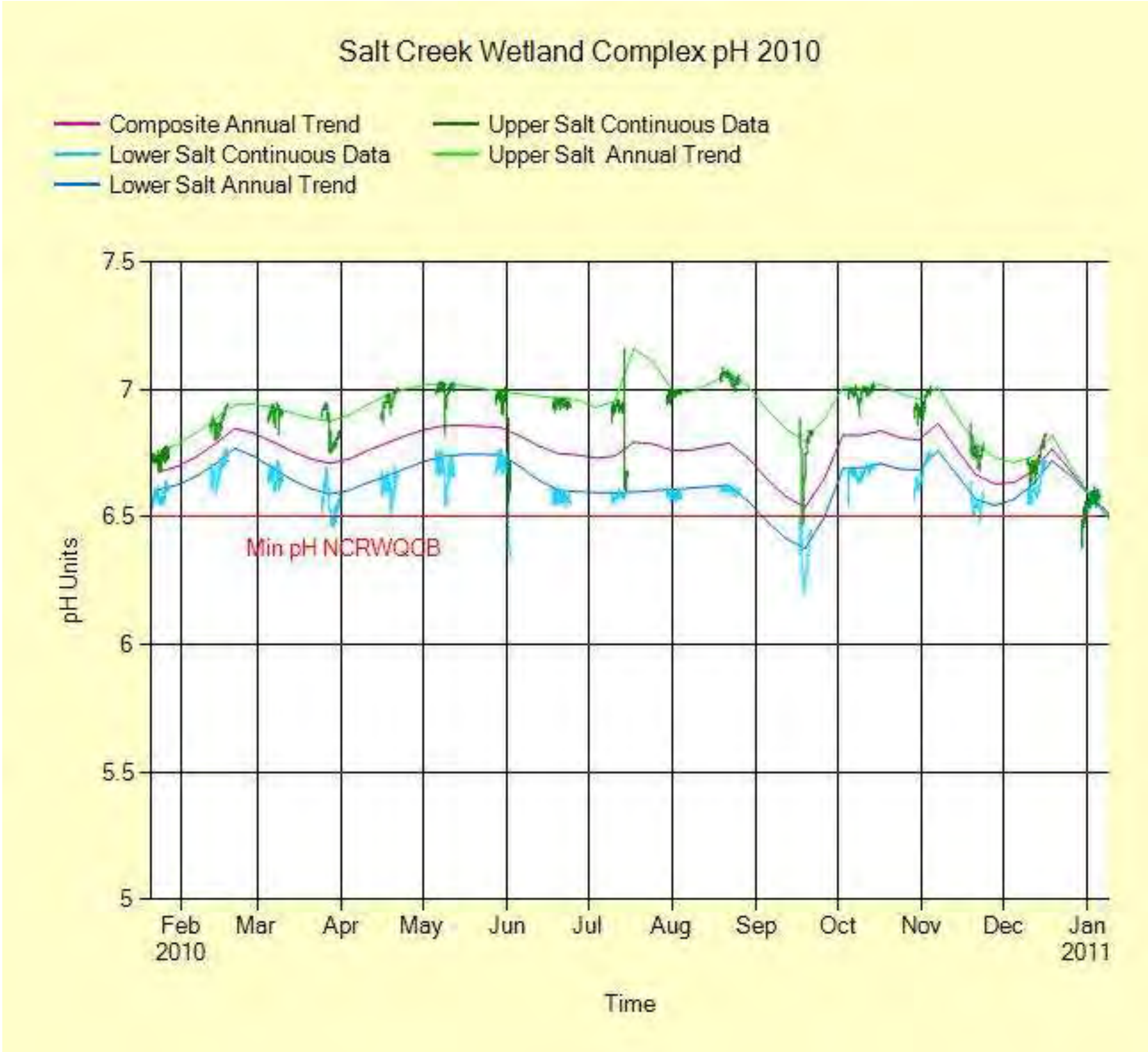

Figure 26: Salt Creek WC pH 2010, continuous data and annual trends.

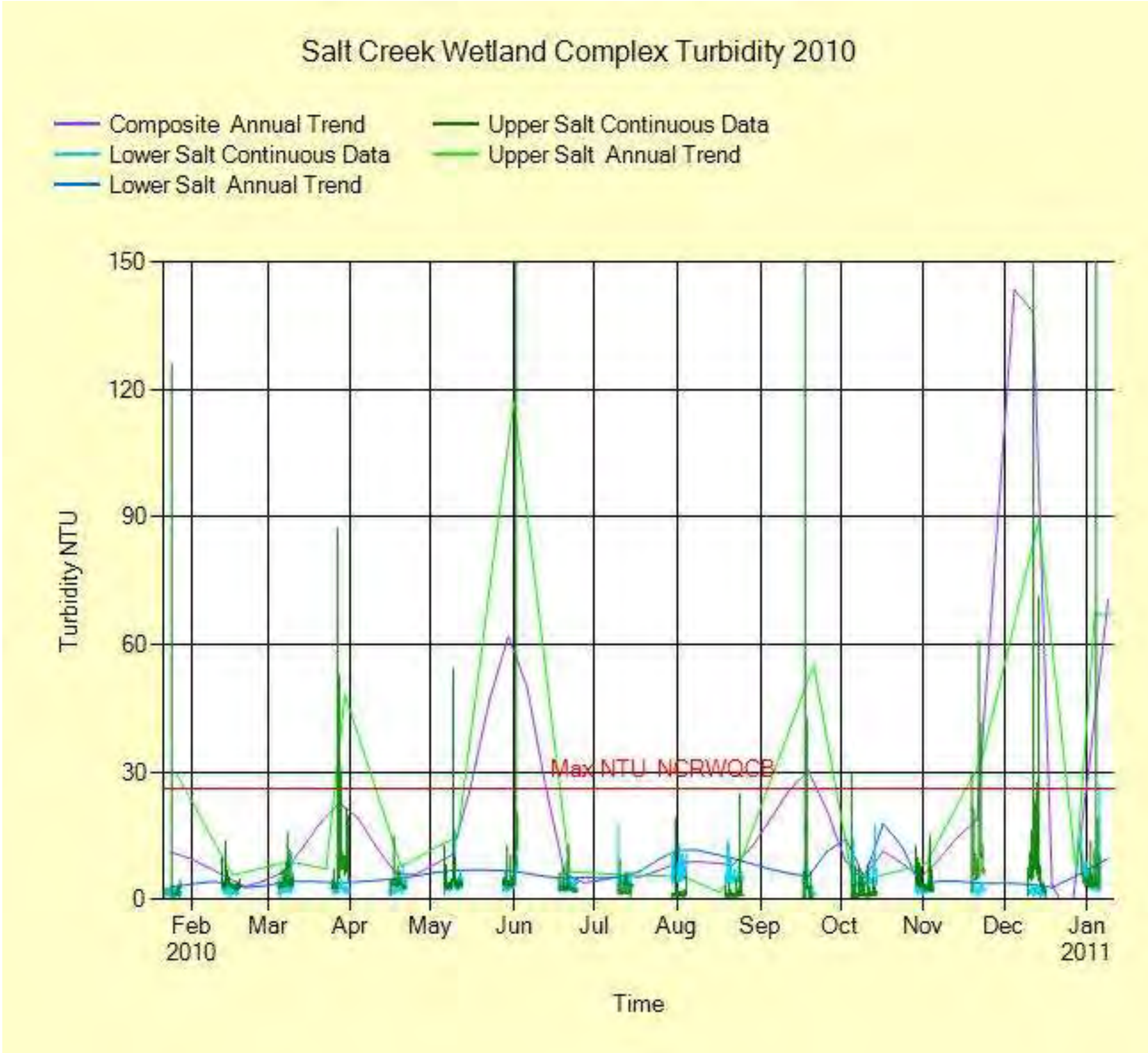

Figure 27: Salt Creek WC Turbidity 2010, continuous data and annual trends.

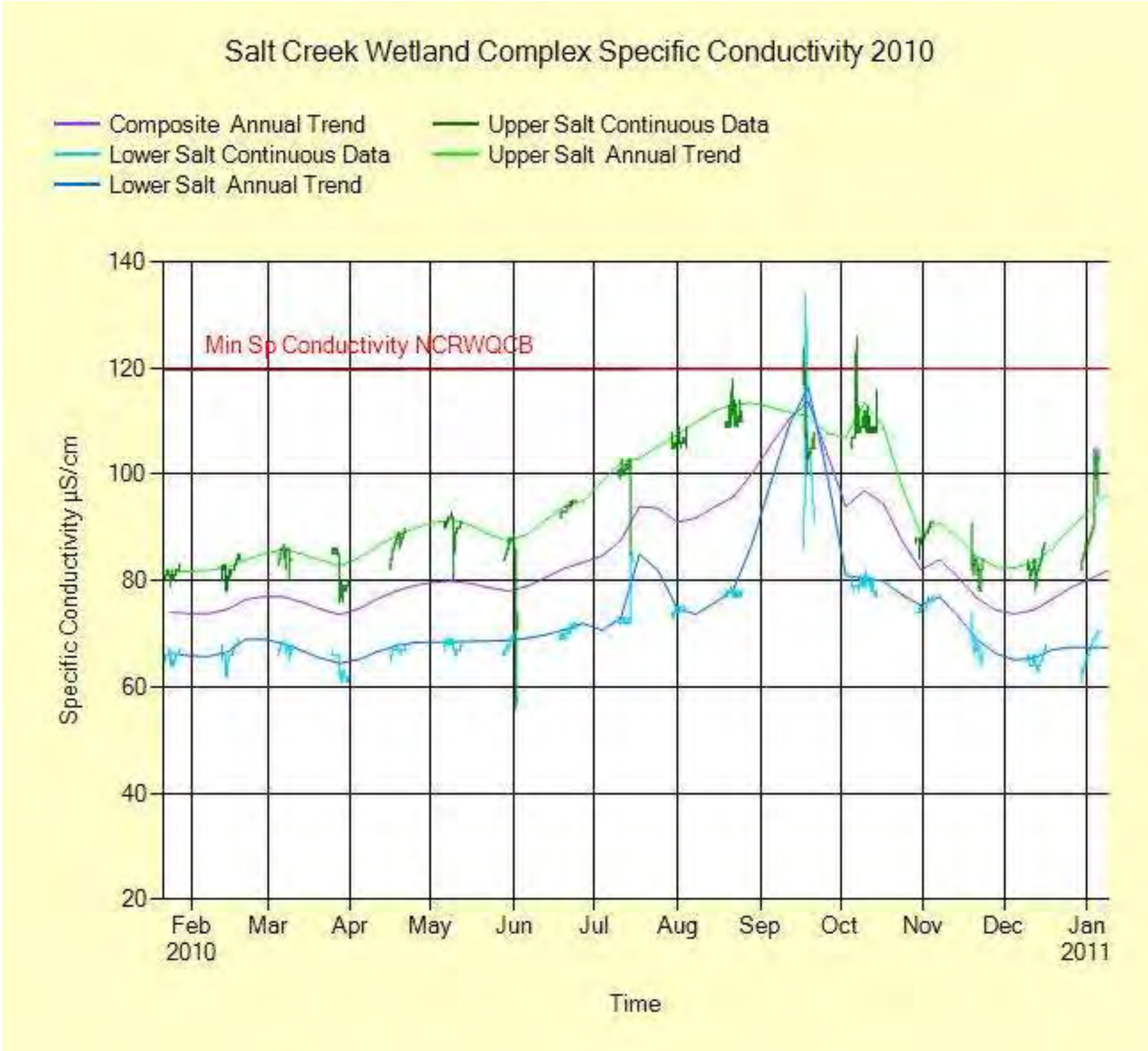

Figure 28: Salt Creek WC Specific Conductivity 2010, continuous data and annual trends.

Table 6: Salt Creek WC water quality scoring based on percent exceedances of the parameters.

Parameter/Units:	Threshhold	Days in Exceedance	Percent Exceedance	Weighting Factor	Parameter Score
Temperature C°	10 to 16	74.38	21.25	40	8.50
Dissolved Oxygen Concentration mg/L	8 mg/L	76.23	21.78	40	8.71
Dissolved Oxygen Saturation %	85%	337.8	96.51	0	0.00
pH	6.5 to 8.5	0	0	10	0
Specific Conductivity µS/cm²	120-200	350	100	0	0
Turbidity NTU	25	75.78	21.65	10	2.17
			Overall Water Quality Score:		19.38

Composite water temperatures in Salt Creek WC exceeded threshold criteria for a total of 74.38 days, all of them coming on the low end of the preferred range, below 10 degrees. A maximum water temperature of approximately 16 degrees was observed in July. A minimum temperature of 6 degrees was observed in January. Composite DO levels had differing levels of exceedances, 76.23 days for concentration, and 337.8 days for saturation. Maximum DO concentration levels were near 12 mg/L in January, and had a minimum of 4.5 mg/L in September. Maximum DO % Saturation levels reached a peak of 105% in April, and a minimum of 45% in September. Composite pH levels exceeded threshold for zero days in the year. Values ranged from a minimum of 6.7 in September to a maximum of 7.2 in July. Composite turbidity levels exceeded threshold for 75.78 days, with a peak value of 200 NTU occurring in January. Composite specific conductivity levels were in exceedance for 350 days, and values ranged from 60 microsiemens in January to 130 microsiemens in October. The overall water quality score for Salt Creek WC is 19.38.

3.1.4 South Slough WC (Figures 29 – 34, Table 7)

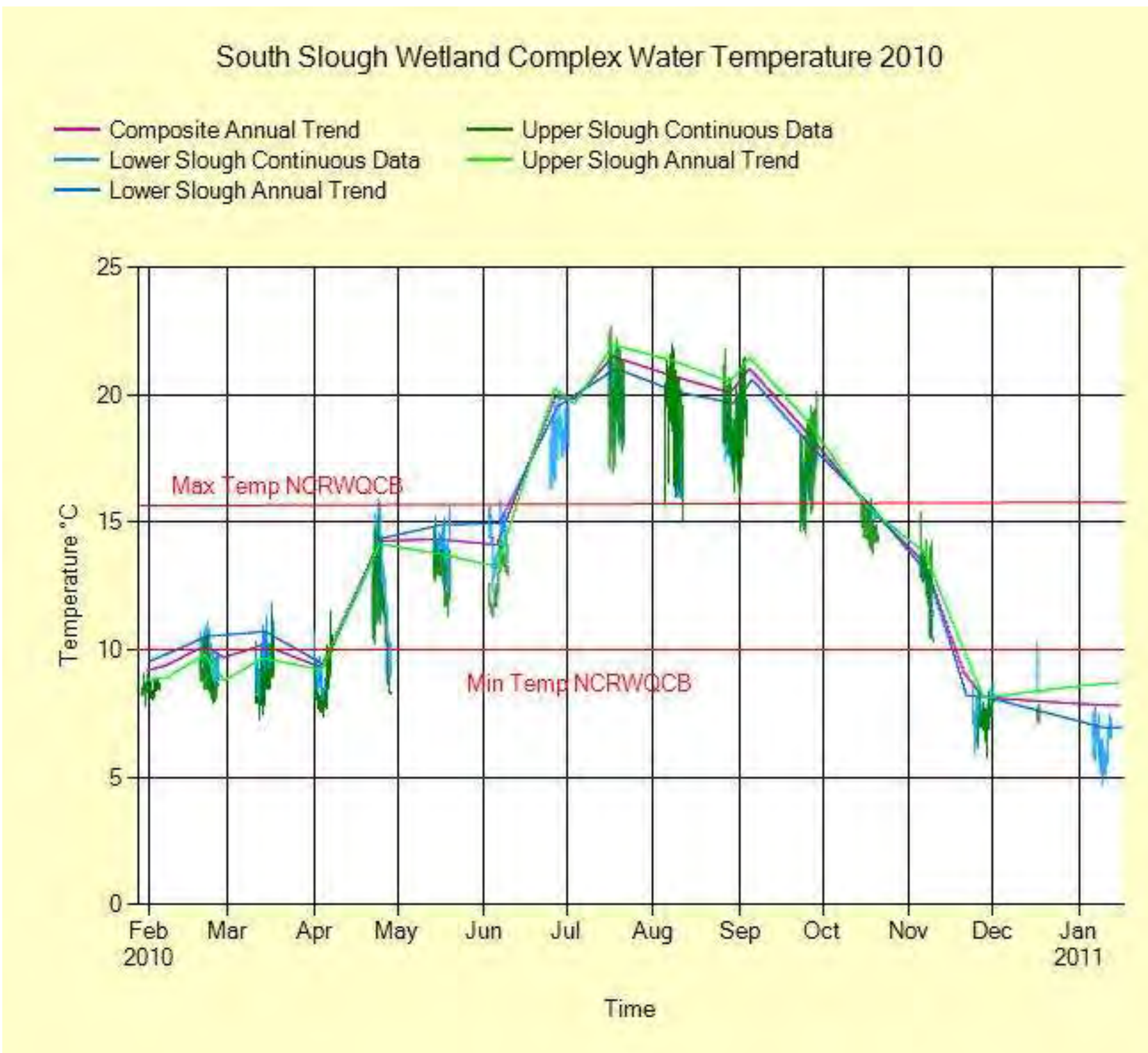

Figure 29: South Slough WC Water Temperature 2010, continuous data and annual trends.

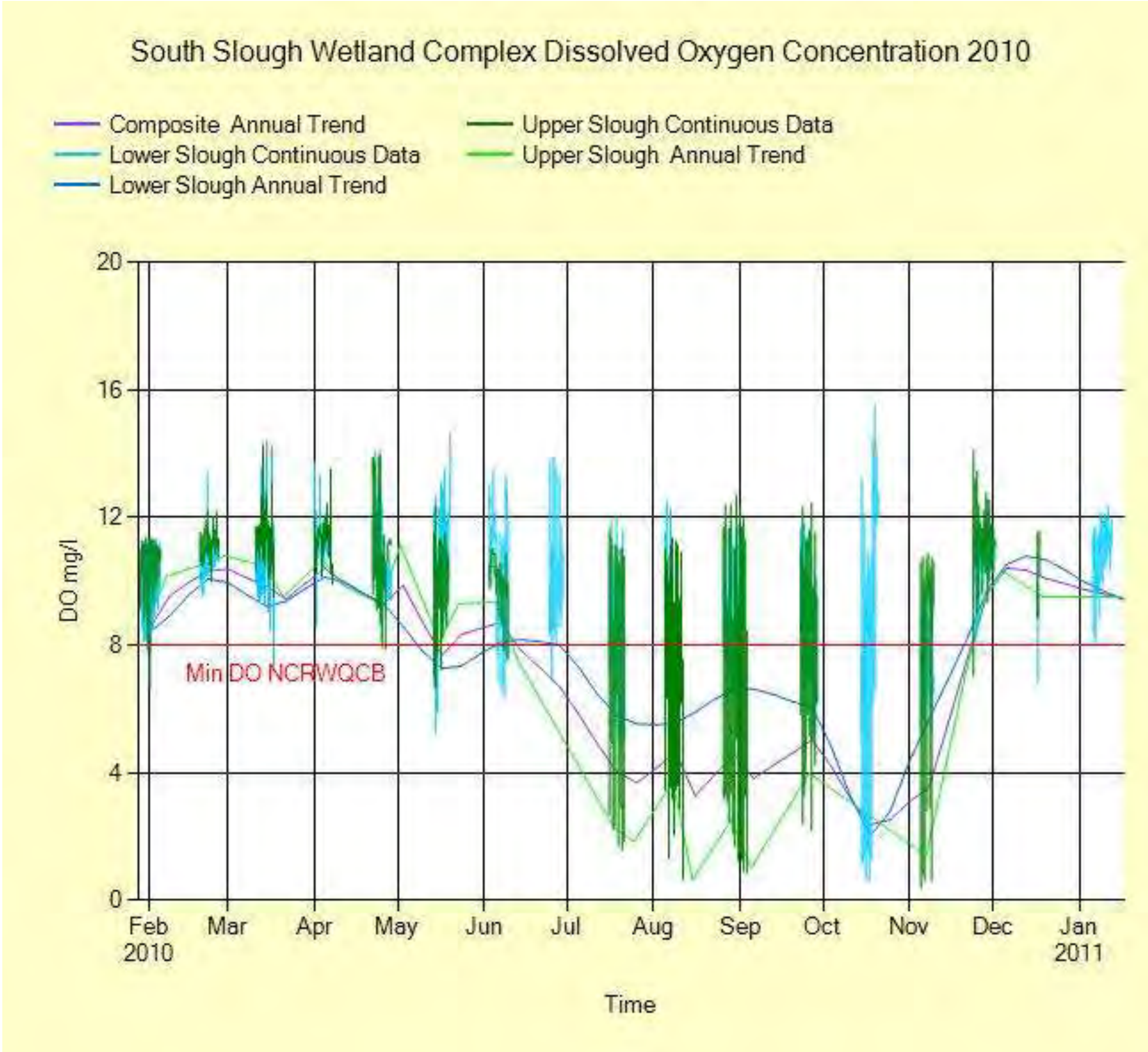

Figure 30: South Slough WC Dissolved Oxygen Concentration 2010, continuous data and annual trends.

