ROCK CREEK WATER QUALITY REPORT

Water Resource Inventory Area 31

Prepared for: WRIA 31 Planning Unit

Project No. 030009-003-01 • June 22, 2005 Final

Project funded through Ecology Grant No. G0400370

ROCK CREEK WATER QUALITY REPORT

Water Resource Inventory Area 31

Prepared for: WRIA 31 Planning Unit

Project No. 030009-003-01 • June 22, 2005 Final

Aspect Consulting, LLC

Steve Germiat, LHG, CGWP
Associate Hydrogeologist
sgermiat@aspectconsulting.com

Timothy J. Flynn, LHG, CGWP
Principal Hydrogeologist
tflynn@aspectconsulting.com

V:\030009 WRIA 31\Final Rock Creek Report\Final Rock Creek WQ Report.doc

Contents

List of Tables

List of Figures

List of Appendices

Executive Summary

Rock Creek was recently listed on the state's 2004 Candidate 303d list for impaired water quality, based on elevated water temperature in one headwater reach. Under this listing, Rock Creek would require a Total Maximum Daily Load (TMDL) to address water temperature. As part of the watershed planning process for Water Resource Inventory Area 31 (WRIA 31), a water quality assessment was completed to evaluate existing Rock Creek water temperature data relative to state water quality standards, and document historical changes to the creek channel and surrounding vegetation that can offer insight into potential causes of the elevated water temperatures. The study also included analysis of nitrate and fecal coliform in creek water to evaluate whether livestock grazing in the subbasin is adversely impacting water quality. Finally, a database was developed for use by the Eastern Klickitat Conservation District (EKCD) in management, evaluation, and reporting of water quality data for Rock Creek.

The conclusions and recommendation from this Rock Creek water quality study are as follow:

- Nitrate and fecal coliform concentrations in Rock Creek surface water meet state water quality standards.
- Rock Creek water temperatures increase in the downstream direction, and typically exceed the state default water temperature standard in downstream monitoring stations throughout the summer months.
- Analysis of historical aerial photographs of the Rock Creek valley indicates that the areal extent of vegetation across the valley bottom has been increasing steadily since 1938. This change is attributed primarily to active suppression of fires over the past century.
- The creek channel in the lower reaches of the Rock Creek is shallow, rocky, and highly dynamic, changing course regularly over the period of photographic record.
- The collective information evaluated in this study indicates that the high water temperatures in Rock Creek may represent the natural condition; therefore, the statewide default water temperature standard may not be applicable for Rock Creek.
- Because Rock Creek represents the best fish habitat in WRIA 31, additional evaluation of elevated water temperatures, the relative contribution of man-made versus natural causes on those temperatures, and the feasibility of taking actions to lower those temperatures, should be included as part of the Phase 3 Watershed Management Plan for WRIA 31.

1 Introduction

This report details the water quality project for the Rock Creek subbasin completed as a part of watershed planning for Water Resource Inventory Area 31 (WRIA 31). The general objectives of this study were to:

- Evaluate existing Rock Creek water temperature data to document water temperatures relative to state standards;
- Measure current nitrate and fecal coliform levels in Rock Creek;
- Develop a database to manage and facilitate analysis of the water quality data for Rock Creek; and
- Analyze available aerial photographs to document historical changes in stream channel alignment and areal extent of vegetation in the Rock Creek valley, both of which can influence water temperature in the creek.

This supplemental water quality project was funded under Grant number G0400370 obtained by the WRIA 31 Planning Unit from the Washington State Department of Ecology (Ecology) under the Watershed Management Act.

The following sections of this report are:

- Project Background;
- Methods;
- Results and Discussion; and
- Recommendations

2 Project Background

This supplemental water quality project addresses water quality in one of the four WRIA 31 subbasins – the Rock Creek subbasin (Figure 1). Background information pertinent to the Rock Creek subbasin is summarized below (from the WRIA 31 Level 1 Assessment; Aspect Consulting and WPN 2004).

2.1 Topography and Climate

WRIA 31 occurs within the Columbia Plateau physiographic province. The Horse Heaven Hills, a broad east-west ridge, forms the Rock Creek subbasin's northern boundary, and the Columbia River gorge forms the southern boundary. The watershed slopes from an elevation of approximately 4,700 feet to the north to approximately 270 feet in the Columbia Gorge.

The Rock Creek subbasin, with its deeply incised canyons, has the most topographic relief with correspondingly higher stream velocities and erosion potential than the other subbasins in WRIA 31. Twenty percent of the subbasin area has slopes greater than 100 percent. The average slope for the Rock Creek subbasin is 36 percent.

The average annual precipitation in the Rock Creek subbasin varies from approximately 10 inches at the mouth to 28 inches near the headwaters of the watershed. The mean annual precipitation calculated for the Rock Creek subbasin as a whole is 16.2 inches (1961-1990). Most of the climate stations within the subbasin typically receive precipitation in the form of snowfall during November through March, with peak snowfall occurring in January. The snowfall period can extend October through May for the higher elevation stations in the subbasin.

Air temperature is important for watershed assessment because it affects the hydrologic regime of a watershed and influences water quality and habitat conditions. Average minimum daily temperatures are typically at or below freezing for December through February, and longer in the mountainous areas. Average daily temperatures are generally highest in July each year with daily maximum temperatures typically exceeding 90 degrees Fahrenheit during much of the summer at lower elevations in the Rock Creek subbasin.

2.2 Geologic Setting and Streamflows

The geology of a watershed, or subbasin, influences to a large extent the occurrence and movement of groundwater and its interaction with surface water in the area. Surface geology can also influence the magnitude and timing of surface runoff, and thus streamflow.

Figure 1 is a surface geologic map of the Rock Creek subbasin (from Washington Department of Natural Resources [DNR] 1:100,000 mapping). The WRIA 31 region is underlain by bedrock of the Columbia River Basalt Group (CRB) and interbedded terrestrial sediments deposited during time periods between sequential basalt flows. The CRB underlies the entire Rock Creek subbasin in WRIA 31. The CRB includes (from oldest to youngest) the Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt, separated by sedimentary interbed units (Figure 2). The Rock Creek valley is typically deeply incised into the Wanapum Basalt, although the Grande Ronde Basalt does outcrop along portions of the stream. Figure 1 also shows locations of major springs mapped by Brown (1979) and on USGS 7.5 minute topographic quadrangle maps.

Rock Creek drains 258 square miles in the western part of WRIA 31. The only information quantifying surface water discharge from the subbasin is from the USGS stream gage on Rock Creek (USGS Station 14036600), located near the tribal long house near the confluence with the Columbia River. The gage was maintained for 6 water years, from 1963-1968. A water year is defined as starting on October 1 and ending on September 30 the following year. Water years correspond to the calendar year in which they end. For example water year 1963 runs from October 1, 1962 through September 30, 1963.

The mean daily flows for the six-year period of record for the Rock Creek gaging station range between 0 and 77 cubic feet per second (cfs). Rock Creek can be considered a seasonal stream with no flow in some reaches during the summer months. Streamflow is typically only present near the confluence with the Columbia River on a consistent basis from December through May each year.

The Rock Creek hydrograph (Figure 3) demonstrates the relatively "flashy" nature of streamflow in this subbasin (high intensity, short duration flows), indicating limited storage within the watershed. Following precipitation events, the rising limb of the hydrograph is relatively steep, indicating a rapid streamflow response as a result of the bedrock terrain and relatively steep slopes in the subbasin. It is inferred that snowmelt runoff in the higher elevation headwaters helps sustain flows into early spring. Although there are numerous springs mapped in the Rock Creek subbasin, groundwater discharges from the Wanapum Basalt, through which the creek incises, provide insufficient baseflow to sustain flows into the dry season.

2.3 Land Use

The predominant land cover in the Rock Creek subbasin is shrubland, comprising nearly 47 percent of the subbasin area based on 1992 LANDSAT mapping. This non-forested rangeland occurs throughout the subbasin except in the highs elevation of the northern portion. The Rock Creek subbasin is the only subbasin within WRIA 31 with a substantial proportion (approximately 26 percent) of forestland. The forestland occurs in the higher elevation areas of the upper subbasin and is mostly privately owned. The dominant use of much of the shrubland and forest land in the subbasin is for livestock grazing. Many of the riparian corridors are also forested, except in the lower elevation reaches. Ehinger (1996) reports that riparian vegetation is intact in most of the upper Rock Creek subbasin, whereas stream banks in the lower portion consist largely of cobble (hence the name Rock Creek) with little to no riparian vegetation. As of the 1992 mapping, agricultural land totaled only 10 percent of subbasin area – 9 percent dryland farming and 1 percent irrigated. By 2001, this percentage dropped, with 4 percent of the subbasin area in dryland farming and 0 percent in irrigation (data from IRZ Consulting 2004). All of the cultivated land occurs within the lower half of the subbasin. Developed land accounts for less than 1 percent of the total subbasin area.

2.4 Existing Studies/Data

In 1995-1996, Ecology in cooperation with Eastern Klickitat Conservation District (EKCD) conducted an evaluation of high water temperature, including the influence of riparian canopy cover, in Rock Creek (Ehinger 1996). The study concluded that the high water temperatures in upper Rock Creek "may be natural for a small creek in a hot, sunny summer climate". It was inferred that the lack of riparian shading and rocky substrate were contributing factors to the observed water temperatures in the lower stream reaches; however, the study did not attempt to resolve whether these conditions were natural or the result of land use changes. Review of General Land Office (GLO) cadastral survey notes from the 1860s, completed as part of the WRIA 31 Level 1 Assessment, indicates that the rocky substrate and lack of trees in the lower portion of Rock Creek observed today is consistent with conditions at that time, providing evidence that it is likely a natural condition (refer to Chapter 5 of Aspect Consulting and WPN 2004). The Ehinger

(1996) study pointed out that it would be difficult to quantitatively estimate what portion of the observed high water temperature is natural versus due to anthropogenic causes.

Based on the stream habitat survey, the Ehinger (1996) study concluded that most of Rock Creek showed little impact from current forestry or agricultural practices, but evidence of past grazing practices and episodic flood events were apparent in the lower reaches. Six of the ten stations monitored in the study had riparian canopy (vegetative) cover more than 10 percent below state target goals for eastern Washington Class A streams.

The outcome of the Ehinger (1996) water quality study was a set of management recommendations to reduce water temperatures and thus improve instream habitat. A Memorandum of Agreement (MOA) was subsequently established between Ecology and EKCD outlining measures to be implemented and reporting requirements. In accordance with the MOA, riparian vegetation was planted along portions of the Rock Creek drainage (adjacent Spring Creek), and EKCD is monitoring water temperatures and other water quality parameters (e.g., nitrate, pH). However, these data are not currently being managed in an efficient manner, nor has a comprehensive assessment of the collected monitoring data been completed to document baseline water temperature conditions. These baseline data are necessary to be able to evaluate whether current and future control measures will have a measurable effect on Rock Creek water temperature. Development of a database to help manage and evaluate these data is one component of this study.

Washington Department of Fish and Wildlife (WDFW) has reported that Rock Creek supports both steelhead and Chinook salmon. Rock Creek has the highest average annual precipitation (including some snowpack), and thus the most persistent streamflow, of any stream in WRIA 31. The Rock Creek subbasin also has a low density of human development and the lowest water use of any of the four WRIA 31 subbasins (refer to Aspect Consulting and WPN 2004). In general, Rock Creek is considered to have the greatest potential for fish habitat of any WRIA 31 stream.

These existing water quality studies from the Rock Creek subbasin provide the baseline information upon which this water quality project is developed.

2.5 Exceedence of State Water Quality Standards

Water quality standards for all surface waters are defined by the State of Washington (Chapter 173-201A WAC). The state adopted changes to Chapter 173-201A WAC in 2003, but the Environmental Protection Agency (EPA) has not yet approved the new standards. Until EPA approval is obtained, the state's 1997 standards remain in effect. The 1997 standards classify surface waters as AA (extraordinary), A (excellent), B (good), C (fair) and Lake. Rock Creek was classified as Class A under the 1997 standards.

Under the 2003 draft standards, all surface waters in the state are protected by narrative criteria, designated uses, and an anti-degradation policy. Designated uses are those uses specified in Chapter 173-201A WAC for each water body, regardless of whether or not the uses currently exist. Based on the use designations, numeric and narrative criteria are assigned to protect existing and designated uses of a water body. Freshwater uses designated by the state include:

- Aquatic life uses, which include six categories based on presence of key aquatic species;
- Recreation uses, which include the three categories of extraordinary primary contact, primary contact, and secondary contact;
- Water supply uses, which include domestic, industrial, agricultural, and stock watering; and
- Miscellaneous uses, which include wildlife habitat, harvesting, commerce and navigation, boating, and aesthetics.

For freshwater water bodies that do not have designated uses specified in WAC 173-201A-600 (Table 602), the following designated uses apply:

- Salmon and trout spawning, non-core rearing, and migration;
- Primary contact recreation;
- Domestic, industrial, agricultural and stock water uses; and
- Wildlife habitat, fish harvesting, commerce and navigation, boating, and aesthetic values.

No WRIA 31 streams are listed in WAC 173-201A-600 (Table 602), so these default water uses and associated water quality criteria apply by default to all surface waters in the WRIA including those of the Rock Creek subbasin (Table 1), whether or not they are used for all categories described in Table 1. The water quality criteria defined for these default uses apply unless Washington State Department of Ecology (Ecology) were to make a site-specific determination to the contrary.

Table 1. Draft Water Quality Criteria for all Surface Waters in WRIA 31

Designated Uses for Surface Water in WRIA 31[1]		Temperature[2]	Dissolved Oxygen[3]	Turbidity	pH
Aquatic	Salmon and trout spawning, noncore rearing, migration	17.5 °C (63.5 °F)	8.0 mg/L	5 NTU over background if the background is 50 NTU or less, 10% increase in turbidity when the background is > 50 NTU	6.5 - 8.5 with human caused variations within the above range of less than 0.2 units
		Bacteria			
Recreation	Primary contact recreation	Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies/100mL, with not more than 10 percent of all samples (or any single sample when less than 10 sample points exist) obtained for calculating the geometric mean value exceeding 200 colonies/100mL.			
		Toxics		**Aesthetics**	
Water Supply	Domestic, industrial, agricultural, stock watering	Toxic, radioactive, or deleterious material concentrations must be below those which have the potential, either singularly or cumulatively, to adversely affect biota dependent upon those waters, or adversely effect public		Aesthetic values must not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste (see WAC 170-201A-230 for guidance on establishing lake nutrient standards to protect aesthetics).	
Miscellaneous	Wildlife habitat, fish harvesting, commerce and navigation, boating, aesthetic values				

Notes:
1) As defined in WAC 173-201A
2) Temperature standards are set by the 7-day average of the daily maximum temperature
3) The Disolved Oxygen standard is set by the lowest one-day minimum
General : All information from WAC 173-201A

As of the mid-1990s, water temperatures in Rock Creek exceeded the applicable state water quality standard (17.5 degrees Celsius; 63.5 degrees Fahrenheit). Note that when a water body does not meet its assigned criteria due to natural climatic or landscape attributes, the natural condition (background) defines the applicable water quality criteria (WAC 173-201A-260[1]). This may be of particular importance with regards to Rock Creek stream temperature, although documenting the historic natural condition with confidence is difficult. Under the 1997 water quality standards, the water temperature standard is 18 °C for Class A streams like Rock Creek.

Rock Creek was recently listed on the state's 2004 Candidate 303d list for impaired water quality based on elevated water temperature in the upper reach (T5N R17E section 13). Consequently, Rock Creek requires a Total Maximum Daily Load (TMDL) to address water temperature.