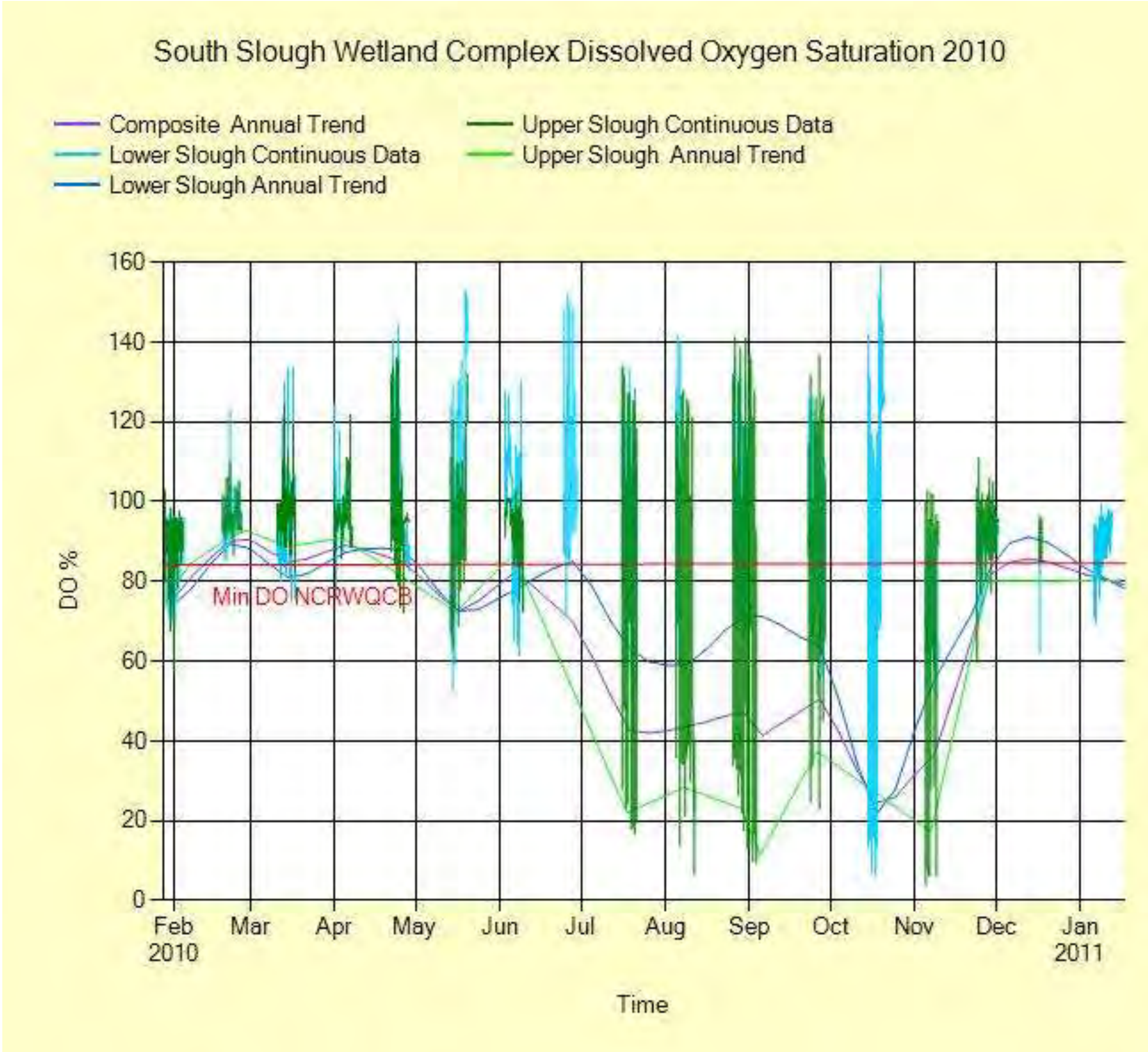

Figure 31: South Slough WC Dissolved Oxygen Saturation 2010, continuous data and annual trends.

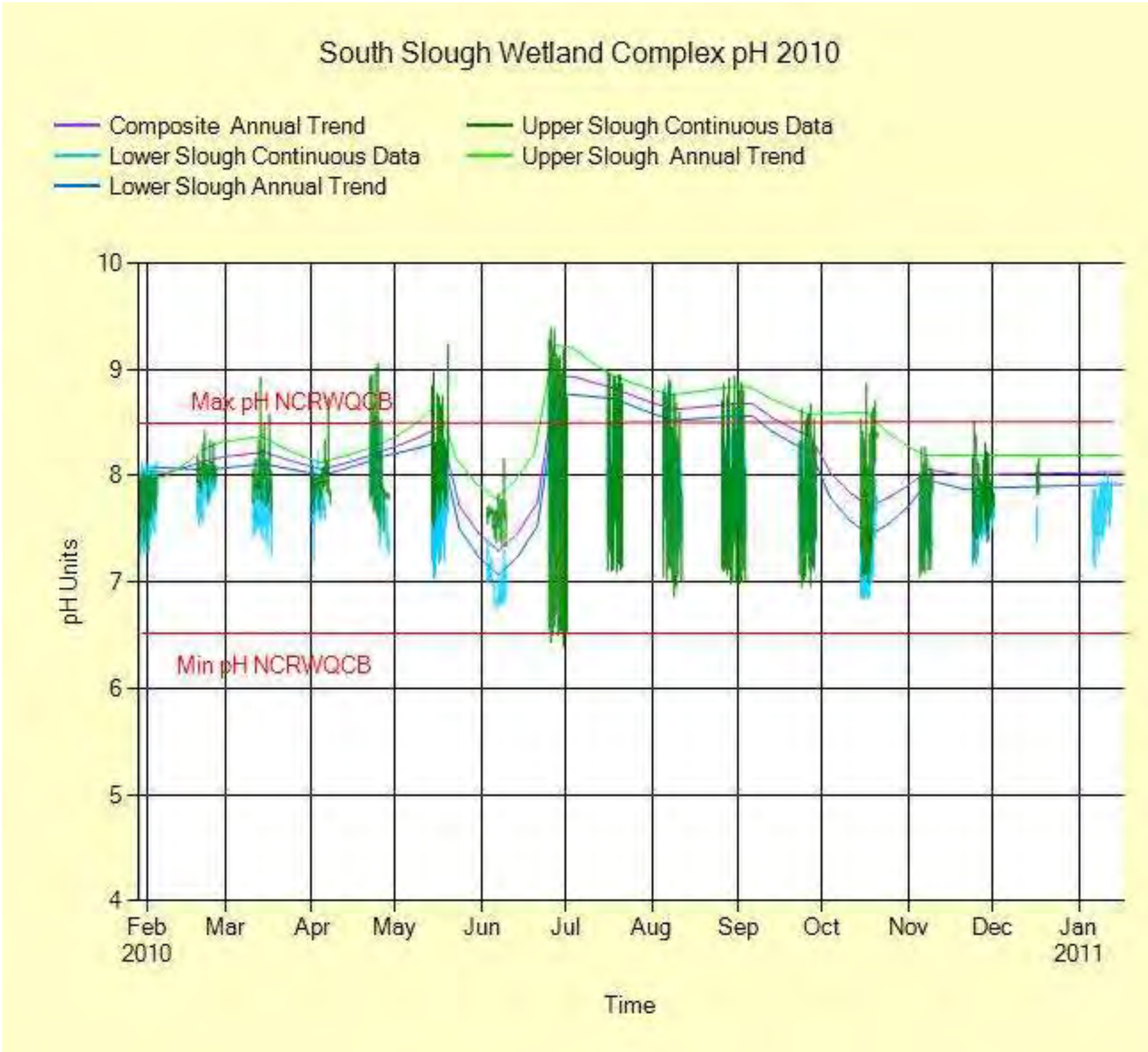

Figure 32: South Slough WC pH 2010, continuous data and annual trends.

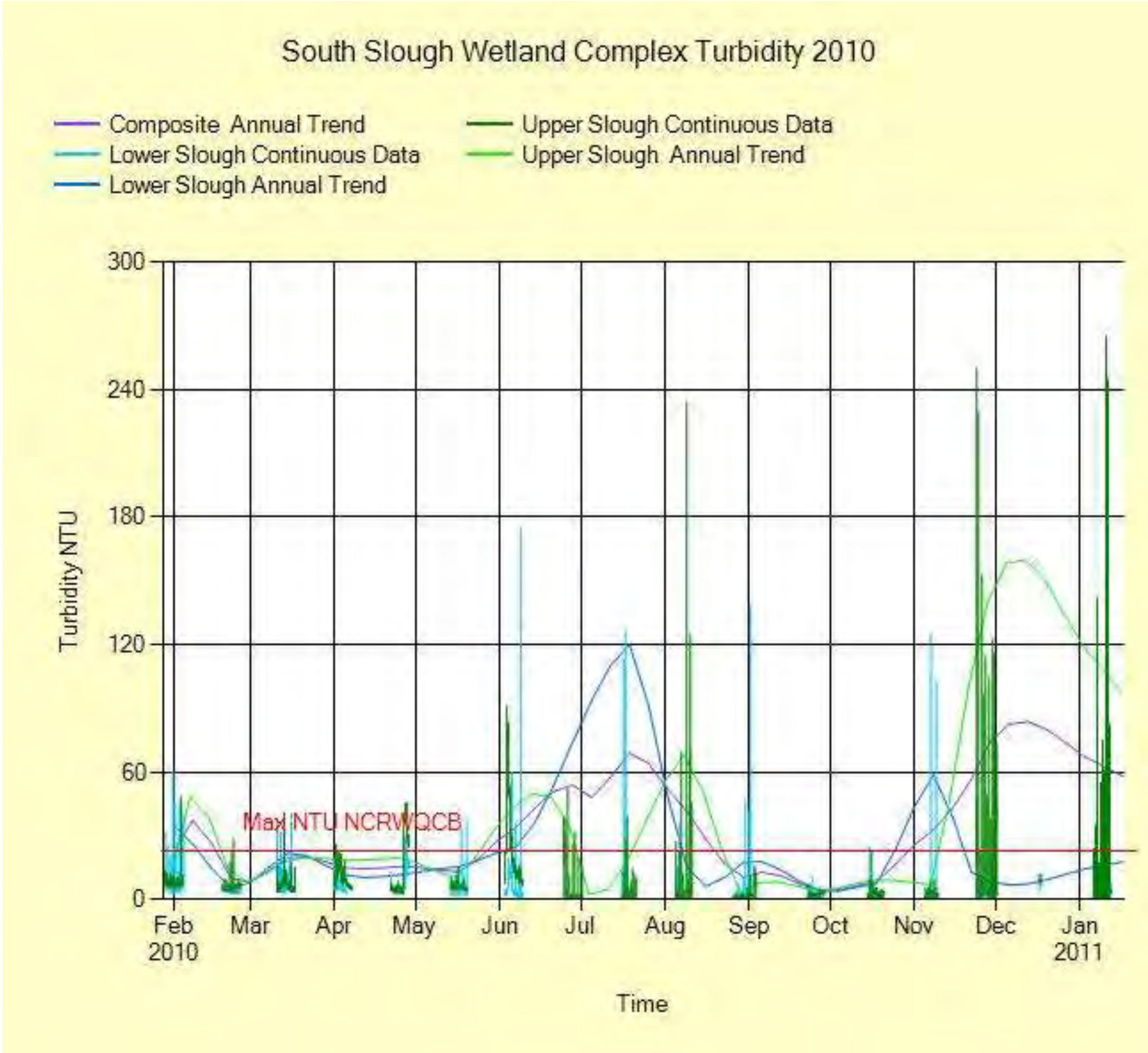

Figure 33: South Slough WC Turbidity 2010, continuous data and annual trends.

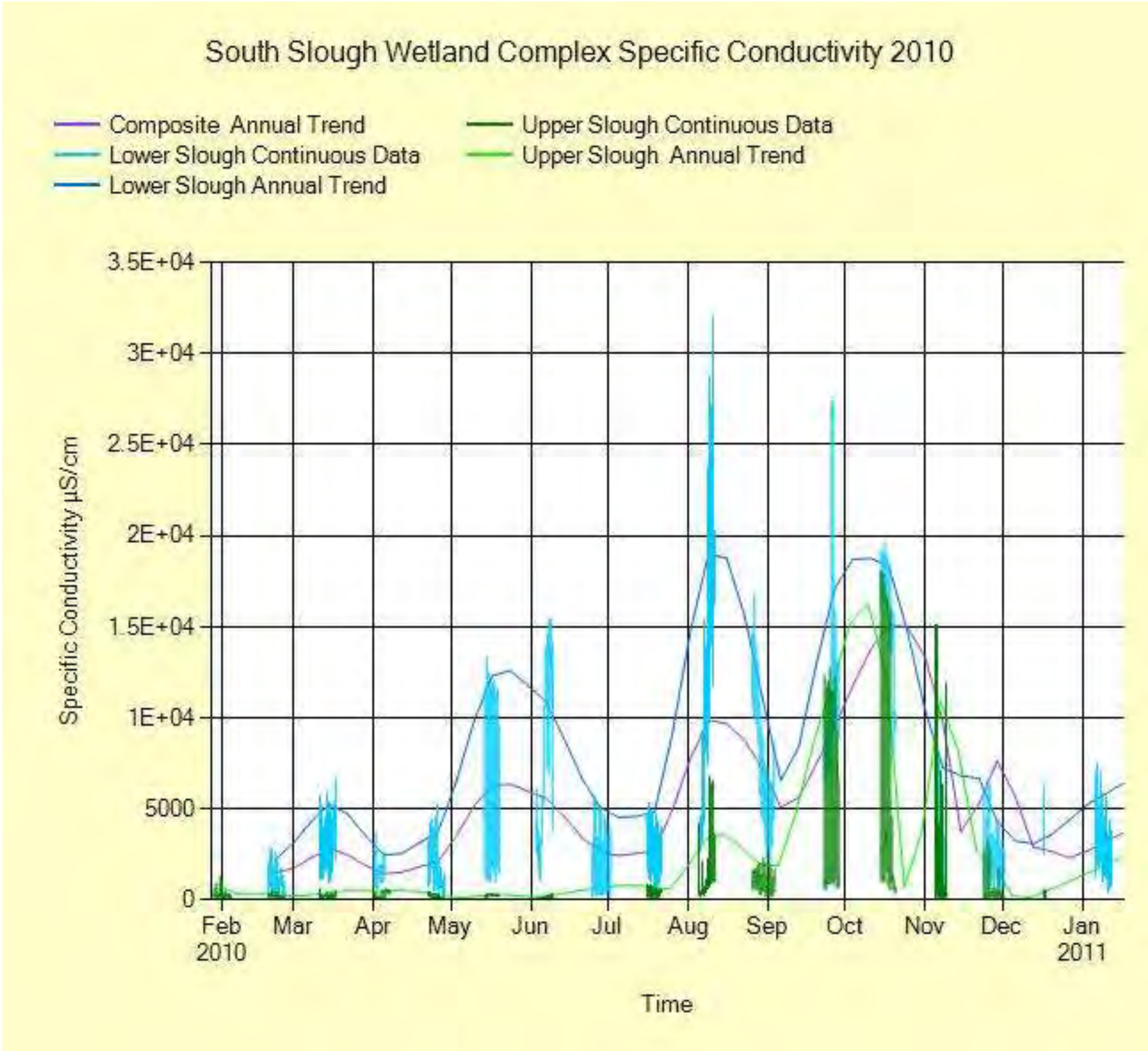

Figure 34: South Slough WC Specific Conductivity 2010, continuous data and annual trends.

Table 7: South Slough WC water quality scoring based on percent exceedances of the parameters.

Parameter/Units:	Threshhold	Days in Exceedance	Percent Exceedance	Weighting Factor	Parameter Score
Temperature C°	10 to 16	205.43	58.69	40	23.48
Dissolved Oxygen Concentration mg/L	8 mg/L	168.82	48.23	40	19.29
Dissolved Oxygen Saturation %	85%	269.10	76.89	0	0
pH	6.5 to 8.5	83.19	23.77	10	2.38
Specific Conductivity µS/cm²	120-200	350.00	100.00	0	0
Turbidity NTU	25	172.90	49.40	10	4.94
			Overall Water Quality Score:		50.09

Composite water temperatures in the South Slough WC exceeded threshold criteria for a total of 205.43 days. A maximum water temperature of 22.5 degrees C was observed in July, while a minimum temperature of 4.9 degrees C was observed in January. Composite DO concentration values exceeded threshold 48.23 days in the year, while composite percent saturation levels exceeded threshold for 269.10 days. A maximum of 15 mg/L, and 160% were observed in October, while lows of 1 mg/L and 10% were observed in October and November. Composite pH levels exceeded threshold for 83.19 days, in the year. A high pH of 9.4 was observed in July, with a low of 6.4 being observed in June. Composite turbidity levels were in exceedance for 172.9 days, with a high turbidity value of 260 NTU occurring in January. Composite specific conductivity values were in exceedance for 350 days, a maximum of 30,000 microsiemens occurred in August and a minimum of 80 microsiemens occurred in June. The overall water quality score for the South Slough WC is 50.09.