3 Water Quality Analysis

3.1 Methods

The sampling and analysis program was completed consistent with that outlined in the Quality Assurance Project Plan (Aspect Consulting 2004), except as noted below.

Project Objectives

The objectives of this subbasin-specific project were to:

- Compile, manage, and analyze the existing East Klickitat Conservation District's (EKCD) water temperature data for Rock Creek to document baseline water temperature conditions relative to riparian plantings and other BMPs implemented;
- Develop a user-friendly water quality data management system (database) for EKCD to compile existing data and provide a repository for future data collection. The database includes data analysis routines to facilitate ongoing analysis of the data and simplifies transfer of data to Ecology in their requested format;
- Analyze readily available aerial photographs to assess historical changes in riparian vegetation within the drainage; and
- Conduct surface water sampling to evaluate concentrations of nitrate and fecal coliform in Rock Creek.

Data Quality Objectives

The data from this project must be of sufficient technical quality to document daily and seasonal changes in Rock Creek water temperature (most of these data already collected, but evaluated in this project), and to allow comparison of concentrations of nitrate and fecal coliform in Rock Creek surface water relative to state standards. Field and laboratory QC procedures to achieve data quality objectives are described in the project Quality Assurance Project Plan (Aspect Consulting 2004).

Field Sampling

Personnel from Aspect Consulting and EKCD completed two rounds of water quality sampling for nitrate, fecal coliform, and field parameters (water temperature, electrical conductance, pH, and dissolved oxygen) at eight Rock Creek locations, and three locations on major Rock Creek tributaries (Luna Gulch and Squaw Creek) (Figure 4). The two sampling events occurred November 17-18, 2004 and March 1-2, 2005. These sampling events generally corresponded to the onset of wet season flows (November) and near the time of peak flows (March). Note that the 2004-2005 winter was exceptionally dry.

Figure 4 shows the locations where surface water samples were collected from the Rock Creek subbasin. These locations correspond to where EKCD has current or historical temperature gaging stations (refer to Chapter 4 of Aspect Consulting and WPN 2004). However, two new alternate stations were established for this study. Those stations – RC-02R and RC-03R – were established because the stream was dry at stations RC-02 and RC-03 during the November sampling event. Establishing the alternate stations allowed samples to be collected during both visits and a seasonal comparison of water quality data from locations near the original RC-02 and RC-03 stations. In addition, stations RC-04 and RC-05 were not sampled for this study. These two stations, at which EKCD had temperature loggers for two or three years in the mid-1990s, have poor accessibility, requiring a several hour hike on steep slopes for a round trip visit. Because of the logistical difficulty in accessing the creek anywhere near these two locations, particularly if monitoring continues into the future, samples were not collected from them for this study. The other sampling stations provide sufficient coverage of the subbasin drainage to understand water quality conditions for the purposes of this study.

Discrete grab samples of surface water were collected, and field parameters were measured, at each location. Surface water samples were collected near mid-channel, upstream of the location the sampler is standing, and at about one-half the stream depth. In accordance with the QAPP (Aspect Consulting 2004), additional precautions were also taken to limit the chance for cross contamination of samples collected for fecal coliform analysis: (1) Disposable gloves were worn during sample collection; (2) the gloves and exterior of the sample sampling cup were disinfected with a chlorine bleach solution prior to sample collection; and (3) gloves and sample container were submerged in the flowing stream for at least 30 seconds to remove residual bleach immediately prior to sample collection.

Field parameters were measured by immersing the probe directly in the stream at the location where the sample was collected. Stream discharge was also estimated visually at each sampling station. In addition, general riparian vegetation type (deciduous trees, conifers, brush, etc.) was noted and photograph(s) taken at each sampling station. These notes are summarized in Section 3.2.

The surface water samples were analyzed for nitrate and fecal coliform by an Ecology-accredited analytical laboratory, and the analytical results were reviewed to ensure suitable data quality. Analytical methods and QC are discussed in Appendix B.

Database Development

To facilitate analysis of the EKCD's vast quantity of water temperature data for the Rock Creek watershed, Aspect Consulting personnel developed a database utility (DataStream) to provide storage, quality control, standardization, and analysis of water quality data. DataStream was developed in coordination with EKCD (as its future user) to update and maintain a database of the water quality data they collect. The utility was written in Visual Basic .NET as a standalone user interface to data stored in a Microsoft Access database, eliminating the need for the user to interact directly with the Access database. This separation allows reliable data analysis (e.g., graphing, calculating statistics) that was cumbersome within the Access environment, as well as a customizable user interface. Its specially tailored user interface and context-sensitive HTML help system allow its use with little or no learning curve.

DataStream was designed to accept bulk input of data from EKCD's temperature transducer logs, as well as manual input of many other types of measurements into the database. All existing EKCD data for the Rock Creek watershed (1995-2004) were imported into the database by Aspect Consulting, including hourly water temperature data, hourly air temperature data, and spot measurements of stream discharge and water quality (pH and dissolved oxygen). EKCD water temperature data from 1995 and 1996 that were collected at 6-minute intervals were synthesized as hourly averages and input into the database as hourly values to reduce the size of the database. Water quality data collected for this study (fecal coliforms and nitrates) were also input into the database.

DataStream also includes a graphing utility that draws line charts of water temperature data that can be overlaid onto air temperature data. Other data, such as stream discharge (flow), pH, dissolved oxygen, nitrates and fecal coliforms can be graphed as column charts. All charts can be exported as images, and their underlying datasets can be exported for use in more advanced analysis tools. The water and air temperature charts are especially useful for identifying time periods when in-stream transducers may have become exposed to air (stream dried out) as well as other data outliers that should be excluded as accurate water temperature values. DataStream allows the user to manually reject data outliers. These data are then excluded from analysis (e.g. charts and statistics) but not deleted from the database. Aspect Consulting personnel used DataStream to perform a quality control review of all EKCD water temperature data for the Rock Creek watershed. DataStream calculates critical statistics from the water temperature data (daily maximum temperature, 7-day average of daily maximum temperatures [7-DADMax] number of consecutive days above a specific temperature) to help identify baseline water temperature for the 1995-2004 period including compliance with state surface water standards. Analysis of these data is discussed in Section 3.2.

DataStream was also designed to assist in preparing data for submission to Ecology via their EIM online data submittal procedure by exporting data in an upload-ready text format. Finally, DataStream also provides features designed to assist in routine workflow, such as automatic generation of pre-printed field forms for easier data collection. The Data Stream software has been submitted to Ecology for their independent review.

3.2 Results and Discussion

Nitrate in Rock Creek Surface Water

Nitrate concentrations measured in Rock Creek surface water during the November 2004 and March 2005 sampling events were low - more than an order of magnitude below the 10 mg/L state drinking water standard. As stated in Section 2.5, there is no surface water quality standard for nitrate. Table 2 presents the nitrate concentrations measured in both sampling events for this study. This table also presents the corresponding measured water quality field parameters: dissolved oxygen, specific electrical conductance, pH, oxidation-reduction potential (Eh), turbidity, and temperature.

Based on the data from this study, nitrate is not considered a water quality concern for Rock Creek at this time.

Spatial Distribution

Nitrate levels are low in surface waters sampled throughout the Rock Creek subbasin. Detected nitrate concentrations ranged from non-detect (less than 0.005 mg/L) to 0.590 mg/L during the November 2004 event and 0.0052 mg/L to 0.419 mg/L during the March 2005 event.

The highest nitrate level was found in monitoring station LG-01, on the north fork of Luna Gulch, during both the November 2004 and March 2005 sampling events. During the November event, the Rock Creek samples downstream of the confluence with Luna Gulch also have slightly elevated nitrate (0.14 to 0.18 mg/L) compared to the upstream samples (0.023 mg/L or less), presumably due to the influence of Luna Gulch. The concentrations downstream of Luna Gulch were lower in March 2005, presumably as a result of the greater flow volume. The distribution of detected nitrate values during the two sampling events is plotted on Figure 5.