<u>3.1.5 Spruce Creek WC</u> (Figures 35 – 40, Table 8)

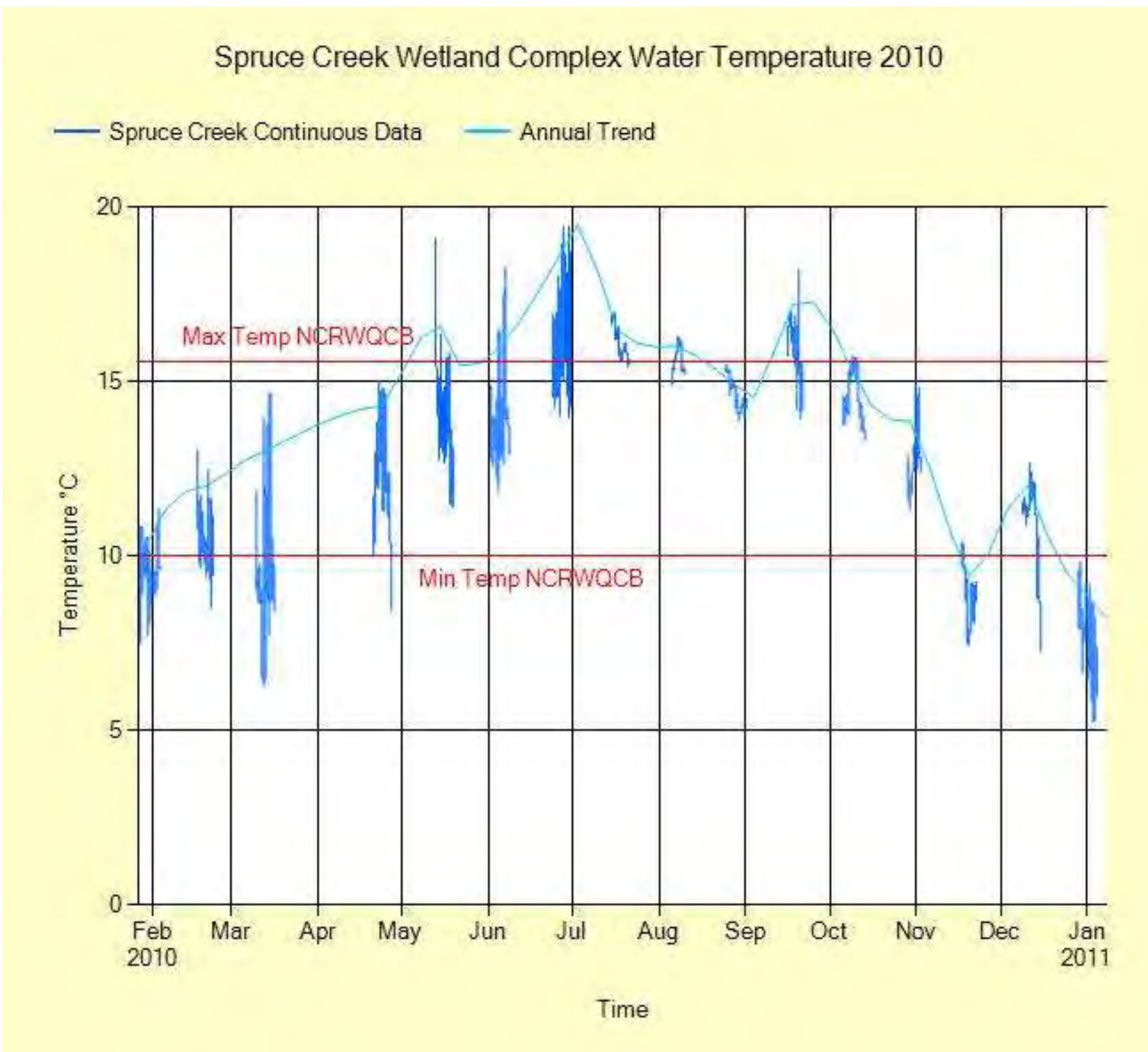

Figure 35: Spruce Creek WC Water Temperature 2010, continuous data and annual trend.

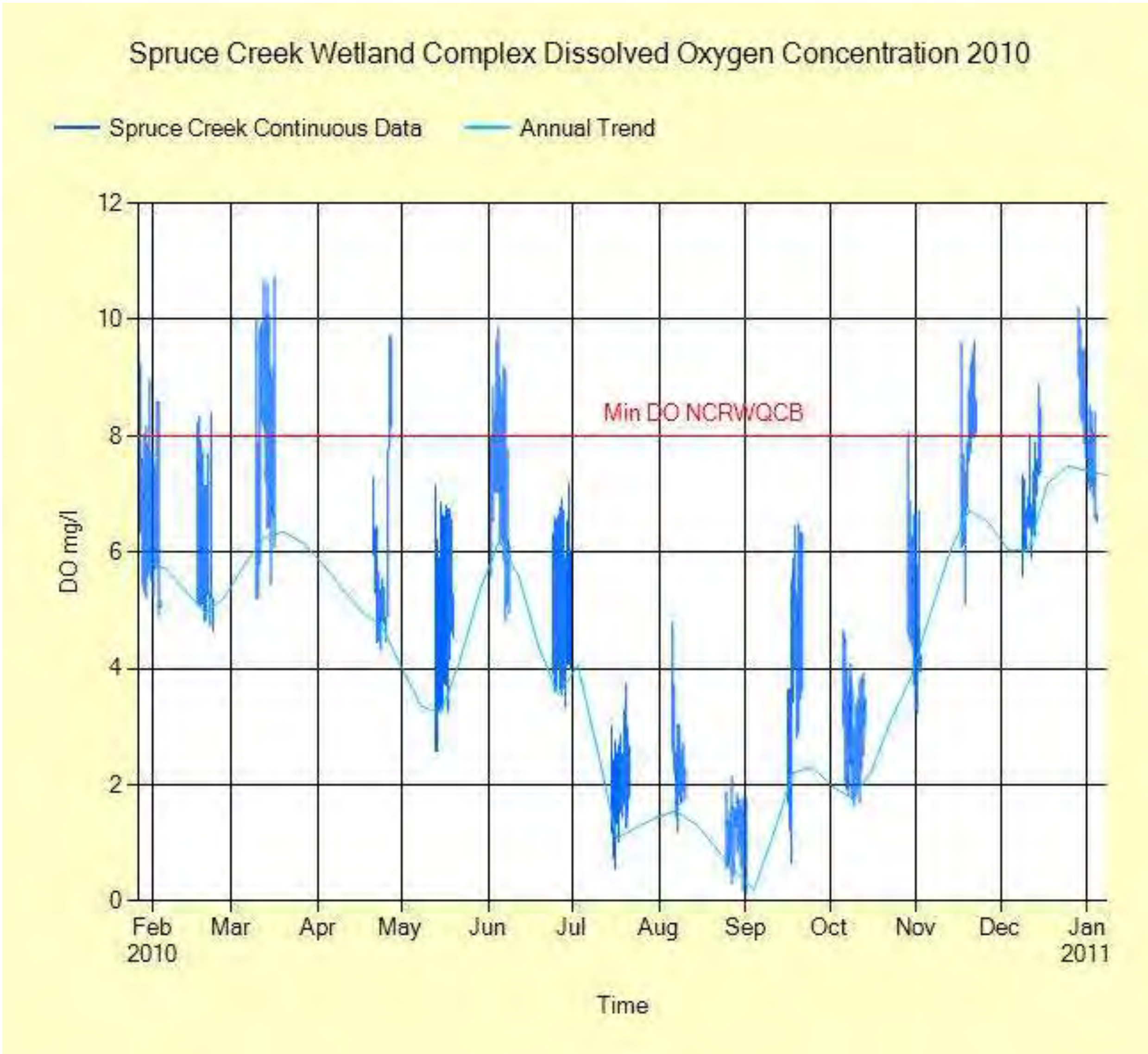

Figure 36: Spruce Creek WC Dissolved Oxygen Concentration 2010, continuous data and annual trend.

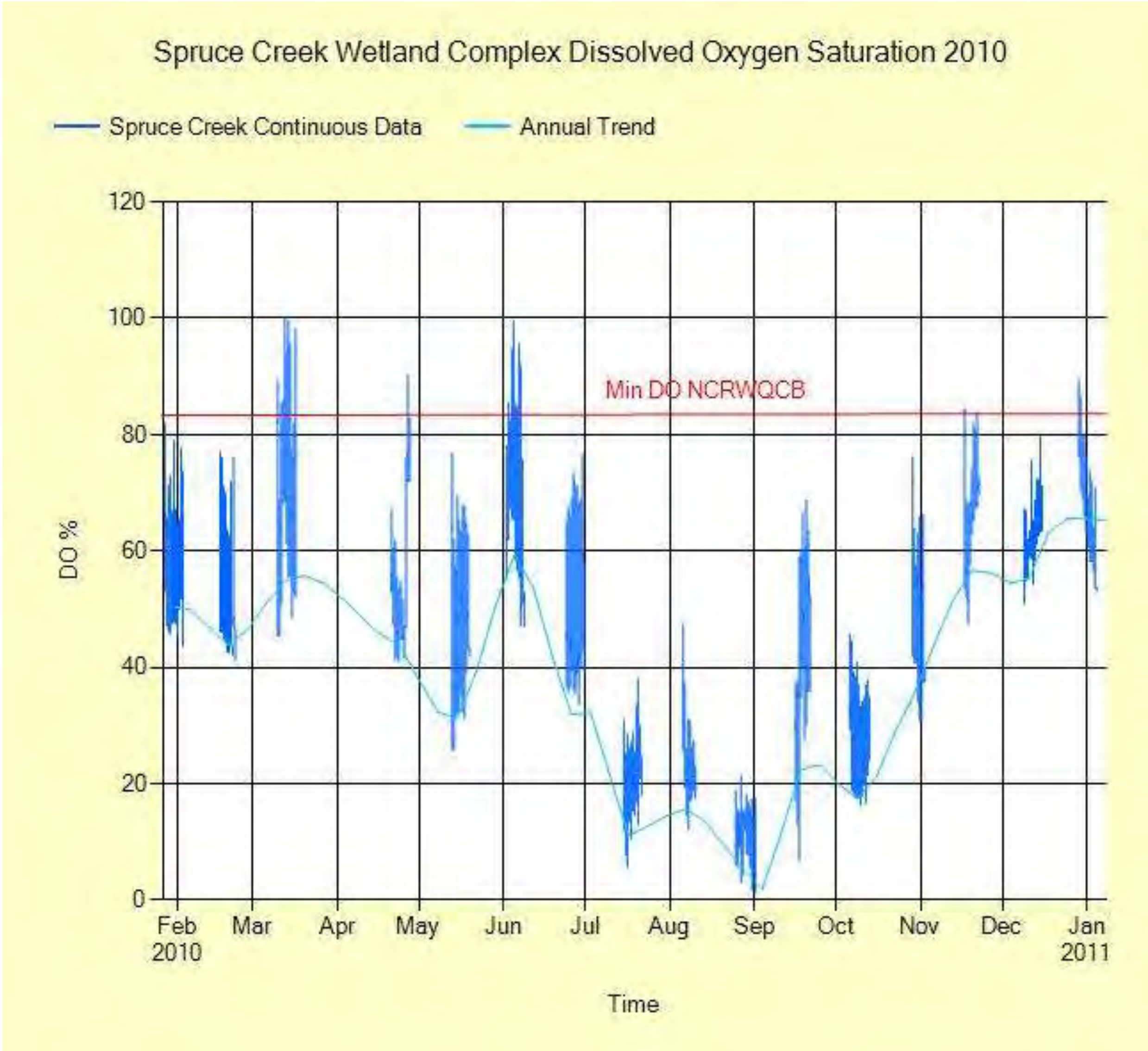

Figure 37: Spruce Creek WC Dissolved Oxygen Saturation 2010, continuous data and annual trend.

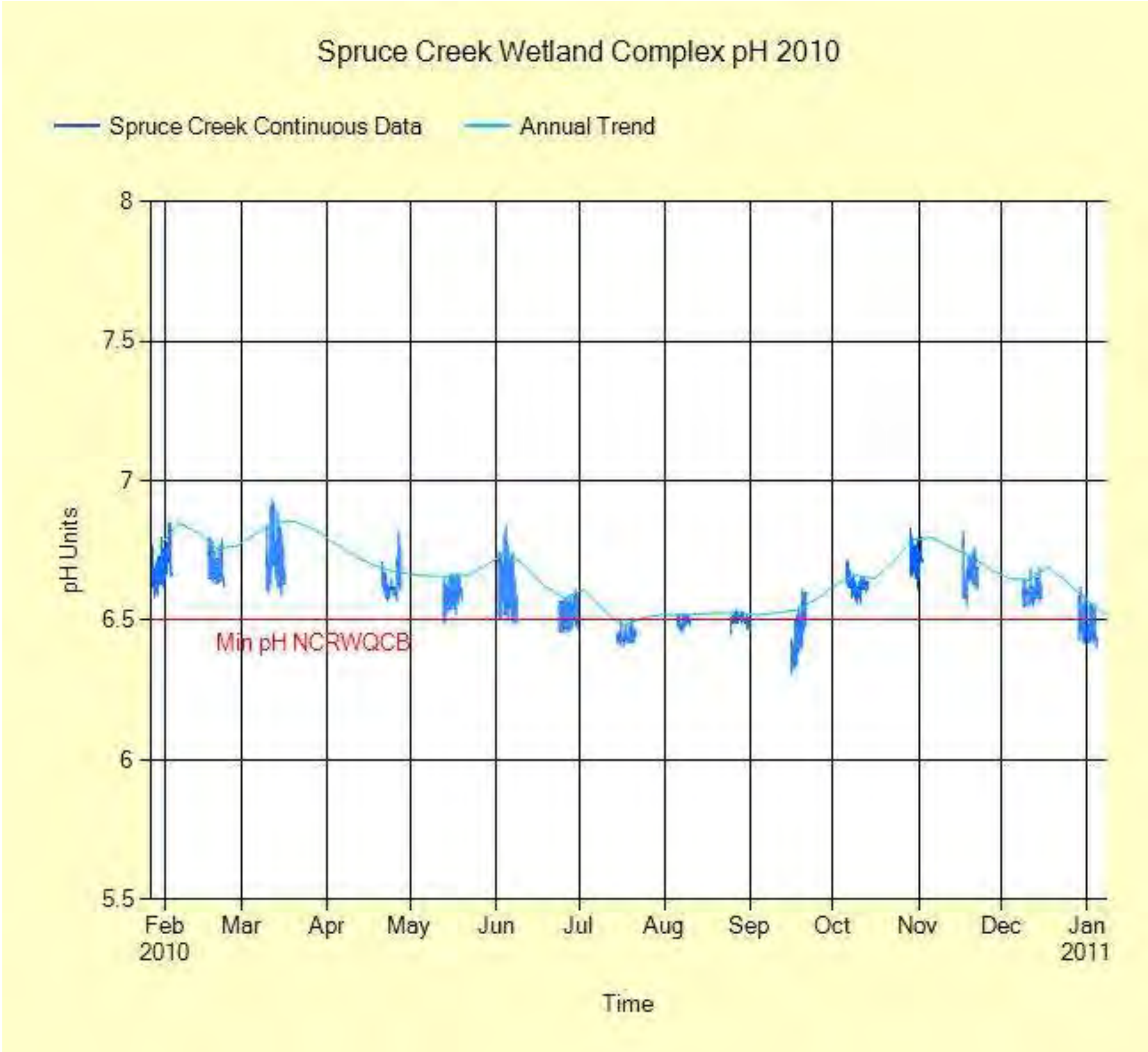

Figure 38: Spruce Creek WC pH 2010, continuous data and annual trend.

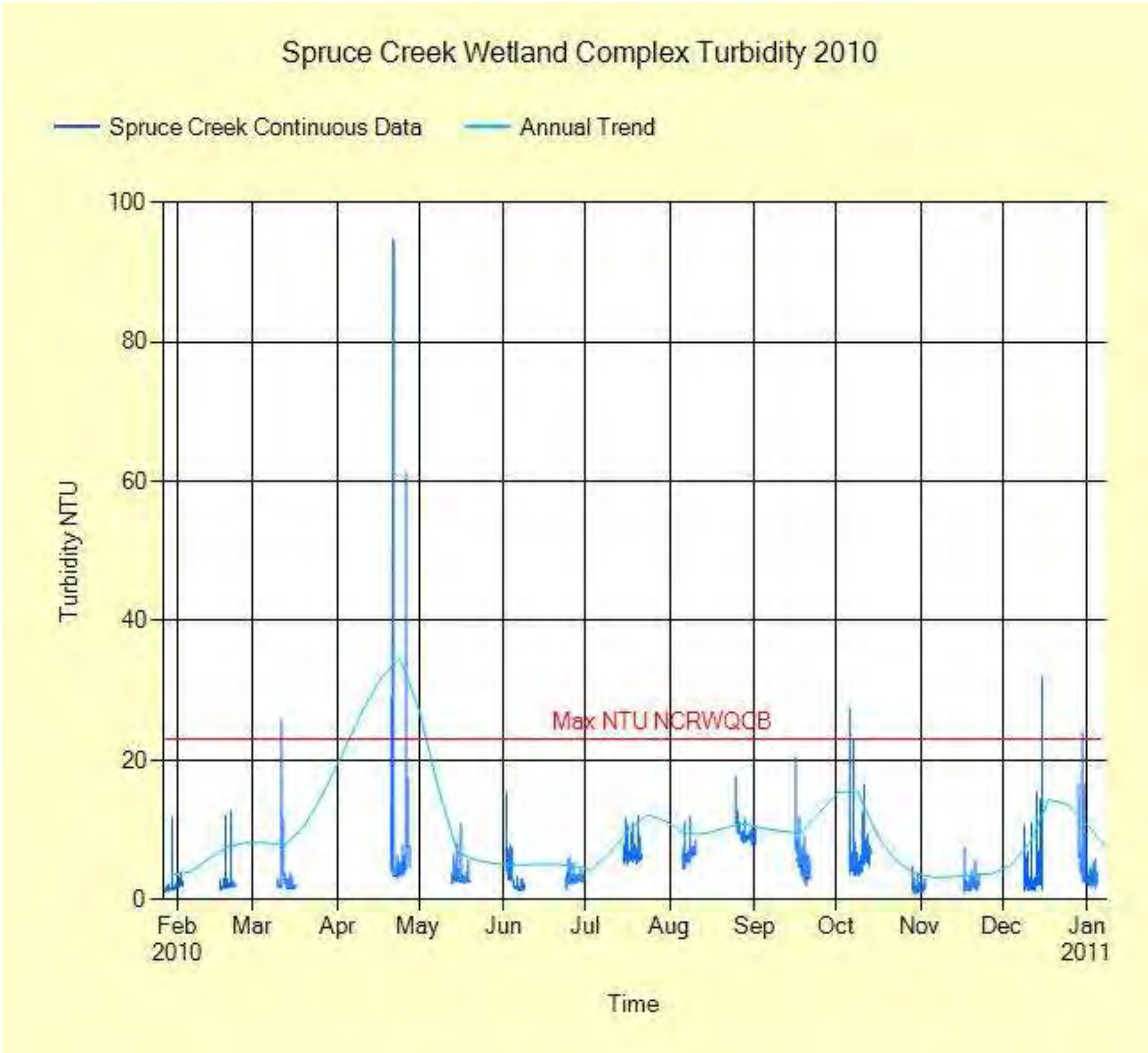

Figure 39: Spruce Creek WC Turbidity 2010, continuous data and annual trend.

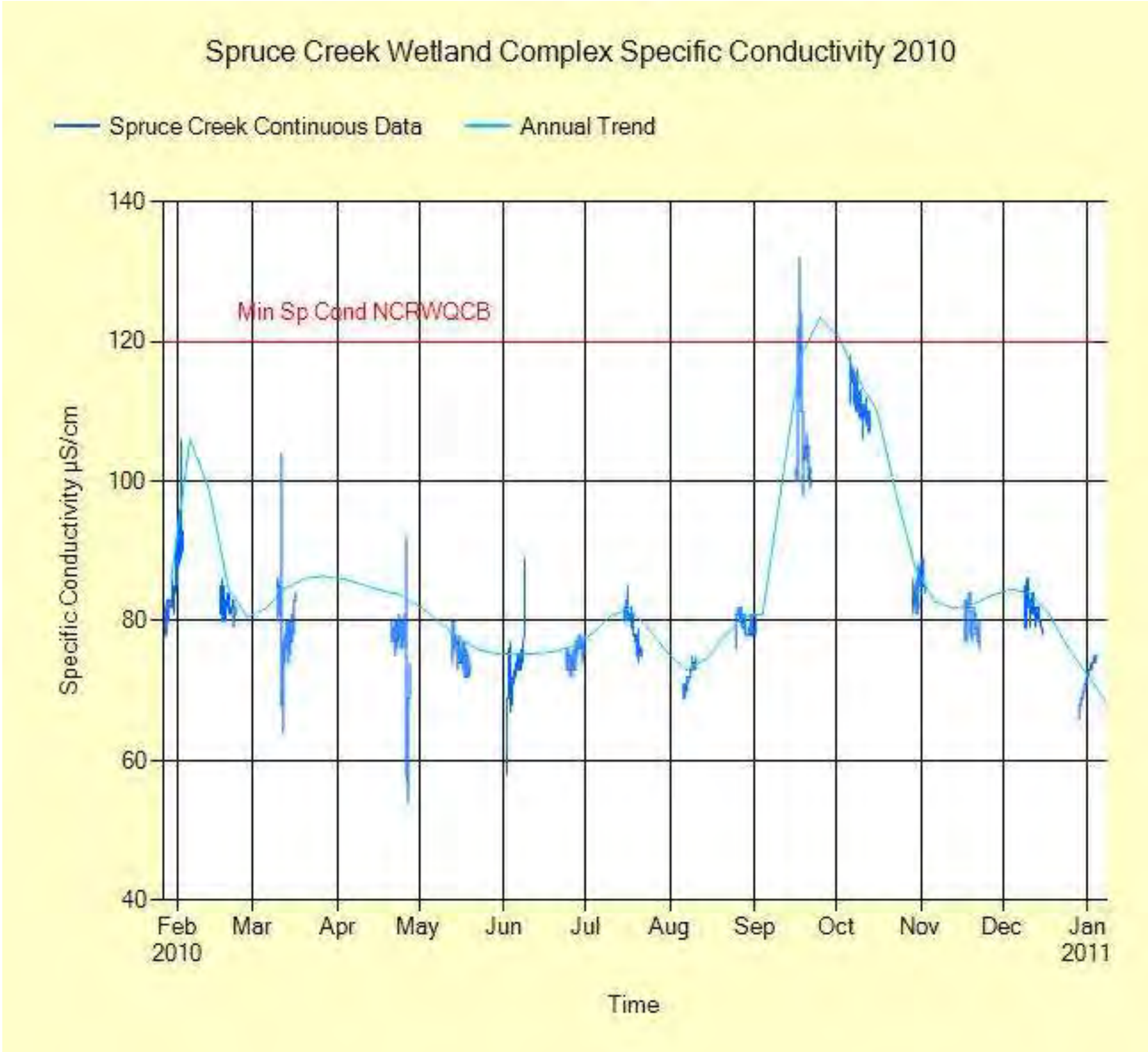

Figure 40: Spruce Creek WC Specific Conductivity 2010, continuous data and annual trend.

Table 8: Spruce Creek WC water quality scoring based on percent exceedances of the parameters.

Parameter/Units:	Threshhold	Days in Exceedance	Percent Exceedance	Weighting Factor	Parameter Score
Temperature C°	10 to 16	121.82	35.52	40	14.21
Dissolved Oxygen Concentration mg/L	8 mg/L	343	100	40	40
Dissolved Oxygen Saturation %	85%	343.00	100	0	0
pH	6.5 to 8.5	130.70	38.10	10	3.81
Specific Conductivity µS/cm²	120-200	330.90	96.47	0	0
Turbidity NTU	25	24.79	7.23	10	0.72
			Overall Water Quality Score:		58.74

Due to landowner permission being denied and limited access to this small WC, only one representative site was monitored for water quality. Water temperatures annual trend exceeded threshold values for 121.82

days. A maximum water temperature of 19 degrees C was observed in July, while a low temperature of 5.5 degrees C was observed in January. DO annual trend for concentration levels had 343 days in exceedance, as did composite dissolved oxygen saturation levels. Maximum DO concentrations reached 11 mg/L and 100% saturation levels in March, while minimums of nearly 0 mg/L and 5% occurred in September. Annual trend pH levels were in exceedance for 130.70 days. A maximum pH value of 6.8 was observed in March, while a minimum of 6.3 was observed in September. Annual trend turbidity levels were exceedance for a total of 24.79 days, with a high turbidity value of 90 NTU occurring in April. Annual trend specific conductivity values were in exceedence for 330.90 days, with a maximum of 130 microsiemens in September and a low of 55 microsiemens in April. The overall water quality score for Spruce Creek WC is 58.74.

3.1.6 Waukell Creek WC (Figures 41 – 46, Table 9)

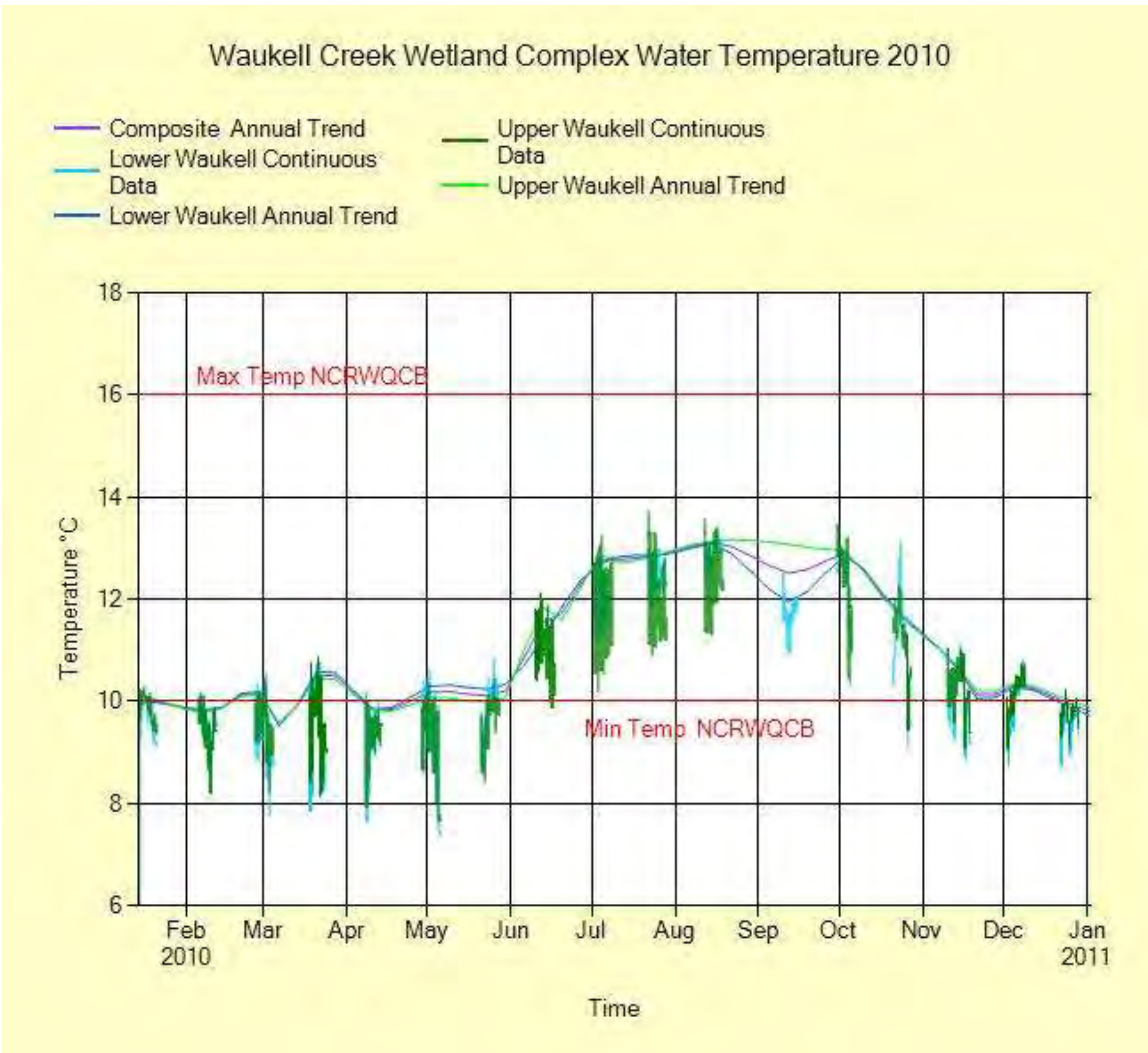

Figure 41: Waukell Creek WC Water Temperature 2010, continuous data and annual trends.

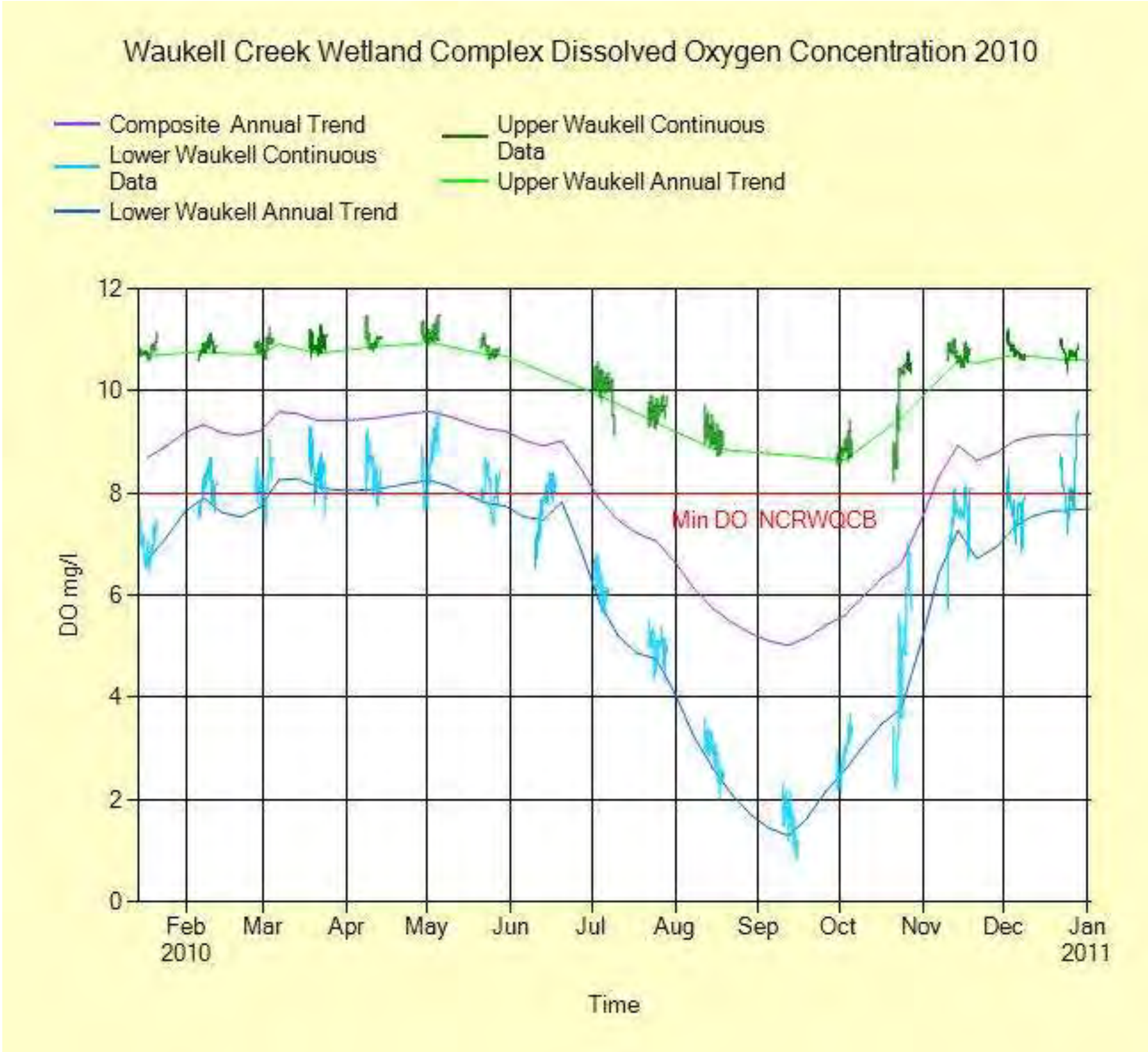

Figure 42: Waukell Creek WC Dissolved Oxygen concentration 2010, continuous data and annual trends.

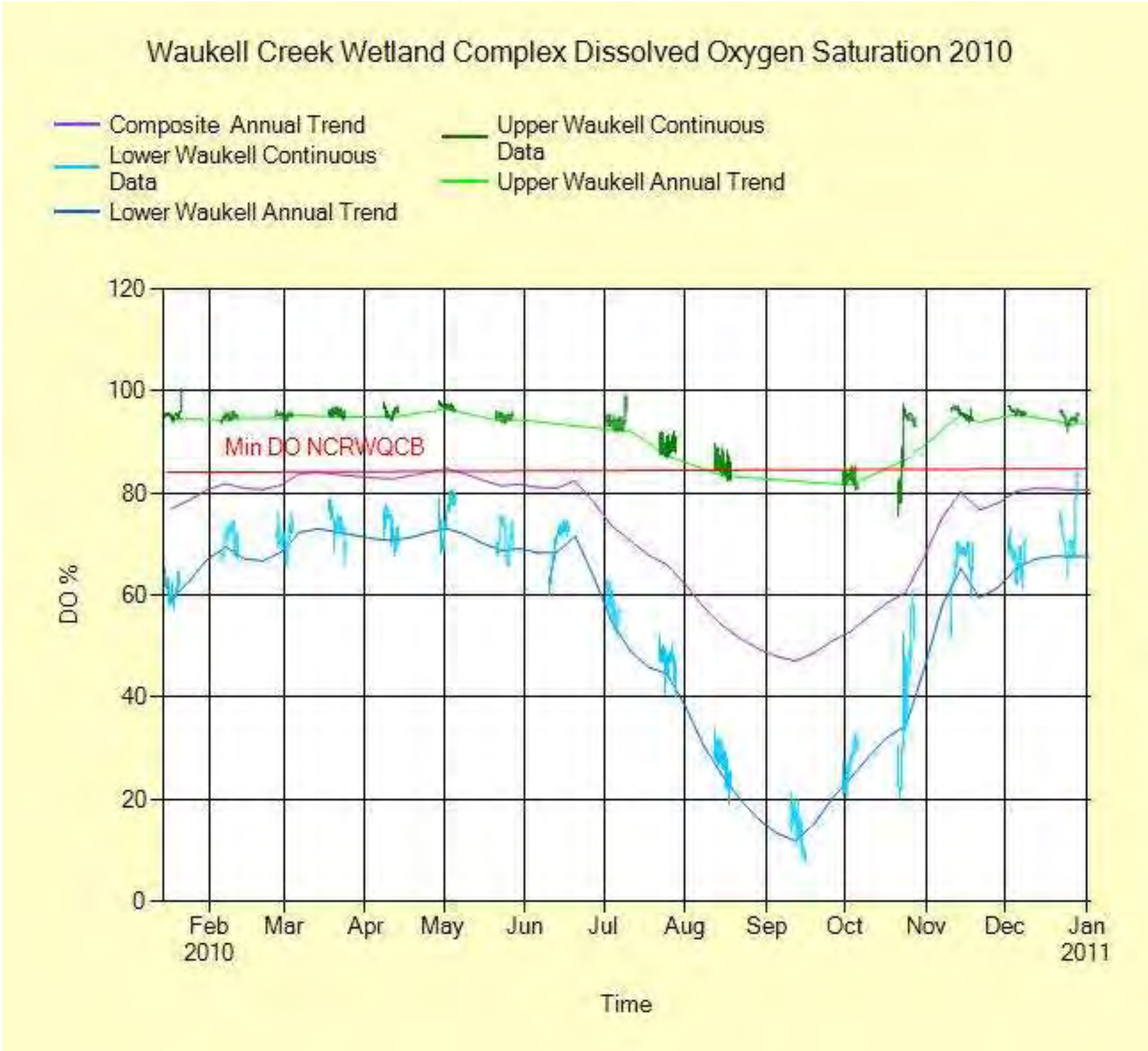

Figure 43: Waukell Creek WC Dissolved Oxygen saturation 2010, continuous data and annual trends.

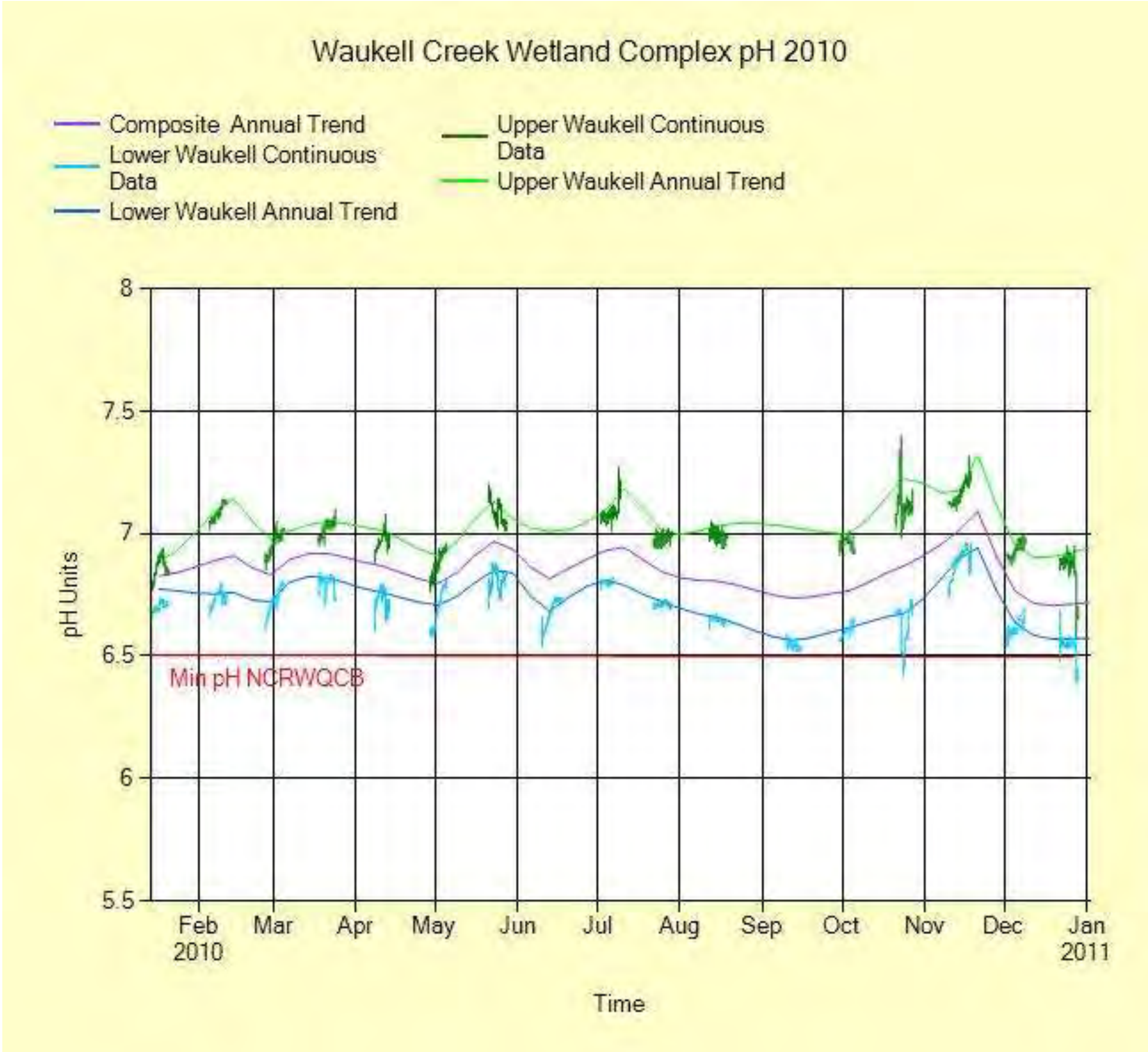

Figure 44: Waukell Creek WC pH 2010, continuous data and annual trends.