Seasonal Distribution

In general, the nitrate values from the March sampling event are lower than the November values. Much of this is probably due to the higher streamflows in March which could be diluting the already low concentrations of nitrates in the stream. Two exceptions to this general trend are RC-06 and RC-07 which had marginally increased nitrate values from November to March (0.00570 to 0.0137 mg/L and 0.00617 to 0.0351 mg/L respectively). Although these represent a large percentage increase, the concentrations are so low that the change is considered insignificant.

Fecal Coliform in Rock Creek Surface Water

Detected fecal coliform levels in Rock Creek surface water samples collected during this study were below the draft state standard. The fecal coliform levels are attributable to livestock grazing in proximity to the stream; however, other wildlife (e.g., deer) can also contribute.

Spatial Distribution

The draft state surface water standard for fecal coliform bacteria levels is based on a sample data set from the waterbody. Fecal coliform levels must not exceed a geometric mean (statistical average) value of 100 colonies/100 mL for the sample data set, and not more than 10 percent of the individual samples can exceed 200 colonies/100 mL (WAC 173-201A-200[2]). This standard is based on human recreational use of the surface water.

The highest concentration of fecal coliform detected during the fall 2004 sampling of Rock Creek was 80 colonies/100 mL at RC-08. Cattle feces were noted near this sampling location at the time of the fall sampling. During the spring 2005 event, the highest value detected was 30 colonies/100 mL at RC-09. Recent cattle activity was observed upstream of this location during this sampling event. Fecal coliform values for each sampling station during the two sampling events are plotted on Figure 6.

Seasonal Distribution

The geometric mean value for the fall 2004 and spring 2005 sample sets were 12.1 colonies/100 mL and 4.5 colonies/100 mL respectively. In general, all the fecal coliform concentrations were lower in March than in November. The only exception to this was for RC-09 which increased from 8 to 30 colonies/100 mL.

Table 2. Water Quality Data Collected in this Study

Stream	Station	Sample Date	Water Quality Parameters: Nitrate + Nitrite as N in mg/L	Water Quality Parameters: Fecal Coliforms in MPN/100 mL	Field Parameters: Dissolved Oxygen in mg/L	Field Parameters: Specific Conduct. in µmhos/cm	Field Parameters: pH	Field Parameters: Eh in mV	Field Parameters: Turbidity in NTU	Field Parameters: Temp. in °F
Quartz Creek	RC-01	11/17/04	0.0175	30	11.2	102	7.2	203	2.2	49.1
		3/2/05	0.00547	2	10.4	93	7.4	267	2.5	42.0
Rock Creek	RC-02R	9/28/04	0.0231	30	10.8	164	6.9	319	2.0	37.2
		3/2/05	0.00917	8	11.3	102	6.8	191	2.2	37.7
Rock Creek	RC-03R	9/28/04	0.005 U	70	10.2	211	7.8	373	2.1	41.9
		3/2/05	0.0100	8	10.9	212	7.7	276	5.1	41.4
Rock Creek	RC-03	3/2/05	0.00521	7	11.7	71	7.5	274	1.7	38.9
Rock Creek	RC-06	11/17/04	0.00570	2	16.4	206	7.5	206	0.5	43.2
		3/1/05	0.0137	2 U	11.8	146	7.6	164	1.6	43.1
Squaw Creek	RC-07	11/17/04	0.00617	2 U	14.6	262	7.4	199	0.5	46.4
		3/1/05	0.0351	2 U	11.1	198	7.5	174	1.4	44.7
Rock Creek	RC-08	11/17/04	0.143	80	15.5	238	7.5	221	0.7	50.4
		3/1/05	0.0133	17	11.0	186	7.5	176	1.6	44.5
Rock Creek	RC-09	11/17/04	0.165	8 J	13.7	244	6.8	176	1.0	48.7
		3/1/05	0.0137	30	11.4	193	6.7	180	1.8	43.6
Rock Creek	RC-10	11/17/04	0.176	2	11.7	223	7.1	182	0.7	56.7
		3/1/05	0.00853	2 U	10.9	190	7.4	179	1.7	44.6
Luna Gulch	LG-01	11/17/04	0.590	17	15.0	224	7.3	195	1.4	42.6
		3/1/05	0.419	2 U	10.3	249	7.6	172	2.6	46.9
Luna Gulch	LG-03	3/1/05	0.0836	2 U	10.7	228	7.5	164	1.8	45.2

Data Qualifier: U = Not detected at or above the reported value
J = Estimated Value

Water Temperature in the Rock Creek Subbasin

Spatial Distribution

The locations of water temperature monitoring stations currently and historically maintained by the EKCD in the Rock Creek subbasin are shown on Figure 4. For reference, Figure 4 also shows the distribution of salmon and steelhead in the Rock Creek subbasin as mapped by Washington Department of Fish and Wildlife (WDFW).

The water temperature recorded by EKCD typically exceeds the default state surface water standard throughout the Rock Creek watershed during the summer months. In general, water temperatures increase downstream. A statistical summary of the EKCD water temperature data is presented in Table 3. The statistical summary includes the period of record (e.g. years when data was collected at each station, usually between May and October for a given year), average number of days the calculated 7-day average daily maximum temperature (7-DADMax) temperature exceeded the default draft standard of 63.5°F per year during the period of record, average percentage of days the 7-DADMax exceeded 63.5°F, and the average percentage of days a single day maximum temperature exceeded 63.5°F. As its name implies, the 7-DADMax is the average of daily maximum water temperatures over a consecutive 7-day period. The percentage calculations were based on number of days exceeding the criterion in a given year, divided by the number of full days that water temperature values were recorded during that year. The average percentage was taken as the arithmetic mean of each individual year's percentage.

Table 3. EKCD Water Temperature Statistics for the Rock Creek Subbasin

Stream Name	Station Number	Period of Record	Average Number of days 7-DADMax Exceeds Draft Standard	Average Percentage of days 7-DADMax Exceeds Draft Standard	Average Percentage of days a single daily maximum temperature Exceeds 63.5 °F
Quartz Creek	RC-01	1995-1996	35	41%	41%
Rock Creek	RC-02	1995-1996	14	28%	29%
Rock Creek	RC-03	1995-2000	44	57%	59%
Rock Creek	RC-04	1995-1997	5	3%	5%
Quartz Creek	RC-05	1995-1996	40	30%	27%
Rock Creek	RC-06	1995-2004	48	46%	46%
Squaw Creek	RC-07	1995-2004	92	64%	62%
Rock Creek	RC-08	1995-2004	74	85%	80%
Rock Creek	RC-09	95-96, 98-99, 01-04	104	84%	81%
Rock Creek	RC-10	1995-2000	79	98%	96%
Luna Gulch	LG-01	1997-2002	53	36%	37%
Luna Gulch	LG-02	1997-1998	82	69%	62%
Luna Gulch	LG-03	1997-2000	37	74%	66%

The stations that consistently record the highest summer stream temperatures are on the lower reach of Rock Creek (RC-10, RC-09, and RC-08) and on Squaw Creek (RC-07) (Figure 4). The typical pattern for water temperature in the entire watershed is that daily maximum temperatures rise above the state standard 7-DADMax of 63.5° F at the beginning of the summer (usually sometime in May) and do not cool down below the standard until the end of September. The lower Rock Creek stations typically exceed the standard for the longest period of time, and have the highest single day maximum temperatures, as illustrated on Figure 7.

Figure 7 is a plot of the average maximum water temperature, every day from May through October, over the 10-year period 1995 through 2004, for four monitoring stations in the Rock Creek subbasin. In other words, the average of the maximum water temperatures recorded for May 15th during the 10-year period is plotted for the May 15 value and so on for each day. The Rock Creek stations plotted are RC-09 just above the backwater pool at the mouth (Ecology river mile 1.5), RC-08 at river mile 8.0 just below the Squaw Creek confluence, and RC-06 at river mile 13.6 adjacent the Badger Gulch confluence. Station RC-07 on Squaw Creek just above its confluence with Rock Creek is also plotted. These four stations have the most complete water temperature record of the EKCD monitoring stations. The 63.5° F standard is also depicted on Figure 7 for reference. This graphic illustrates that, over most of the year, the water temperature increases progressively in the downstream direction. This is expected since the water is exposed to progressively greater cumulative solar radiation (heating) as it flows across the rocky, poorly vegetated lower reach of Rock Creek.

Chapter 5 of the Level 1 watershed assessment for WRIA 31 (Aspect Consulting and WPN, 2004) identifies Chinook Salmon and Steelhead in the mainstem of Rock Creek from the mouth upstream to the confluence with Luna Gulch, and only Steelhead further upstream to approximately 1 mile above the Bickleton Highway. Steelhead are also mapped in Squaw Creek upstream to the confluence with Harrison Creek (Figure 4). The life cycle of the Chinook Salmon makes it unlikely that this species would inhabit Rock

Creek during the summer high temperature time (refer to Figure 5-2 in the WRIA 31 Level 1 Assessment). However, Steelhead rear in the lower and middle portions of Rock and Squaw Creeks for up to two years before migrating to the ocean. EKCD made observations of "trout" throughout the Rock Creek system since their water temperature monitoring began in 1995; however, it is unclear whether these were juvenile salmon, steelhead, or native trout.

Each water temperature station currently and historically maintained by the EKCD in the Rock Creek subbasin is described briefly below. Photos were taken during this study looking upstream (except photo for stations RC-04 and RC-05 which was taken from a ridge above the stations looking south). The photos are included in Appendix A.

Quartz Creek Station RC-01

The EKCD water temperature station RC-01 was maintained during the summers of 1995 and 1996. The station was located near the headwaters of the Rock Creek watershed on the Quartz Creek tributary (Figure 4). During the period of record, streamflow at the station would typically reduce to stagnant pools, but did not completely dry up. Summer water temperatures (as represented by the 7-DADMax) exceeded the draft default state water temperature standard 41% of the time during the period of record. EKCD staff noted "little fishes" in the stream on June 27, 1995, but no more specific information was recorded. A site visit to RC-01 on November 17, 2004, found minimal (<0.1 cfs) flow in the stream, and the water temperature was 49° F. A site visit on March 2, 2005 found slightly higher streamflow (~0.5 cfs) and lower water temperature (42° F). Again, the winter of 2004-2005 was exceptionally dry, and greater flows would be expected at RC-01 in March during most years. The stream channel is deep and vegetated with Ponderosa pine and brush covered banks (Photo 1 in Appendix A).

Rock Creek Station RC-02

The EKCD water temperature station RC-02 on Rock Creek was maintained during the summers of 1995 and 1996. The station was located near the headwaters of the Rock Creek watershed (Figure 4). During the period of record, streamflow at the station would typically reduce to stagnant pools, and went dry in 1996. Summer water temperatures (7-DADMax) exceeded the draft state water temperature standard 28% of the time during the period of record. EKCD staff noted a "small trout in pool" in the stream on August 30, 1995. During the site visit to RC-02 on November 18, 2004, the stream was dry. Consequently, a water quality sample was collected from adjacent location RC-02R that had some flow (see Section 3.3). The stream banks at RC-02 were vegetated with scattered Ponderosa pine and Aspen (Photo 2 in Appendix A).

Rock Creek Station RC-03

The EKCD water temperature station RC-03 on Rock Creek was maintained during the summers of 1995 through 2000. The station was located near the headwaters of the Rock Creek watershed (Figure 4). During the period of record, streamflow at the station would typically reduce to stagnant pools, and went dry in 1998. Summer water temperatures (7-DADMax) exceeded the draft state water temperature standard 57% of the time during the period of record. EKCD staff noted a "6 inch trout in pool" in the stream on July 20, 1998. During the site visit to RC-03 on November 18, 2004, the stream was dry, so a sample was collected from nearby location RC-03R (Section 3.3). The site visit to RC-03 on March 2, 2005, found the stream flowing approximately 3-5 cfs. The stream banks were heavily vegetated with deciduous and conifer trees and brush (Photo 3 in Appendix A).

Rock Creek Station RC-04

The EKCD water temperature station RC-04 on Rock Creek was maintained during the summers of 1995 through 1997. The station was located on Rock Creek just upstream of the confluence with Quartz Creek (Figure 4). During the period of record, streamflow at the station would occasionally reduce to stagnant pools. Summer water temperatures (7-DADMax) exceeded the draft state water temperature standard only 3% of the time during the period of record. EKCD staff typically observed “small fish” in the stream during the summer of 1995. The stream channel is heavily vegetated with Oak and Ponderosa Pine in a deep canyon (Photo 4 in Appendix A).

Quartz Creek Station RC-05

The EKCD water temperature station RC-05 on Quartz Creek was maintained during the summers of 1995 through 1996. The station was located on Quartz Creek near the confluence with Rock Creek (Figure 4). During the period of record, streamflow at the station would occasionally reduce to stagnant pools. Summer water temperatures (7-DADMax) exceeded the draft state water temperature standard 30% of the time during the period of record. EKCD staff typically observed “1-5 inch fish” in the stream during the summer of 1995. The stream channel is heavily vegetated with Oak and Ponderosa Pine in a deep canyon (Photo 4 in Appendix A).

Rock Creek Station RC-06

The EKCD water temperature station RC-06 on Rock Creek has been maintained during the summer from 1995 to present. The station is located on the mainstem of Rock Creek upstream of the Bickleton Highway (Figure 4). During the period of record, streamflow at the station was typically always flowing but did go dry in 1995 and 2002. Summer water temperatures (7-DADMax) exceeded the draft state water temperature standard 46% of the time during the period of record. EKCD staff typically observed “8 inch trout” in the stream on during the summer. A site visit to RC-06 on November 17, 2004, found the stream flowing approximately 2-3 cfs and the water temperature was 43° F. A site visit on March 1, 2005 found higher streamflow (~ 7-10 cfs) and the same water temperature (43° F). The stream channel near the station was heavily shaded by mature Alder trees on both banks (Photo 5 in Appendix A).

Squaw Creek Station RC-07

The EKCD water temperature station RC-07 on Squaw Creek has been maintained during the summers from 1995 to present. The station is located on Squaw Creek upstream of the Rock Creek confluence and the Rock Creek Road Bridge (Figure 4). During the period of record, streamflow at the station was typically reduced to stagnant pools but never completely dry. Summer water temperatures (7-DADMax) exceeded the draft state water temperature standard 64% of the time during the period of record. EKCD staff typically observed many “12 inch trout” in the stream during the summer. EKCD staff also noted that they observe native steelhead spawning at this location each February (see Photo 6 in Appendix A). A site visit to RC-07 on November 17, 2004, found the stream flowing approximately 0.5-1 cfs, and the water temperature was 46° F. A site visit on

March 1, 2005 found slightly higher streamflow (~ 2-3 cfs) and slightly lower water temperature (45° F). The stream channel near the station was lightly shaded by scattered Alder trees on both banks (Photo 6 in Appendix A).

Rock Creek Station RC-08

The EKCD water temperature station RC-08 on Rock Creek has been maintained during the summers from 1995 to present. The station is located on the mainstem of Rock Creek just downstream of the confluence with Squaw Creek (Figure 4). During the period of record, streamflow at the station was typically reduced to stagnant pools and often (every year since 2000) goes dry. Summer water temperatures (7-DADMax) exceeded the draft state water temperature standard 85% of the time during the period of record. EKCD staff typically observed fish up to an "8 inch trout" in the stream during the summer. A site visit to RC-08 on November 17, 2004, found the stream flowing approximately 0.5-1 cfs, and the water temperature was 50° F. A site visit on March 1, 2005 found higher streamflow (~5-6 cfs) and lower water temperature (45° F). The stream channel near the station was rocky and very slightly shaded by Willow clumps on the right banks (Photo 7 in Appendix A).