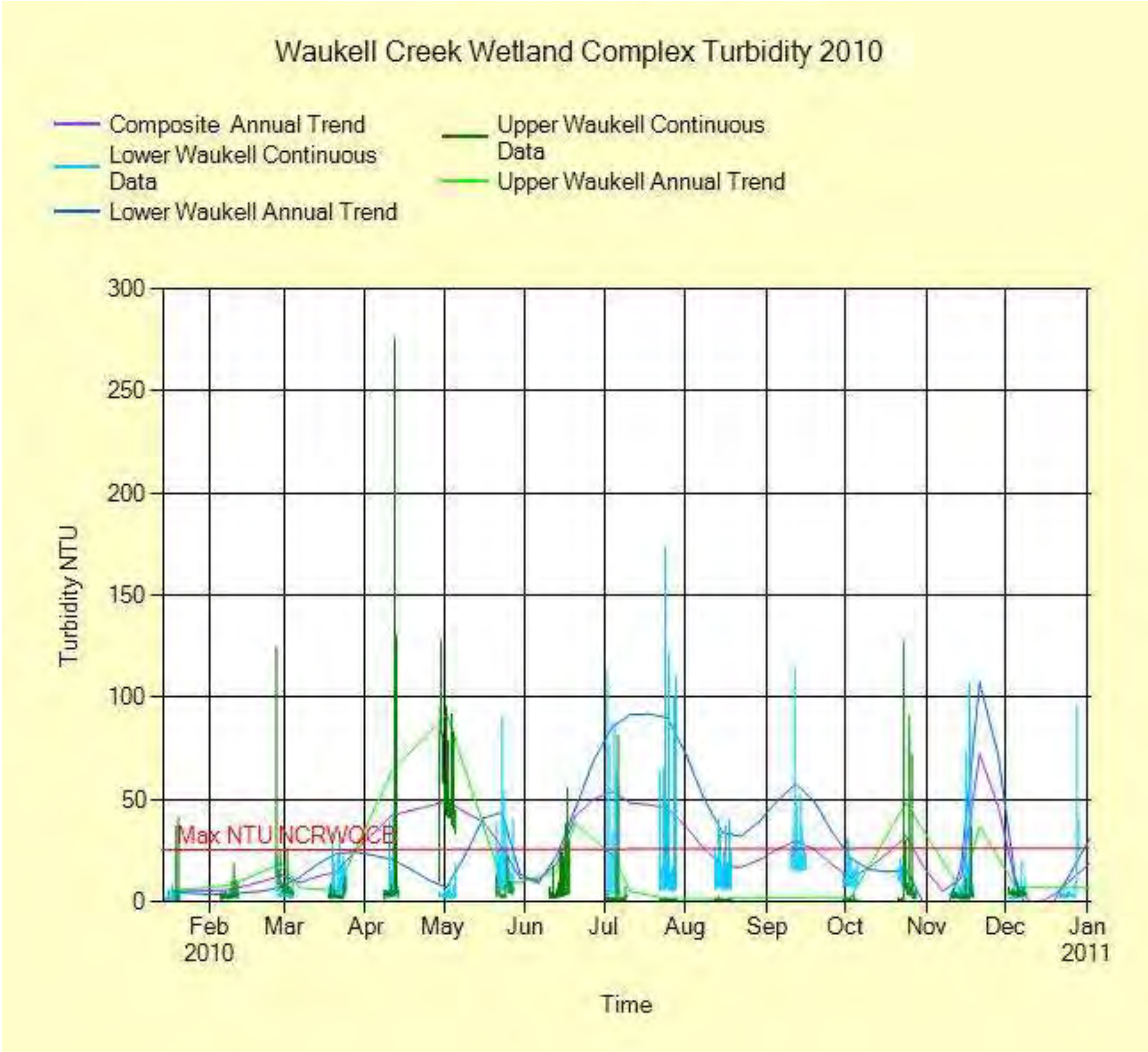

Figure 45: Waukell Creek WC Turbidity 2010, continuous data and annual trends.

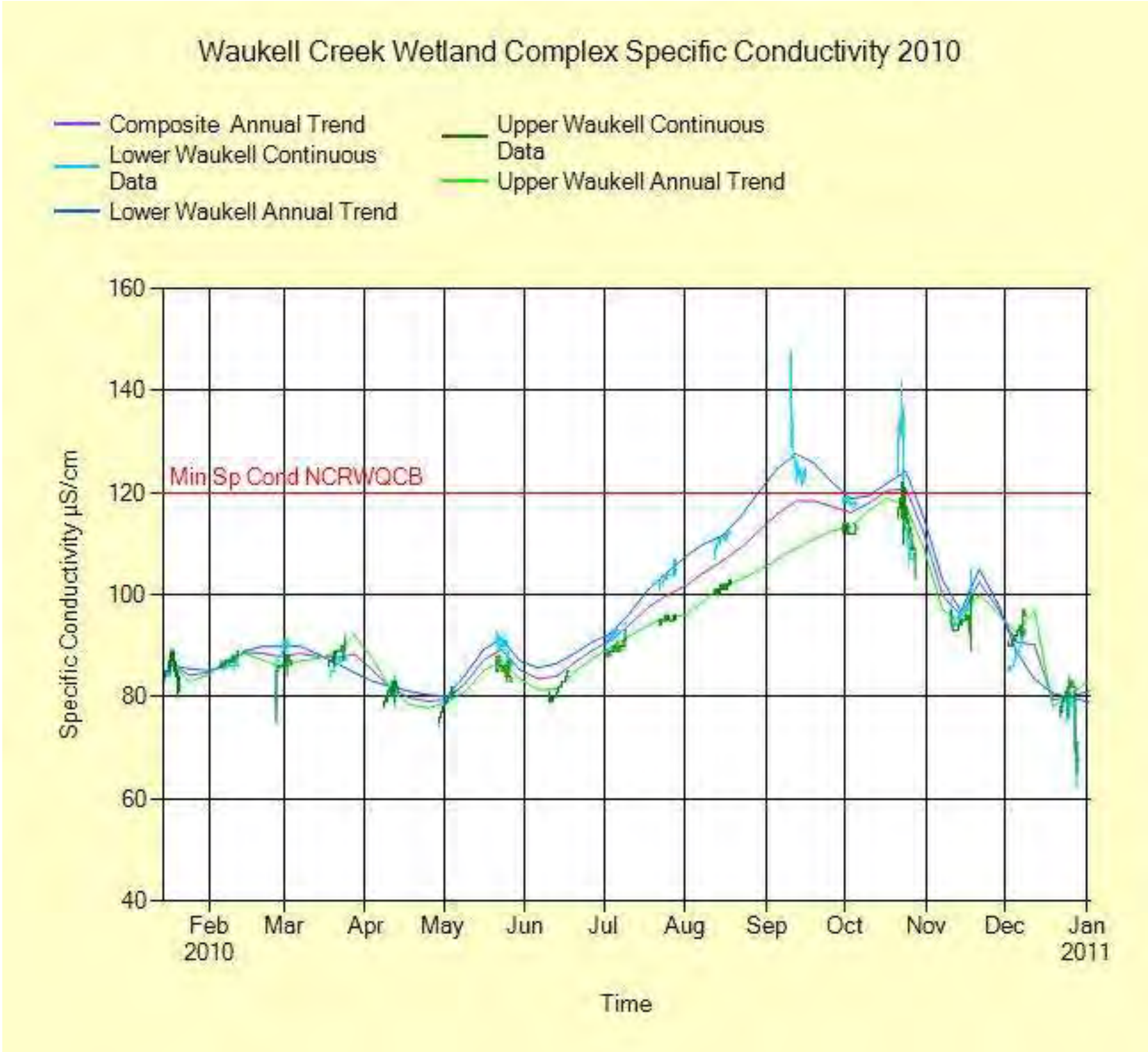

Figure 46: Waukell Creek WC Specific Conductivity 2010, continuous data and annual trends.

Table 9: Waukell Creek WC water quality scoring based on percent exceedances of the parameters.

Parameter/Units:	Threshhold	Days in Exceedance	Percent Exceedance	Weighting Factor	Parameter Score
Temperature C°	10 to 16	67.05	19.16	40	7.66
Dissolved Oxygen Concentration mg/L	8 mg/L	124.83	35.67	40	14.27
Dissolved Oxygen Saturation %	85%	350	100	0	0
pH	6.5 to 8.5	0	0	10	0
Specific Conductivity µS/cm²	120-200	341.14	97.47	0	0
Turbidity NTU	25	152.16	43.47	10	4.35
			Overall Water Quality Score:		26.28

The Waukell Creek WC composite minimum water temperature values exceeded the threshold criteria of 10 degrees C for a total of 67.05 days. A maximum water temperature of 13.5 degrees C was recorded in July, while a minimum of 7.5 degrees C was observed in May. Composite DO concentration levels were in exceedance for 124.38 days, with a maximum value of 11.5 mg/L occurring in May, and a minimum of 1 mg/L occurring in September. Composite DO % saturation levels had 350 days of exceedance, a maximum of 100% in January and a minimum of 10% in September. Composite pH values were in exceedance for a total of zero days, with a high of 7.3 occurring in October, and a low of 6.4 in December. Composite turbidity levels were in exceedance for a total of 152.16 days, with a maximum turbidity value of 270 NTU recorded in April. Composite specific conductivity levels were in exceedance for 341.14 days, with a maximum value of 150 microsiemens recorded in September and a minimum of 65 microsiemens in December. The overall water quality score for Waukell Creek WC is 26.28.

3.1.7 Summary of KRE WC Water Quality

From this study, we have seen that is difficult to characterize all KRE WC water quality conditions as exactly alike because they each have distinct characteristics that make them unique. It should not be assumed that because all the wetlands are similar in elevation, and climate that they will have similar water quality conditions. In fact, there is a range of conditions that exist that are due to the many natural processes that occur in wetlands, as well as anthropogenic stressors. The development of the water quality score presented in this report is one way to compare water quality conditions in the various WCs (Table 10).

Table 10: KRE WC water quality scores, 2010.

WC	Water Quality Score
Salt	19.38
Richardson	23.50
Waukell	26.28
Panther	41.09
Slough	50.09
Spruce	58.74

Note: A score of 100 would represent 100% exceedances in all weighted parameters. The most heavily weighted paramaters are water temperature and dissolved oxygen concentration.

From this study, it may be safe to make certain generalized characterizations about all KRE WCs, at least for the 2010 sampling period. The South Slough WC has been shown to be in its own category due to the water quality conditions it represents and the type of wetland. There is a unique dynamic which is controlled by the tidal influence of the ocean and the mainstem water quality conditions controlled by the Klamath Basin and the very large Watershed of the Klamath River. This information has been well documented in the past (Wallace, 1995; Wallace, 1997; Wallace, 2001; Hiner and Brown, 2004) and needs to be reiterated in this report. The remaining 5 WCs which are tributaries to the estuary are independent of these controls, and this is reflected in their water quality conditions. Table 11 illustrates a relative comparison of the percent exceedances for all sites, and this is a good way to show the overall similarities between WCs, and the most prevalent limiting parameters.

The freshwater WCs maintained adequate water temperatures for salmonids for most of the year except for a brief period in September; otherwise, water temperatures may be slightly cooler than optimum levels during January. There is an apparent warming trend in the wetlands as water moves downstream during the late spring summer and early fall months (Figures 47 & 48). DO levels is the limiting factor for salmonids in these habitats, and is the most influential parameter on the water quality score. DO had the highest percent exceedences of the parameters used in the water quality score. In addition percent saturation levels were more often in exceedance of the threshold (85%) than were DO concentration levels (8 mg/L) (Figures 49 – 52). A downstream effect of decreased DO is apparent, and is more prominent in late summer. pH levels were stable overall and have a tendency to be between 6.5 and 7.0 most of the year (Figures 53 & 54). This is contrary to the KRE which is above 8.0 most of the year. Only two sites had percent exceedances in the pH parameter. Turbidity appears to be highly variable and is a more difficult parameter to assess (Figures 55 & 56). The pulse nature of turbidity in response to storm events really requires a complete continuous data set to fully understand, and ensure comparability from site to site. Annual trends may not be as representative of conditions as originally planned. However, the peak turbidity values do seem to decrease in the lower portion of a wetland, potentially providing refuge for salmonids. Specific conductivity levels were consistently under the value of 120 microsiemens for Lower Klamath HA streams as set forth by the NCRWQCB Basin Plan (Figures 57 & 58). However, as previously stated this value is developed to protect beneficial uses and is not a requirement for salmonids, thus it has not been given any weight in the water quality score.

Table 11: WC water quality scores, percent exceedances parameters and averages.

Wetland Complex	Water Quality Score	Temp % Exceedance	DO mg/L % Exceedance	DO % % Exceedance	pH % Exceedance	Turbidity % Exceedance	Specific Conductivity % Exceedance
Salt	19.38	21.25	21.78	96.51*	0	21.65	100*
Richardson	23.50	27.2	28.71	48.25*	0	11.42	100*
Waukell	26.28	19.16	35.67	100*	0	43.47	100*
Panther	41.09	1.5	99.18	100*	0	7.9	100*
Slough	50.09	58.69	48.23	76.89*	23.77	49.4	100*
Spruce	58.74	35.52	100	100*	38.1	7.23	100*
Average	NA	27.22	55.60	70.86*	10.31	23.51	100*

*Dissolved oxygen saturation and specific conductivity levels are not specific to salmonids, and not weighted in the water quality score.

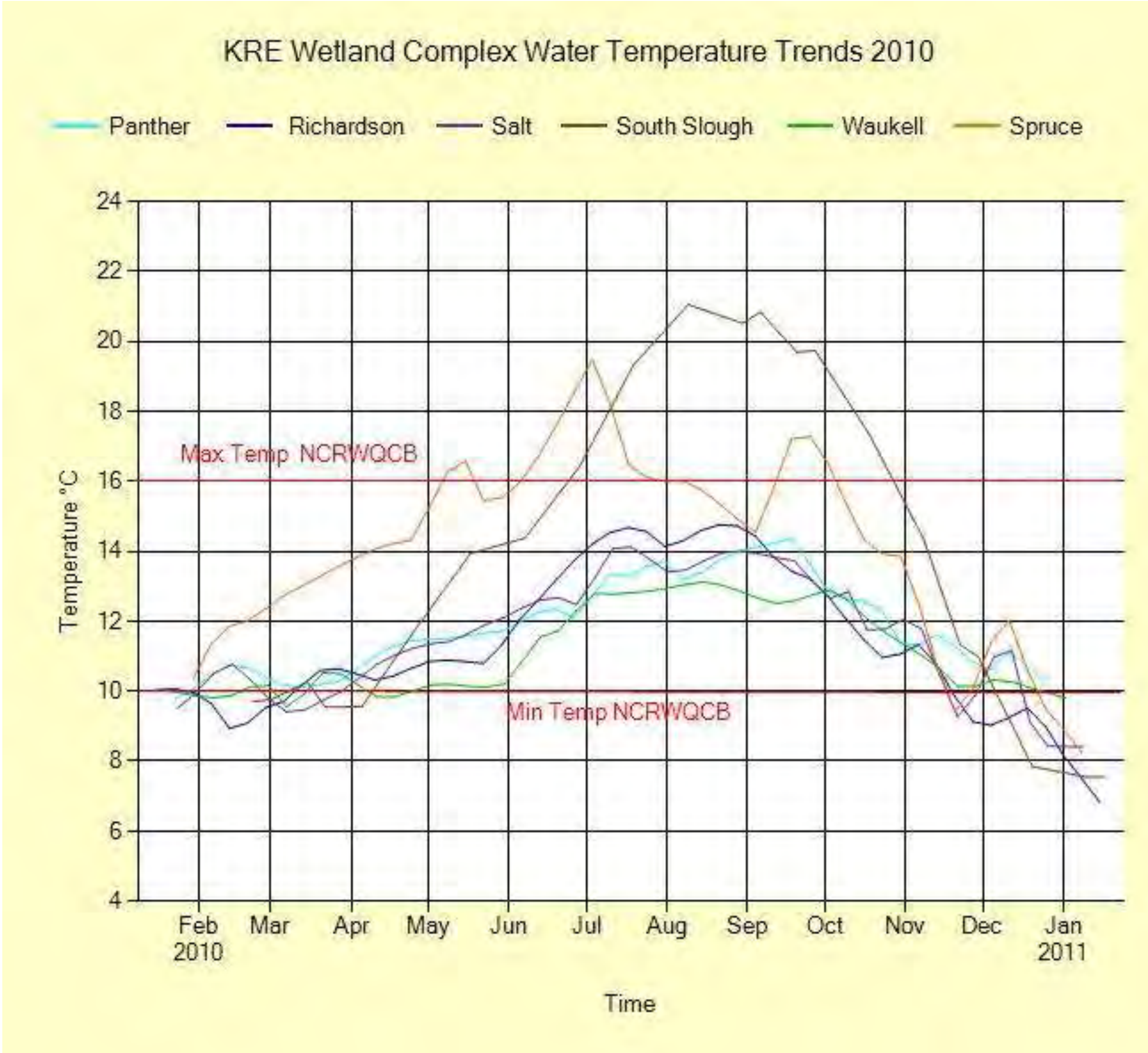

Figure 47: KRE WC Water Temperature Trends 2010. Note: Trends are based on composite data sets.