Rock Creek Station RC-09

The EKCD water temperature station RC-09 on Rock Creek has been maintained during the summers from 1995 to present, excluding 1997 and 2000. The station is located on the mainstem of Rock Creek just upstream of the Columbia River backwater pool (Figure 4). During the period of record, streamflow at the station was typically reduced to stagnant pools but only went dry in 1995. Summer water temperatures (7-DADMax) exceeded the draft state water temperature standard 84% of the time during the period of record. EKCD staff observed small fish in the stream during the summer of 1998. A site visit to RC-08 on November 17, 2004, found the stream flowing approximately 3 cfs, and the water temperature was 49° F. A site visit on March 1, 2005 found much higher streamflow (~15-20 cfs) and lower water temperature (44° F). The stream channel near the station is lightly shaded by tall grass and scattered mature Alder trees on both banks (Photo 8 in Appendix A).

Rock Creek Station RC-10

The EKCD water temperature station RC-10 on Rock Creek was maintained during the summers from 1995 to 2000. The station is located on the mainstem of Rock Creek upstream of the Highway 8 Bridge (Figure 4). During the period of record, streamflow at the station was typically reduced to stagnant pools and went dry from 1998-2000. Summer water temperatures (7-DADMax) exceeded the draft state water temperature standard 98% of the time during the period of record. EKCD staff observed small fish in the stream during the summer of 1998. A site visit to RC-08 on November 17, 2004, found the stream flowing approximately 0.5-1 cfs, and the water temperature was 57 ° F. A site visit on March 2, 2005, found higher streamflow (~5-6 cfs) and much lower water temperature (45° F). The stream channel near the station is very slightly shaded by Willow clumps and scattered mature Alder trees on the right bank. (Photo 9 in Appendix A).

Luna Gulch Station LG-01

The EKCD water temperature station LG-01 on Luna Gulch was maintained during the summers from 1997 to 2002. The station is located on the north fork of Luna Creek downstream of the Oak Flat Road crossing (Figure 4). During the period of record, streamflow at the station was typically reduced to stagnant pools. Summer water temperatures (7-DADMax) exceeded the draft state water temperature standard 36% of the time during the period of record. A site visit to LG-01 on November 17, 2004, found the stream flowing less than 0.1 cfs, and the water temperature was 43° F. A site visit on March 2, 2005, found approximately the same streamflow and higher water temperature (47° F). The stream channel near the station is heavily shaded by Oak trees on both banks (Photo 10 in Appendix A).

Luna Gulch Station LG-02

The EKCD water temperature station LG-02 on Luna Gulch was maintained during the summers of 1997 and 1998. The station is located on Luna Gulch just upstream of its confluence with Rock Creek (Figure 4). During the period of record, streamflow at the station was typically reduced to stagnant or very slow pools. Summer water temperatures (7-DADMax) exceeded the draft state water temperature standard 69% of the time during the period of record. A site visit on March 1, 2005 found the stream flowing approximately 1 cfs and a water temperature of 45° F. The stream channel was slightly shaded with mature oak and willow clumps scattered on both banks (Photo 11 in Appendix A).

Luna Gulch Station LG-03

The EKCD water temperature station LG-03 on Luna Gulch was maintained during the summers from 1997 to 2000. The station is located on the south fork of Luna Gulch approximately 1 mile upstream of the Oak Flat Road Bridge (Figure 4). During the period of record, streamflow at the station was typically reduced to alternating stagnant or very slow pools and dry periods. Summer water temperatures (7-DADMax) exceeded the draft state water temperature standard 74% of the time during the period of record. A site visit on March 1, 2005, found the stream flowing approximately 2 cfs. The stream channel was slightly shaded with mature Ponderosa pine, oak, willow clumps and grasses scattered on both banks (Photo 12 in Appendix A).

Correlation with Air Temperature

The EKCD also deploys temperature loggers to collect ambient air temperature values at several of their water temperature monitoring stations. The locations of the air temperature data vary by year based on logger availability; however, in the Rock Creek watershed they are most often deployed at stations RC-06, RC-07, and RC-09. To identify a correlation between air and water temperature at each of these stations, daily maximum air values were potted against daily maximum water temperatures for each given day when both data exist (Figure 8). Note that the daily maximum air temperature may not occur at the same time as the daily maximum water temperature.

As expected, there is a clear correlation between air and water temperatures at all three stations - as air temperature increases, water temperature also increases. However, the water temperature increases at slightly different rates in response to increasing air temperature at each station, as indicated by the slope of the regression line fit to each data set. The regression line for RC-09 has the largest slope of 0.585 (e.g. every 1°F increase in air temperature yields 0.585°F increase in water temperature for the data set as a whole) and RC-06 has the smallest slope (0.464). This indicates that ambient air temperature has a greater influence on water temperature at RC-09 than at RC-06. This is likely due, in part, to the fact that the stream at RC-06 is much more shaded than at RC-09. Furthermore, the water at RC-09 has flown through the unvegetated, shallow, braided stream channel upstream of it, where the influence of air temperature would be significant.

For a given air temperature around 75°F at each station, the water temperature typically varies up to 15°F at RC-06 and up to 20°F at RC-07 and RC-09. This variability in water temperature for a given air temperature is a reflection, in part, of the time of year that the 75°F air temperature occurs. Water temperatures will generally be lower early in the year (e.g., the first time the daily maximum air temperature reaches 75°F) than later in the year.

Note that the particular temperature loggers used by the EKCD only record a maximum temperature up to 100.8 °F (air or water). This explains the linear cluster of points at that value in the plots for RC-06 and RC-07. This data clustering reduces the correlation coefficient (R^2) calculated for the regression lines in Figure 8.

4 Historical Riparian Vegetation Analyses

4.1 Methods

An additional objective of this water quality project was to complete a preliminary evaluation of historical changes in the extent of riparian vegetation along Rock Creek. This arose from discussions with the Rock Creek Watershed Group at their June 2004 meeting. At that meeting, there was discussion regarding the effects of floods on riparian vegetation and the stream channel, and the implications for enhancing riparian vegetation through plantings as has been started. Consequently, the specific objective of this aerial photo analysis was to evaluate how the Rock Creek stream channel has meandered across its valley, and how the extent of vegetation across the valley bottom has changed, over the period of photographic record (64 years). More detailed assessment of specific vegetation type and density was beyond the scope of this assessment. Consequently, this is not an assessment of stream shade. However, changes to Rock Creek's channel location and associated vegetation in response to natural forces (e.g., floods) has implications for whether it is technically feasible, in the long term, to lower stream temperature by planting riparian vegetation to provide shade. This information can be used in Phase 3 watershed plan development in evaluating possible strategies for reducing Rock Creek water temperature.

In order to assess historical changes in riparian vegetation in the Rock Creek valley, we analyzed aerial photographs obtained from the Natural Resource Conservation District's (NRCS) Goldendale office. The methodology for the analysis was as follows.

Hard copies of June 1938 (approximate scale of 1:15840) and May 1969 (1:12000) aerial photos for the Rock Creek area were borrowed from the NRCS and digitized into GIS. July 1996 digital photos (orthoquads) were also acquired from the United States Geologic Survey. 2002 color digital orthophotos were also acquired from Klickitat County Public Works. Hard copies of 1981 and 1990 aerial photos were also borrowed from NRCS but were not used in this analysis.

A subset of photos from each year was selected to cover the mainstem of Rock Creek from the Columbia River to approximately 1.1 miles above the Bickleton Highway bridge. The upstream extent of this analysis was defined by the northernmost 1969 photograph, and it nearly encompasses the upstream extent of salmonids in the mainstem of Rock Creek as mapped by WDFW (Figure 4). The analysis was limited to the mainstem of Rock Creek due to the time -consuming process of georeferencing digitally scanned aerial photos (1938 and 1969) into a GIS format using ESRI's ArcGIS 9 georeferencing module. All aerial photographs have spatial distortion away from the photograph center (parallax) that must be corrected for if using the photo to measure distances or areas. Georeferencing refers to the process of adjusting the image (or portions of it in this case) to match known location control points. The 1996 USGS digital orthoquads are georeferenced and were used as the reference data set for the georeferencing. The 2002 color orthophotos were also already georeferenced. The resulting aerial photo mosaics for 1969, 1996, and 2002 represent the base maps for Figures 9 and 10, 11 and 12, and 13 and 14, respectively. With this software it is not possible to correct for elevation changes so reference positions were only chosen from within the stream's valley bottom. This explains why many of the hilltops do not line up between photographs (not georeferenced) when the valley bottom does (Figures 9 through 14).

To assess the extents of vegetated versus unvegetated areas, the georeferenced images from all four years where then categorized using ESRI's ArcView Image Analysis module. An ISODATA (Iterative Self-Organizing Data Analysis) technique was used to categorize each image, pixel by pixel, into 16 classes based on each pixel's spectral character (basically, its lightness or darkness). ISODATA iteratively conducts an unsupervised categorization of single or multiband continuous data to create a thematic data theme, and recalculates statistics for each iteration. The statistics are changed as each pixel's similarity to each other is evaluated. The technique is designed to evaluate the spectral differences in the data and, based on those differences, assign the data to distinct classes. The ISODATA technique is controlled by a maximum number of iterations and a convergence threshold (ESRI 2000).

Following categorization of each image, the derived thematic grids where analyzed to determine which categories represented riparian vegetation within the stream corridor. The thematic grids where then processed to only include these categories. Some further hand editing occurred to eliminate areas in the 1938 and 1969 photos that where included as vegetation by GIS analysis but, based on review of the original images, would not fall into this category. This included writing on the images, some plowed fields, some segments of open water, and some areas of low lying vegetation. Such manual reviews could not be completed for the 1996 or 2002 photos since an original photographs were not available. However, because the 2002 photos were color, we have a high level of confidence in identifying on it those areas that are vegetated versus those that are not.

The thematic grids were then clipped to the boundary of the stream valley bottom since this was the area of interest and the area that was georeferenced. The valley bottom boundary was determined using slope changes derived from USGS Digital Elevation Models (DEM) and confirmed with USGS topographic maps. Individual grids where then merged to create one coverage of riparian vegetation extent for each year.

4.2 Results and Discussion

The analysis of historical aerial photographs reveals that the areal extent of vegetation in the valley bottom of the mainstem of Rock Creek (lower 15 miles of the creek, excluding the area of the Columbia River backwater pool) increased 7% from 1938 to 1969,increased 46 % from 1969 to 1996, and increased 10% from 1996 to 2002 (Table 4). On average, riparian vegetation increased at a rate of approximately 0.4 acres per year from 1938 to 1969, 3.2 acres per year from 1969 to 1996, and 4.8 acres per year from 1996 to 2002, indicating that the rate of vegetation increase has gradually accelerated over the period of record.

The 1969 photos were taken roughly 4 ½ years after a major flood in December of 1964. The 1996 photos were taken approximately 6 months after a major flood (January 1996). Assuming that the 1938 photos can be used to establish a baseline condition of riparian vegetation along the mainstem (albeit not a predevelopment condition), this analysis suggests that the 1964 flood did not remove enough vegetation to create a net reduction in vegetated acres across the valley bottom as a whole. Likewise, the data suggest that riparian vegetation along the mainstem has increased significantly from 1969 to 1996 despite a major flood just before the 1996 photos were taken. According to this rationale, the major floods observed in 1964 and 1996 did little to remove vegetation from the valley bottom as a whole. This is, however, contradictory to locals' observations of the stream channel before and after major floods. It is likely that vegetation immediately adjacent the stream channel has been removed during floods, with little change occurring at greater distance from the channel. The stream channel does move across the valley bottom with regularity, likely switching channels during flood flows, as discussed below.

One possible explanation for the increased total acreage of vegetation in the valley bottom from 1938-2002 is the use of fire suppression in the watershed. Fire suppression likely began to be implemented in the watershed around the turn of the century. This implies that if it is the cause of riparian vegetation increases from 1969 to 2002, a similar increase in vegetation might be observed from 1938 to 1969. However, it is possible that the 1964 flood removed much of this new vegetation. This may be observed in a few sections of the stream where a net loss in vegetation occurred between 1938-1969 (e.g., T04N R18E Section 25, and R04N R19E Sections 30, 29, 32).

To identify possible trends in vegetation gains and losses over time, the northern half of the analysis area (north of Squaw Creek confluence) was analyzed independently of the southern half (south of Squaw Creek confluence). Figures 9 through14 show areas where vegetation was gained (green), lost (red), or remained unchanged (yellow) between each set of photos for the northern half and southern half of the analysis area. This information is developed using GIS to compare the identified vegetated areas for each year. From this information, acres of vegetation gained, lost, and unchanged are calculated. Between 1938 and 1969, vegetation increased by 6% north of the Squaw Creek confluence and 9% to the south. Similarly, from 1969 to 1996, vegetation increased 45% in the northern half and 70% in the southern half (Table 4).

Table 4. Historical Riparian Vegetation Statistics for the Mainstem of Rock Creek

Year	Riparian Vegetation in Acres	Percent Change From Previous Photo Year
Rock Creek (Total)		
1938	177	**0%**
1969	189	**7%**
1996	276	**46%**
2002	305	**10%**
North of Squaw Creek		
1938	96	**0%**
1969	102	**6%**
1996	140	**37%**
2002	157	**12%**
South of Squaw Creek		
1938	80	**0%**
1969	88	**9%**
1996	137	**56%**
2002	148	**8%**

Vegetation change statistics were also calculated by each section in a downstream direction to identify which reaches of the stream are the most dynamic over the period of photographic record. Table 5 lists percent of vegetated acres lost, gained, and unchanged for each section for the two time periods analyzed (1938-1969 and 1969-1996). Note that some sections contain greater areas of valley bottom than others (e.g., see Figures 9 and 10). By expressing the change data as percentages, those differences are normalized.

The most dynamic sections of the stream can be identified by the lowest percentage of acreage unchanged between years. Overall, although the total vegetation between 1938 and 1969 increased only slightly (7%), typically less than 50% of the vegetated area in each section remained unchanged. Vegetation between 1969 and 1996, and 1996 and 2002, was more stable, with typically 50 to 80% of the vegetated acreage unchanged in each section (Figure 15).

There are no gaging data from Rock Creek to document the size of the 1996 flood relative to the 1964 flood in Rock Creek (1964 flood noted on Figure 3). USGS gaging data from the Klickitat River and White Salmon River to the west suggest the 1996 flood was considerably larger than the 1964 flood. However, gaging data from the Walla Walla River to the east indicated the two floods were of comparable size.

Despite the overall increasing trend in vegetated acres over the period of record, the analysis indicates greater than 10% losses in vegetation between 1996 and 2002 in some part of the valley (T3N/R19E Section 4, T3N/R19E Sections 20 and 21; Table 5). Communications with Roscoe Imrie and Jim Beeks, members of the WRIA 31 Planning Unit who are long-time residents of the area and very familiar with Rock Creek, reviewed the vegetation change estimates and felt the changes for 1996-2002 appear reasonable based on their knowledge of the creek valley. Both indicated that these larger acreage losses are likely a result of wild fires. Mr. Beeks was able to confirm, through discussion with other local residents, that fires burned in T3N/R19E Sections 20 and 21 on July 28, 2000, and again on August 18, 2001. In T3N/R19E Section 4, the majority of the vegetation lost occurs in a single area (Figure 14), suggesting loss by fire.

One of the most dynamic sections in each time period was T04N R19E Section 9, just upstream of the Old Highway 8 Bridge and EKCD monitoring station RC-10, in the southern half of the analysis area (33%, 50%, and 68% unchanged in 1969, 1996, and 2002, respectively). The vegetation characteristics are likely so dynamic due to the characteristics of the stream channel itself. Historically, the stream channel in T04N R19E Section 9 has changed course many times, and it has distinctly different courses in 1938, 1969, 1996, and 2002. It is not surprising that this section is also one of the least densely vegetated along the mainstem of Rock Creek. Ehinger (1996) noted that the lower portion of Rock Creek typically has a lack of riparian cover and a shallow, braided stream channel, which is exemplified in T04N R19E Section 9.