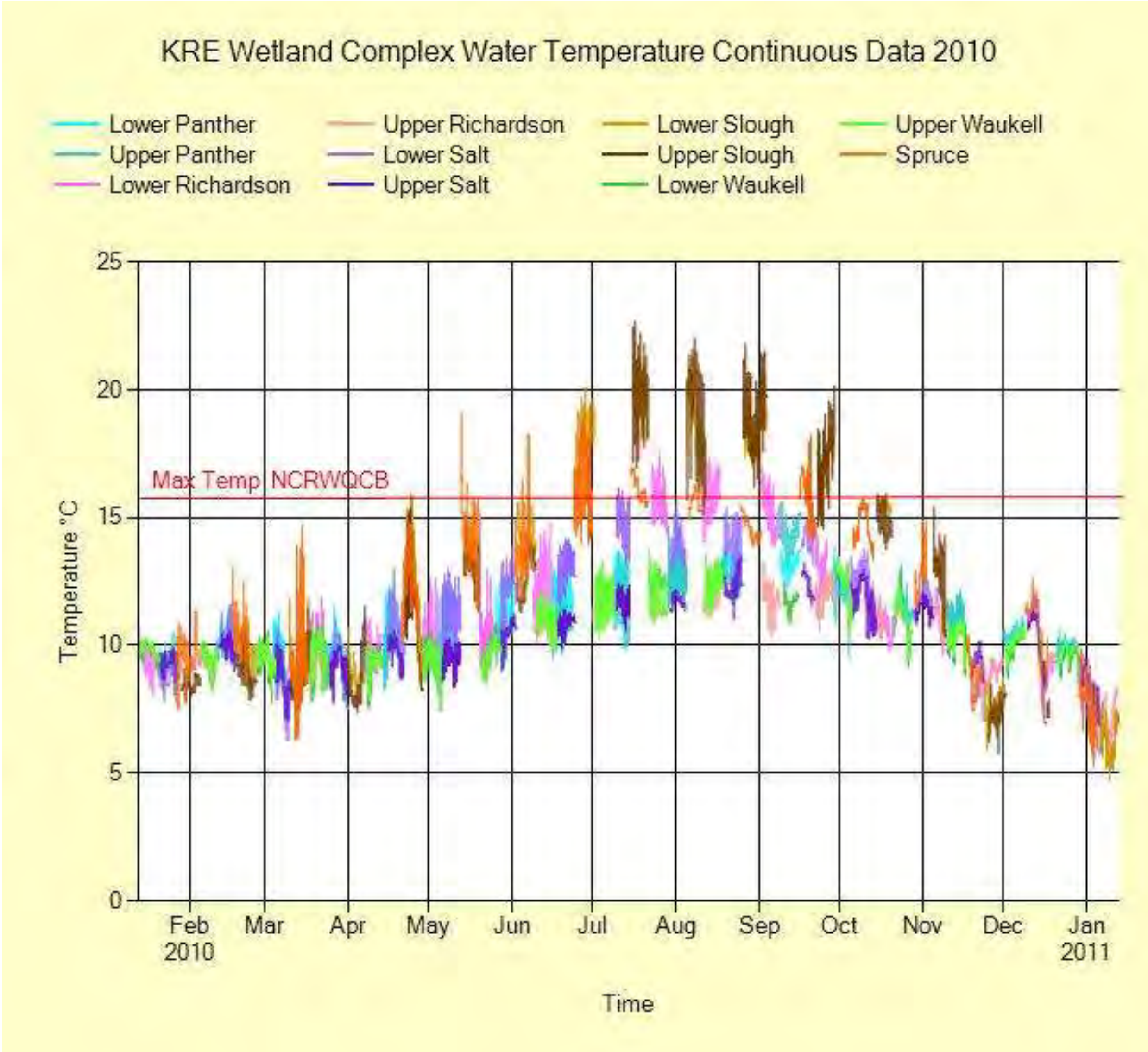

Figure 48: KRE WC Water Temperature Continuous Data 2010.

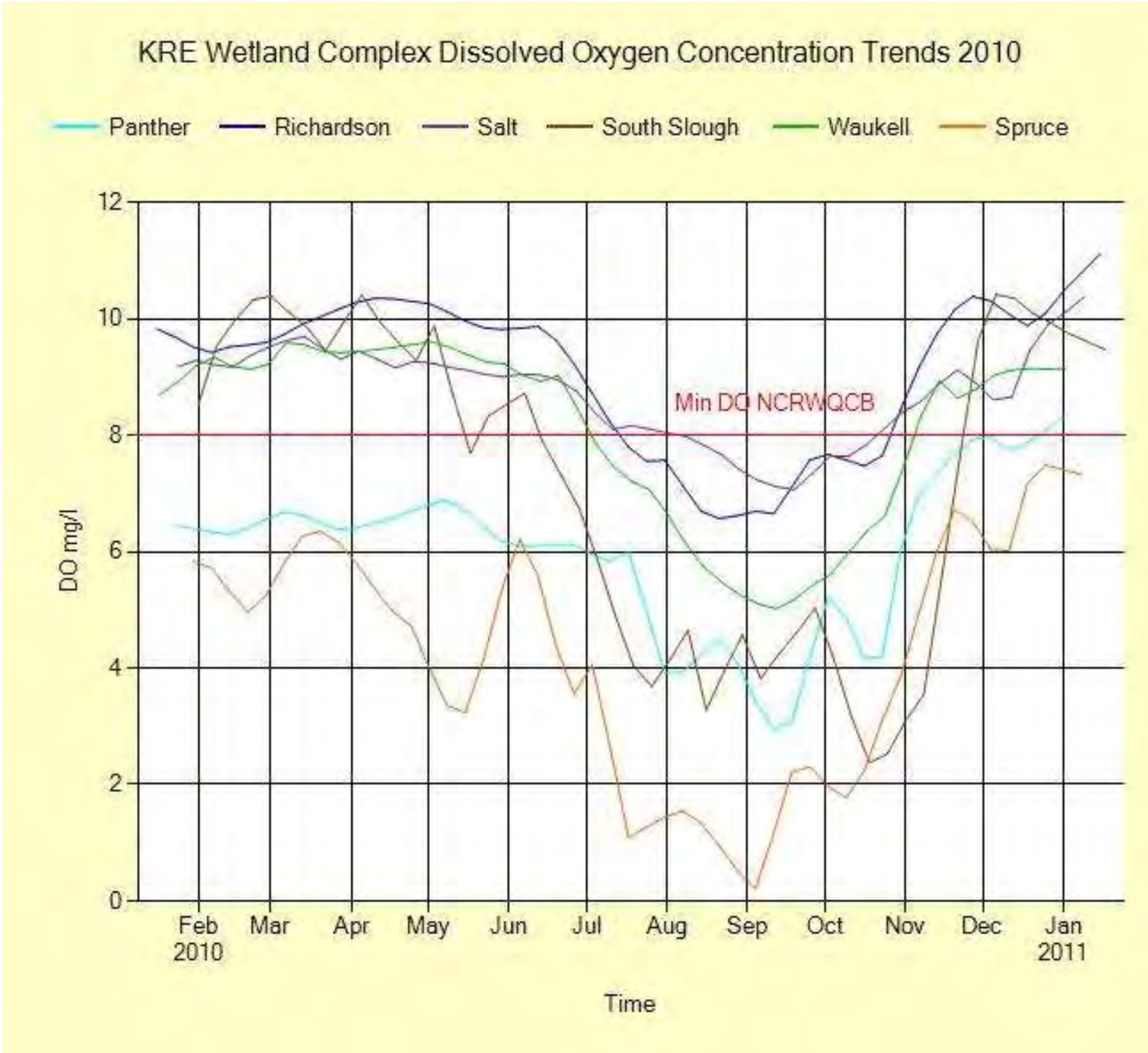

Figure 49: KRE WC Dissolved Oxygen Concentration Trends 2010**.** Note: Trends are based on composite data sets.

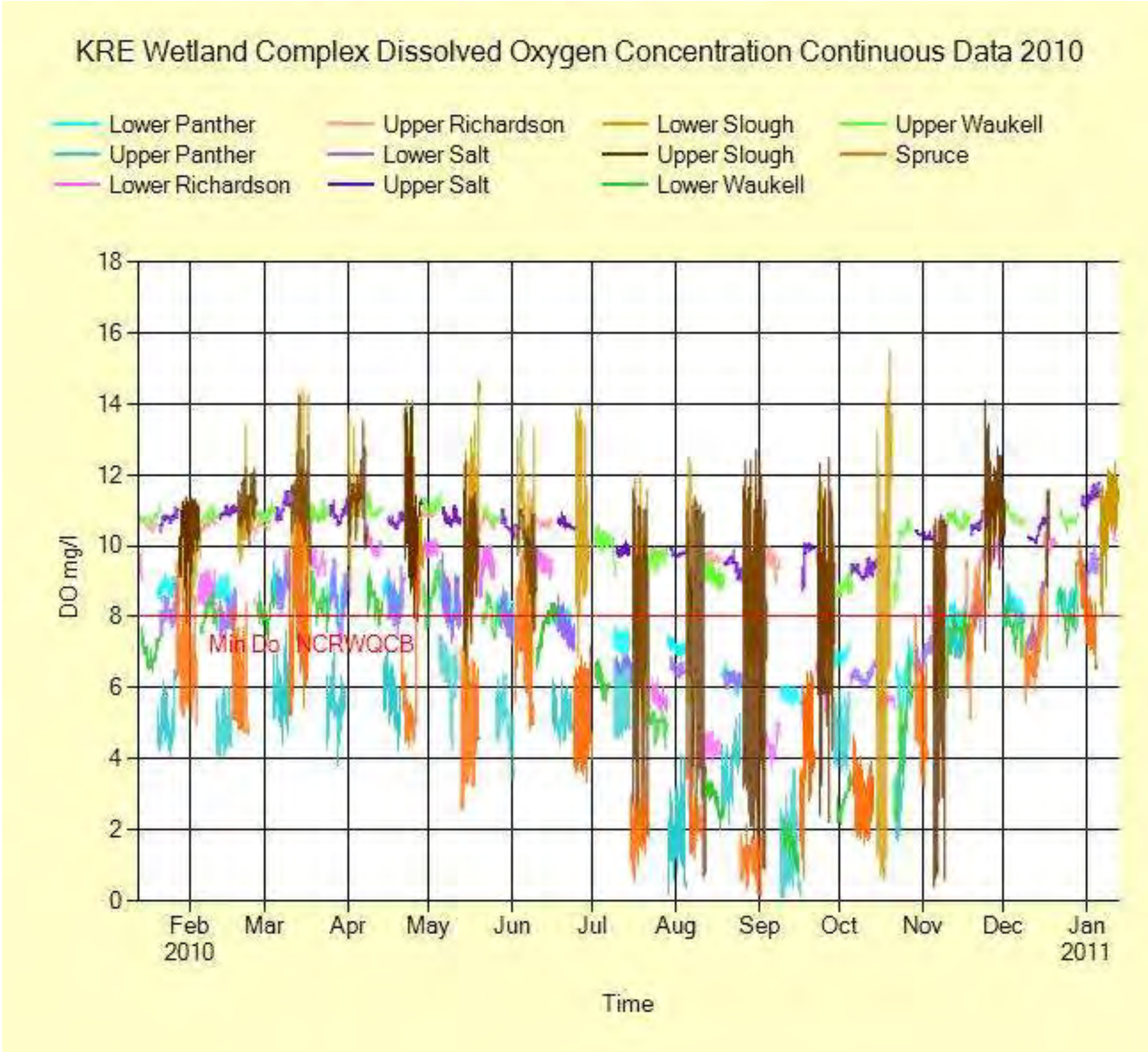

Figure 50: KRE WC Dissolved Oxygen Concentration Continuous Data 2010.

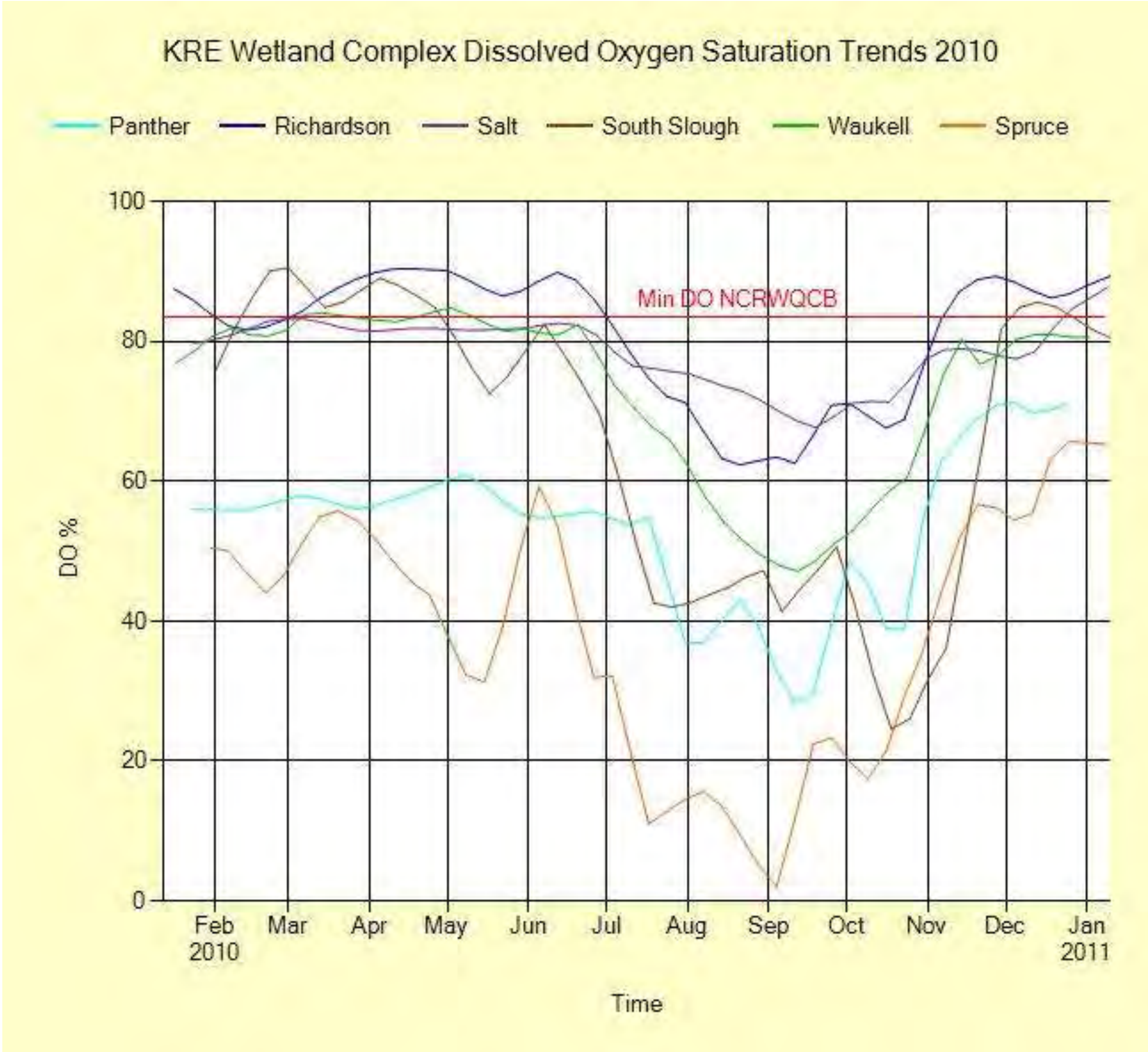

Figure 51: KRE WC Dissolved Oxygen Saturation Trends 2010. Note: Trends are based on composite data sets.

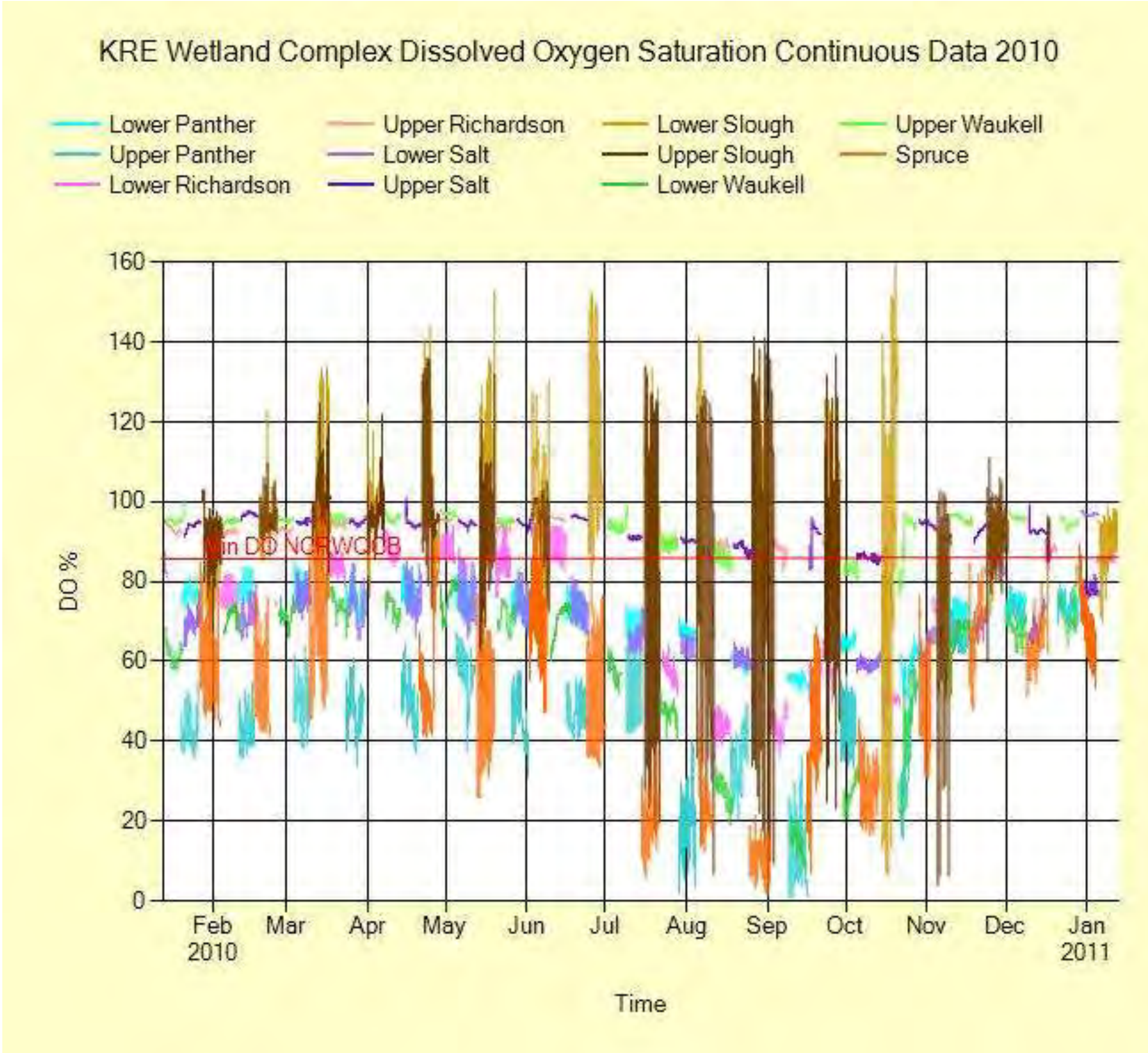

Figure 52: KRE WC Dissolved Oxygen Saturation Continuous Data 2010.

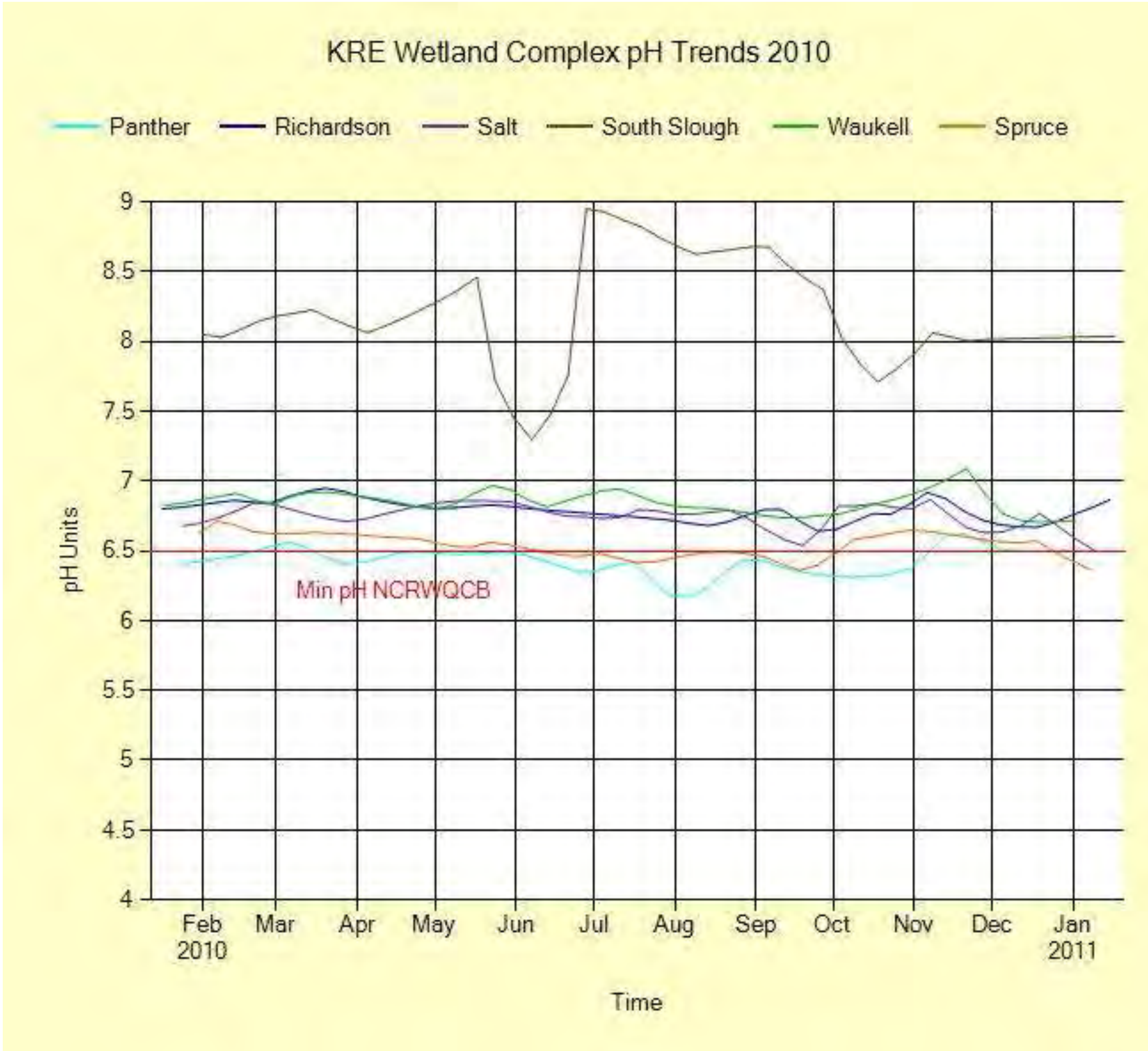

Figure 53: KRE WC pH Trends 2010. Note: Trends are based on composite data sets.

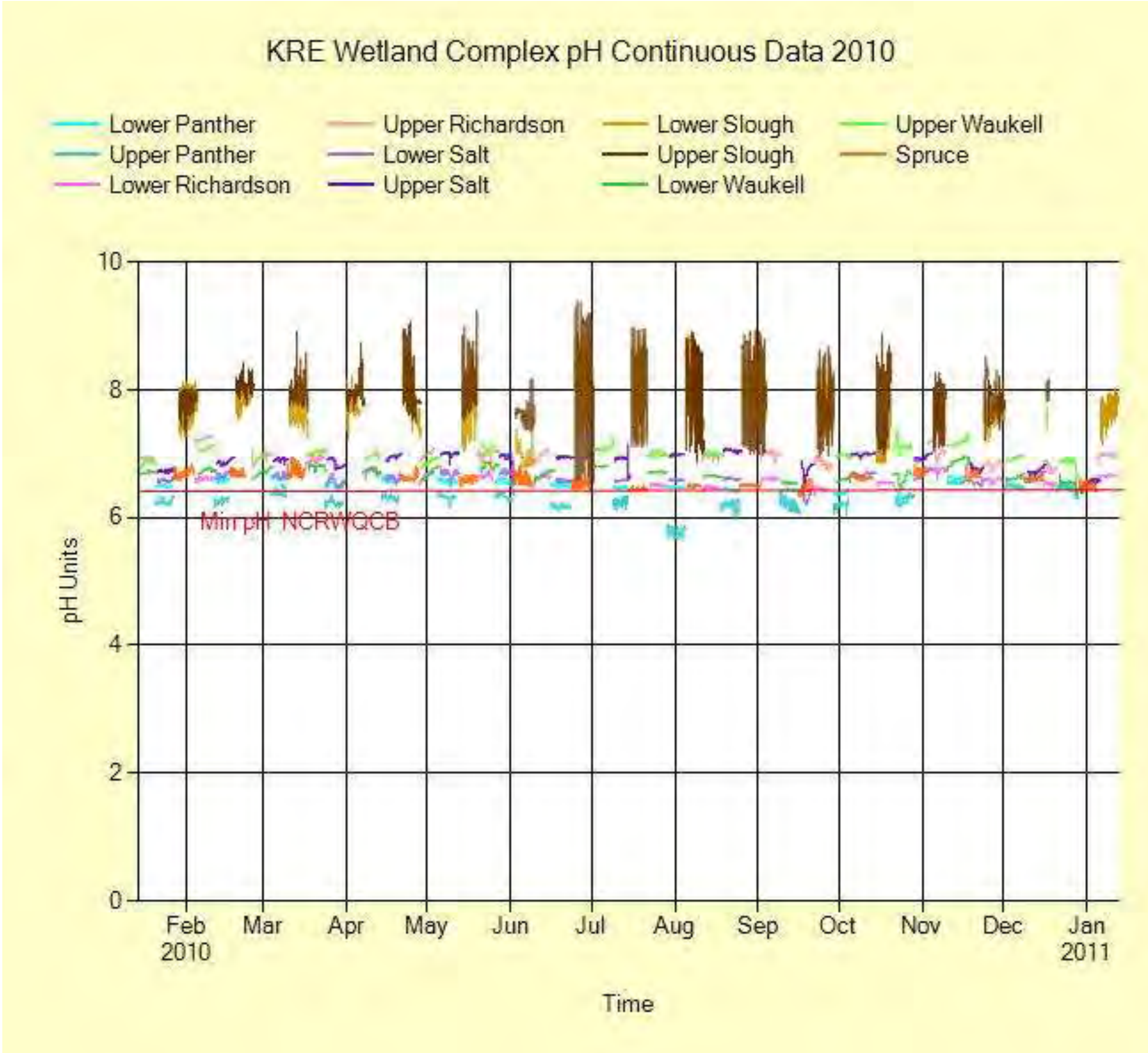

Figure 54: KRE WC pH Continuous Data 2010.

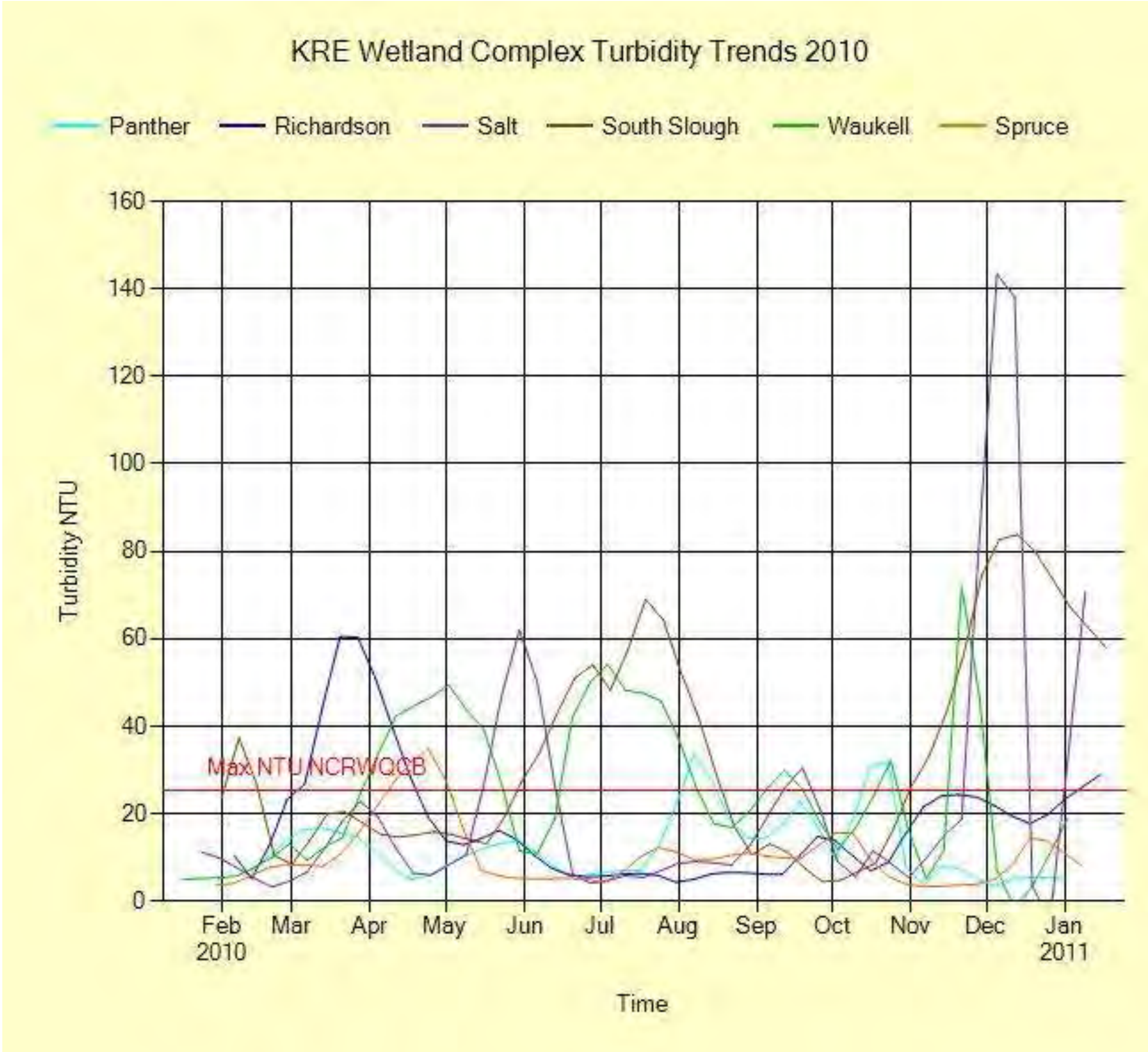

Figure 55: KRE WC Turbidity Trends 2010. Note: Trends are based on composite data sets.

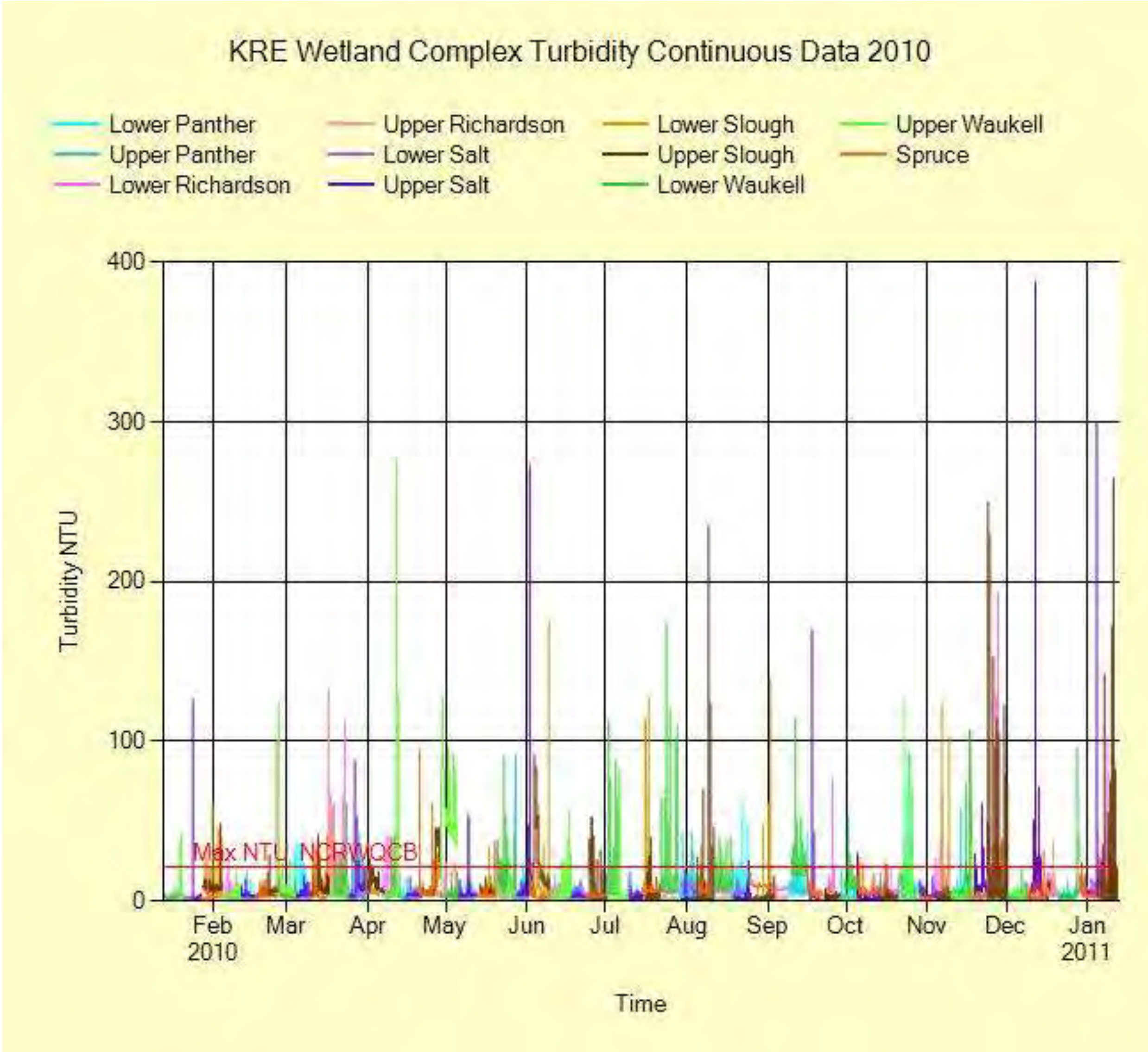

Figure 56: KRE WC Turbidity Continuous Data 2010.

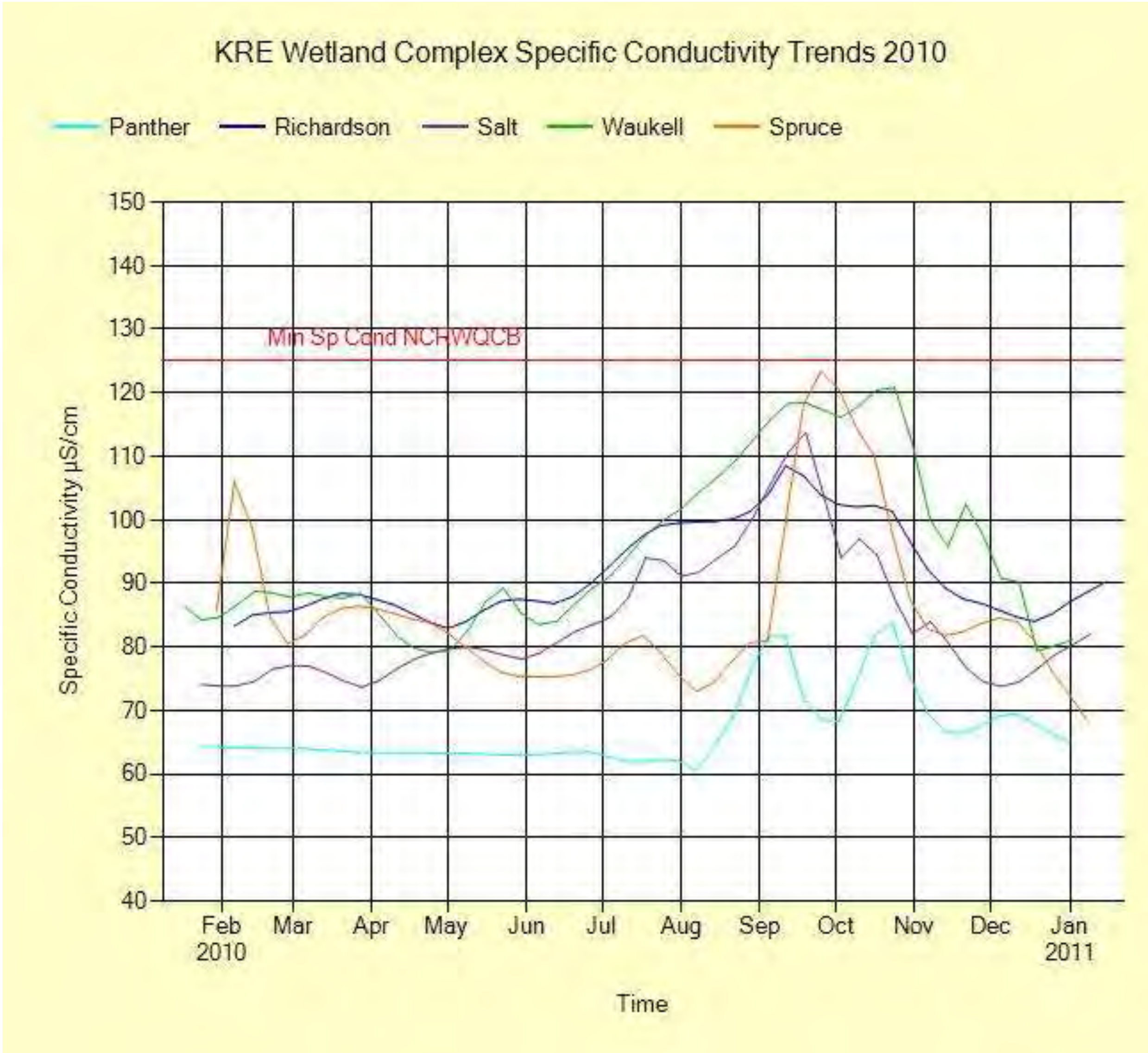

Figure 57: KRE WC Specific Conductivity Trends 2010. Note: South Slough not shown in this graph due to very high values. Note: Trends are based on composite data sets.

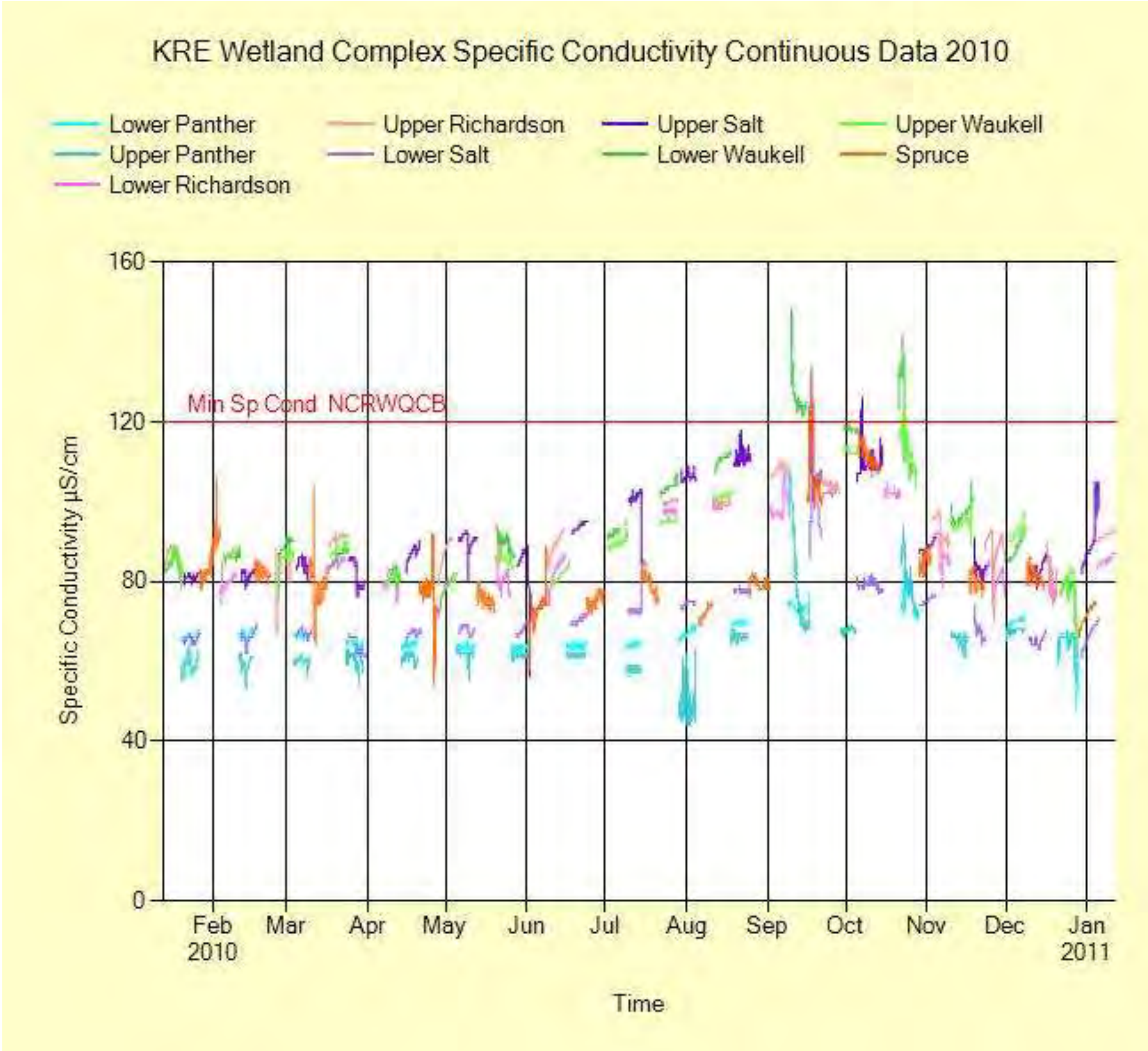

Figure 58: KRE Wetland Specific Conductivity Continuous data 2010. Note: South Slough not shown in this graph due to very high values.

3.2 Fisheries Results

3.2.1 Evaluating Juvenile Salmonid Rearing Habitat

Juvenile salmonid rearing habitat scores ranged from 25 to 13 for the KRE wetland study areas (Table 12). The Panther Creek WC had the highest score with a total of 25 points and therefore received the highest rank. The Salt Creek WC scored a total of 24 points and therefore ranked second. The Spruce Creek and the South Slough WCs both had a total score of 21 and therefore were given the same rank. The Richardson Creek and Waukell Creek WCs had the lowest scores with total scores of 17 and 13, respectively (Table 12).

The parameters that most influenced the overall scores were Rearing Habitat Availability and Rearing Habitat Complexity (Table 12). Salt, Panther, and Spruce WCs scored high for Rearing Habitat Availability; while, the Sough Slough, Richardson, and Waukell had intermediate scores for this parameter. Salt, Panther, South

Table 12. Results of an assessment of juvenile salmonid rearing habitat functionality for six Klamath River estuary wetland complexes, Klamath River, California.

Parameter	Salt Creek	Panther Creek	Spruce Creek	South Slough	Richardson Creek	Waukell Creek
Natal Salmonid Populations	2	3	3	3	1	2
Non-Natal Coho Use	2	2	2	2	2	2
Rearing Habitat Availability	5	5	5	2	2	2
Low Flow Access	2	2	2	2	0	2
Non-Native Fish Species	0	0	0	0	0	0
Bull Frogs	2	2	0	0	0	0
Invasive Plant Impairment	1	1	1	1	1	0
Rearing Habitat Complexity	5	5	2	5	5	0
Distance from Ocean	3	3	3	3	3	3
Distance from Klamath River	2	2	3	3	3	2
Total Habitat Score	**24**	**25**	**21**	**21**	**17**	**13**
Overall Rank	**2**	**1**	**3**	**3**	**4**	**5**

Slough, and Richardson WCs scored high for Rearing Habitat Complexity; while the Spruce Creek WC scored intermediate and Waukell scored a zero for this parameter. The other parameters where differences of two or more points occurred among the sites included Natal Salmonid Populations, Low Flow Access, and Bull Frogs (Table 12).

4.0 Analysis

Relationships between data sets have been investigated in an attempt to identify the potential use of CRAM as an indicator of Water Quality and/or Fisheries Functionality Score. This was accomplished through the completion of several steps. First, the WCs were ranked according to their scores in each of the data sets (Table 13). Then rankings were combined to show overall how wetlands rank according to the 3 data sets.

Table 13: WC Rankings

Site Location	Water Quality Score	WQ Rank	CRAM Score	CRAM Rank	Fish Habitat Function Score	Fish Habitat Rank	Combined Rank	Overall Rank
Richardson	23.5	2	74	2	17	4	8	2
Salt	19.38	1	67.95	4	24	2	7	1
Slough	50.09	5	79.29	1	21	3	9	3
Waukell	26.28	3	65.5	6	13	5	14	4
Spruce	58.74	6	66.14	5	21	3	14	4
Panther	41.09	4	68	3	25	1	8	2

The next step was to compare each of the data set rankings to one another and determine how much the rankings correlated. If CRAM is indicative of fish score, the rankings in each of the datasets would match closely. Likewise, if CRAM is indicative of water quality, the rankings would closely match.

The highest scoring CRAM location was in the South Slough with a score of 79.29. The water quality score for the South Slough was 50.09 and ranked fifth. The fish habitat score for the South Slough was a 21 and ranked third. Combined ranking for the South Slough was third overall.

The second highest scoring WC in CRAM was Richardson Creek, with a score of 74. Richardson Creek ranked second in water quality score, with a 23.5, and fourth in fish habitat score with a 17. Overall, Richardson ranked second in combined data set rankings.

Third in CRAM score with a 68 was Panther Creek WC. It ranked, fourth in water quality score with a 41.09, and second in fish habitat score with a 25. Overall Panther Creek WC is second, in combined data set rankings.

The fourth highest CRAM score was 67.95, in the Salt Creek WC. The water quality score was 19.38, the highest of all WCs. The fish habitat score was good as well with a 24, and ranked second. Overall the Salt Creek WC is the highest in combined data set rankings.

The fifth lowest CRAM score was Spruce WC, with a 66.14. It ranked last in water quality score, with a 58.74. The fish habitat score for Spruce was a 21, which ranked it third. Overall Spruce Creek WC is last in combined data set rankings.

The lowest scoring WC in CRAM was the Waukell Creek WC, with a 65.5. In water quality score, Waukell ranked third, and in fish habitat it scored last. Overall, Waukell WC was last in combined data set rankings.

What we saw was that there is not a finite correlation with the data set rankings, but this may be due to several factors. Some of the CRAM scores are very close, and the small differences in CRAM may not be discernable, when compared to water quality and fish use. That is, the difference in CRAM scores between 4 of the 5 wetland complexes was so small, that it is possible that the rankings may be different due to the inherent variability in CRAM score. In addition the fish scores were very close in range. Due to unique characteristic of the south slough, those being a estuarine type (tidally influence) WC, and water quality controlled by the mainstem Klamath River and Pacific Ocean, this WC was excluded and allowed for analysis of just freshwater WCs. The South Slough ranked fifth in water quality, and first in CRAM, and is an indication that CRAM may not be a good indicator of water quality in KRE wetlands.

Table 14: Data set rankings with for freshwater WCs only (South Slough excluded).

Site Location	Water Quality Score	WQ Rank	CRAM Score	CRAM Rank	Fish Habitat Function Score	Fish Rank
Richardson	23.5	2	74	1	17	4
Salt	19.38	1	67.95	3	24	2
Waukell	26.28	3	65.5	5	13	5
Spruce	58.74	5	66.14	4	21	3
Panther	41.09	4	68	2	25	1

Information in Table 14 suggests that there that there is not a direct correlation in CRAM data set rankings with water quality rankings, or fish score rankings. In the South Slough it easily understood that the water quality conditions controlled by the mainstem Klamath River and the Pacific Ocean play in a role in the lack of water quality and fish use, but the disconnect between CRAM and water quality and fish use is more difficult to understand in freshwater complexes. For example, Richardson Creek WC scored high in CRAM, and high in water quality (Table 14), yet nearly last in fish score. This information may lead one to believe that the area may have good potential for a restoration project but suffers from other factors limiting the fish score, such as fish passage.

4.1 Reference Wetlands

In support of long term monitoring, restoration, and mitigation guidance, reference wetlands have been developed in the light of multiple existing data sets. These 3 data sets, CRAM, water quality, and fisheries data, lead to a better understanding of the current conditions in wetlands and help to identify the wetland areas that are the least impacted by anthropogenic activities and maintain high levels of functionality. Reference wetlands can be used in long term monitoring to extrapolate goals to other sites and are designed to guide adoption of specific assessment objectives (US EPA 2006). The primary goal in the case of this report is to help define reference wetlands which are highly functioning wetlands in regards to salmonid habitat, and provide diverse supplemental habitats to the KRE, which continue to serve various wetland functions and maintain beneficial uses.

To identify reference wetlands 3 data sets have been used. The CRAM data set reveals the best overall wetland condition of KRE wetlands based on attributes, and also identifies the stressors leading to a decline in score. The water quality and fisheries data sets provide a “level 3” or “site intensive assessment” (USEPA, 2006) which can be used to further validate findings from CRAM, and further characterize wetland condition and identification of stressors. The relationships between data sets can lead to refined performance standards, and be used to develop water quality standards for wetlands protection (USEPA, 2006).

In analyzing the 3 data sets and combining ranks, we can identify the WC which can be used as a reference wetland based on the 3 data sets. As is seen in Table 13, Salt Creek is the WC which has been identified as a reference wetland (Figure 59). Salt Creek WC, ranked number one in water quality score, number four in CRAM score, and number two in fish score.

Figure 59: Fish habitat in the Salt Creek WC**.**

4.2 At-Risk Wetlands

Wetlands that have continued anthropogenic and natural stressors are often labeled low quality or low functioning. These areas are more often than not the wetlands that are permitted to undergo further degradation. Many wetlands are permitted to be filled each year under the CWA section 404 permit (Ambrose, 2000). The purpose of establishing at-risk wetlands in this report is to identify wetlands in need of protection from further wetland degradation which can potentially lead to a loss of wetlands in the KRE. Under current CWA regulations and "no net loss" policies, permitting agencies support a variety of mitigation options especially mitigation banks, which allow for the loss of wetlands to be compensated for by creation of wetlands in another location (USACOE, 2008). In the KRE, cumulative impacts have severely reduced wetlands and further loss is unacceptable, and furthermore, not conducive to restoring Klamath Basin salmonid populations.

At-Risk wetlands have been identified using the same 3 data sets as reference wetlands, but in the opposite manner. The areas severely impacted through anthropogenic stressors, and natural disturbances will have representative, CRAM, water quality and fish scores. The lowest scoring wetlands in all three data sets combined will be identified.

As seen in Table 13, there were two WCs identified as At-Risk wetlands, each having the same combined rankings. Waukell Creek WC ranked third in water quality score, sixth (last) in CRAM score and 5ifth (last) in fish score (Figure 60). Additionally, Spruce Creek WC scored last in water quality rank, fifth in CRAM score, and third in fish score (Figure 61).

Figure 60: Waukell Creek WC.


F

Figure 61: Spruce Creek WC.

5.0 Conclusion

The data presented in this report should be used to support decision making in regards to wetland protection, mitigation, and restoration in the KRE. Understanding salmonid populations and wetland habitats is a complex issue, making the prioritization of wetland mitigation and restoration projects a more difficult task when focusing wetland function as providing habitat for juvenile salmonids. YTEP supports YTFP in developing wetland mitigation and restoration projects in for the KRE with a focus on salmonids. It is anticipated that YTFP will produce a restoration plan for the Lower Klamath River which includes the KRE and associated WCs. It is anticipated that this restoration plan will include functional goals of wetlands focused more specifically for habitat for juvenile salmonids, and prioritize sites based on scientific research. The presented data in this report will supplement and contribute to such planning efforts. Previous efforts of prioritizing mitigation and restoration efforts in the KRE relied solely on CRAM assessment data. This information is very useful and informative but alone is inadequate for developing functional based restoration priorities. Water quality data presented in this report is another layer of wetland condition assessment, which is site intensive and specific to juvenile salmonids. Fisheries population data sets and qualitative assessments of fisheries habitat can also be additional layers of information applied in the decision making process. How these three data sets are used in the decision making process remains subjective, and adaptable as more research and monitoring is conducted in the future. It is intended that this report and the information in it be used to supplement the previous KRE Wetlands Restoration Prioritization Plan (Patterson, 2009).

5.1 Future Recommendations

5.1.2 Water Quality Monitoring

YTEP has planned to develop water quality standards for wetlands in the future. This task is outlined in YTEP's Wetland Program Plan (YTEP, 2011) and scheduled for completion by the end of 2016. These standards will contribute to the protection of wetland functions and condition, primarily in regards to salmonids. These standards may be enforced through several protection measures including an envisioned Wetlands Protection Ordinance, and the existing Yurok Tribe Water Quality Control Plan Water Quality Certification process. YTEP anticipates that the water quality data presented in this report, along with further water quality monitoring will be necessary in developing numeric water quality standards. Specific recommendations for further water quality monitoring will be developed in a joint effort between YTEP and YTFP.

5.1.2 Benthic Macroinvertebrate Studies

In 2012 and 2013, YTEP plans to conduct assessments of the benthic macroinvertebrate communities populating the KRE WCs. This additional layer of site intensive assessment data can be used to further characterize the conditions of the WCs and has potential as an indicator of wetland function. Benthic macroinvertebrate community assessments serve as independent information and are related to stream health and are indicators of water quality, substrate, and anthropogenic degradation (Ode, 2007; Fetscher et al., 2009). The data can be used to answer many different questions, create and test various hypotheses. Of particular interest in this case is how benthic macroinvertebrate communities are related to fish populations, and water quality (chemistry), the role they play in the ecologic food web, and in regards to providing a food source. Standardized macroinvertebrate sampling methods have been well established for in stream habitats, and specific Indices of Biological Integrity (IBI) have been developed for Northern California, yet wetland macroinvertebrate studies remain a less standardized area of research, and currently IBIs do not exist for the KRE, or associated freshwater WCs.

5.1.3 Evaluating Juvenile Salmonid Rearing Habitat

As previously stated, the set of parameters developed to assess the functionality of juvenile salmonid rearing habitat should be refined and expanded as more information becomes available or is collected in future phases of YTEP's wetland program. At a minimum, YTFP-LKD recommends adding more quantitative measures including seasonal abundance and growth (e.g. winter and summer).

A quantitative measure often assessed when considering the functionality of wetlands as rearing habitats is the relationship between surface area of the wetland and the estimated number of salmonids present (Keeley and Slaney, 1996; Koning and Keeley, 1997). In general, the number of salmonids that can rear in a wetland increases with wetland size; however, based on data collected throughout the Pacific Northwest, smaller wetlands are relatively more productive than larger wetlands (Lister et al., 1980; Cederholm and Scarlet, 1991; Keeley and Slaney, 1996; Koning and Keeley, 1997). YTFP-LKD has conducted winter-spring abundance estimates for juvenile coho and trout in several of the KRE WCs (Figure 62). Abundance estimates generated for KRE wetlands suggests there is variability between KRE wetlands as well as a fairly high degree of annual variability for individual sites (Silloway, 2010; Silloway and Beesley, 2011). Therefore, more effort should be made to continue and expand abundance surveys in KRE wetlands to better characterize the range in use.

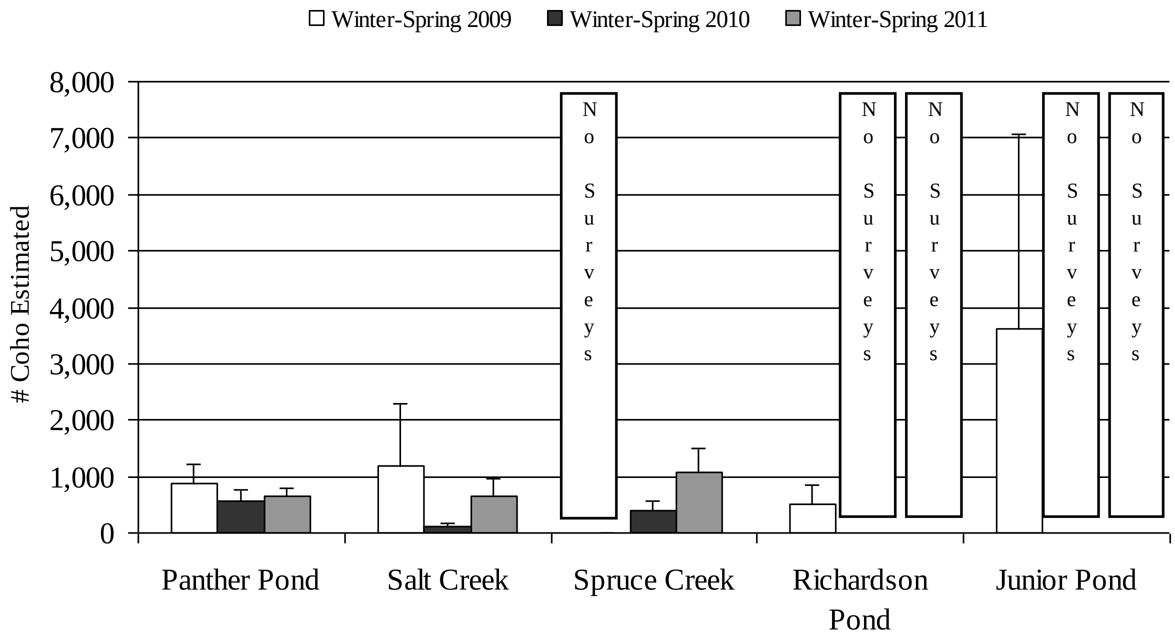

Figure 62: Mark-recapture abundance estimates for juvenile coho salmon in several wetland complexes of the Klamath River estuary (Winter-Spring 2009 – 2011), California.

One of the most important parameters that should be incorporated into the assessment of juvenile salmonid rearing habitat functionality is growth. Juvenile salmonid growth is directly related to the quality and quantity of food available as well as other important environmental variables such as water quality (e.g. temperature, dissolved oxygen). Given the positive relationship of smolt size at ocean entry and ocean survival, wetlands that support higher juvenile salmonid growth should be valued higher than areas where salmonid growth is limited or low. YTFP-LKD recently began assessing growth rates for juvenile coho salmon residing in Spruce Creek, Panther Pond, and in two constructed wetlands in Terwer Creek, a coastal tributary of the Lower Klamath (Silloway and Beesley, 2011; Hiner et al., 2011). However, future growth studies should be conducted using consistent methods and over the same time period to allow for a comparison of growth rates between sites. Assessments of food availability (e.g. macroinvertebrate studies) should also be conducted in conjunction with growth estimates to further our understanding of rearing habitat productivity.

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