Figure 16 shows views of the Rock Creek valley bottom in T04N R19E Section 9 for the years 1938, 1969, 1996, and 2002. The interpreted location of the main stream channel is highlighted in blue for each year, which helps illustrate the dynamic nature of the stream channel in this area. The stream channel location was delineated for this figure based on presence of open water and, in areas lacking water, the apparent most recent stream channel based on visual review of the aerial photographs.

In the northern part of Section 9, the main channel switches to the west between 1938 and 1969, making its way in a channel apparent in the 1938 photo but with a straighter channel upstream of it that was not readily apparent in the 1938 photo. This course change may have been a result of the 1964 flood. Also note the road running along the creek in the northern portion of Section 9 in 1938 has been moved to the east, farther from the creek, by 1969. Between 1969 and 1996, the main channel in this area switches back to the east, similar to but not the same as the 1938 course. In 2002, the channel is similar to that in 1996, although there were two channels merging to one in the northern part of Section 9, and apparently confined to a single channel to the south rather than the braided nature of the stream in 1996. The multiple channel traces apparent in these photos document the numerous paths the creek has taken over time in this braided stretch.

Table 5. Historical Riparian Vegetation Statistics by Section

		1938 to 1969						1969 to 1996						1996 to 2002					
	Township, Range, Section	**Acres Veg'd in 1938**	Acres of veg lost from 1938	Acres of veg gained from 1938	Acres of veg unchanged from 1938	**Acres Veg'd in 1969**	**Net % change in veg'd acres, 1938-1969**	**Acres Veg'd in 1969**	Acres of veg lost from 1969	Acres of veg gained from 1969	Acres of veg unchanged from 1969	**Acres Veg'd in 1996**	**Net % change in veg'd acres, 1969-1996**	**Acres Veg'd in 1996**	Acres of veg lost from 1996	Acres of veg gained from 1996	Acres of veg unchanged from 1996	**Acres Veg'd in 2002**	**Net % change in veg'd acres, 1996-2002**
Upstream End	T04R18E3	3.9	1.8	4.3	2.1	6.4	64%	6.4	1.1	2.3	5.3	7.6	20%	7.6	1.2	1.9	6.5	8.3	9%
	T04R18E10	4.9	2.2	5.6	2.7	8.3	70%	8.3	1.4	4.1	7.0	11.0	32%	11.0	1.2	1.4	9.8	11.1	1%
	T04R18E11	5.9	3.0	4.6	2.9	7.5	27%	7.5	1.3	4.3	6.3	10.5	40%	10.5	1.8	1.2	8.7	9.9	-6%
	T04R18E14	18.8	8.2	12.6	10.6	23.2	24%	23.2	4.3	14.8	18.9	33.7	45%	33.7	3.4	4.4	30.3	34.7	3%
	T04R18E23	15.0	8.6	9.3	6.4	15.6	5%	15.6	5.8	11.2	9.8	21.0	34%	21.0	4.3	6.9	16.8	23.6	13%
	T04R18E24	0.8	0.4	0.4	0.4	0.9	2%	0.9	0.2	0.6	0.7	1.3	49%	1.3	0.2	0.2	1.0	1.2	-2%
	T04R18E26	2.3	1.6	1.7	0.7	2.3	2%	2.3	1.0	1.8	1.3	3.1	33%	3.1	1.0	1.5	2.1	3.7	19%
	T04R18E25	21.9	12.1	9.7	9.8	19.5	-11%	19.5	8.2	12.1	11.3	23.4	20%	23.4	3.8	8.7	19.8	28.3	21%
	T04R19E30	15.3	9.3	6.3	6.0	12.4	-19%	12.4	4.1	9.6	8.2	17.8	44%	17.8	3.2	8.2	14.8	22.8	28%
	T04R19E29	7.8	4.1	2.7	3.7	6.3	-18%	6.3	1.2	6.5	5.1	11.6	83%	11.6	1.9	3.8	9.8	13.5	16%
	T04R19E32	21.0	12.3	8.9	8.7	17.6	-16%	17.6	4.4	18.5	13.2	31.7	80%	31.7	8.0	11.0	23.9	34.7	9%
	T04R19E33	6.5	3.5	3.9	3.0	7.0	7%	7.0	1.9	5.8	5.0	10.8	56%	10.8	4.4	3.6	6.4	10.0	-8%
Downstream End	T03R19E4	15.6	8.3	11.0	7.3	18.3	17%	18.3	3.2	16.8	15.1	31.9	74%	31.9	12.4	7.4	19.6	26.9	-16%
	T03R19E9	7.1	4.7	6.6	2.3	8.9	26%	8.9	4.5	7.3	4.4	11.8	32%	11.8	3.8	11.9	8.0	19.9	69%
	T03R19E16	13.8	7.4	11.1	6.4	17.5	26%	17.5	5.5	14.8	12.0	26.9	54%	26.9	7.0	14.0	19.9	33.8	26%
	T03R19E21	10.0	4.7	8.4	5.4	13.8	37%	13.8	5.9	7.4	7.9	15.2	11%	15.2	6.4	4.9	9.1	13.8	-10%
	T03R19E20	2.8	2.3	3.3	0.6	3.9	38%	3.9	2.1	4.3	1.8	6.0	55%	6.0	3.5	2.4	2.8	5.0	-18%
	T03R19E29	3.1	3.1	0.0	0.0	0.0	-100%	0.0	0.0	0.8	0.0	0.8	NA	0.8	0.5	1.7	0.2	1.9	152%
	Totals:	**176**				**189**	**7%**	**189**				**276**	**46%**	**276**				**303**	**10%**

Examination of the NRCS' 1990 and 1981 aerial photos (not digitized for analysis) revealed that this same area was sparsely vegetated and had different stream channels in both 1981 and 1990. Also note that T04N R19E Section 9 represents about 1 mile of riparian area upstream of EKCD monitoring station RC-10, which has had the highest water temperature values observed in the watershed (see Section 4.3).

Ehinger (1996) implies that confining Rock Creek to a more established channel, rather than its current broad, shallow, braided channel system, may be one way to reduce water temperature. Given the naturally dynamic nature of the Rock Creek channel in areas like T04N R19E Section 9, it is questionable whether it would be technically and/or economically feasible to confine the creek into a single permanent channel.

5 Conclusions and Recommendations

5.1 Water Quality

Nitrate and fecal coliform concentrations in surface waters of the Rock Creek subbasin are low, meeting state water quality standards. These levels were measured in a dry year, suggesting they are conservatively high (greater flow equates to greater dilution). To maintain high surface water quality throughout the watershed, we recommend continuing the practice of managing livestock grazing in a sustainable and responsible way. Care should be taken to keep grazing away from sensitive stream areas as much as possible. We understand that NRCS is working closely with local ranchers to construct fences in an effort to keep livestock out of Rock Creek and its tributaries. Periodic water quality monitoring (nitrate and fecal coliform) could be continued to document whether water quality is changing relative to conditions documented in this study.

5.2 Water Temperature

Comprehensive analysis of EKCD's water temperature revealed that summer stream temperatures consistently exceed the draft state default surface water standard of 63.5 °F throughout the Rock Creek watershed. The highest temperatures are typically measured in the lower reach of Rock Creek (RC-08, RC-09, and RC-10) and Squaw Creek (RC-07).

The information compiled in this study indicates that the high water temperatures in Rock Creek may represent the natural condition. Ehinger (1996) concluded that the high water temperatures in upper Rock Creek "may be natural for a small creek in a hot, sunny summer climate". The available information indicates increasingly that this is the case. Namely, the Rock Creek subbasin is sparsely populated with minimal water use, and geologic conditions limit the quantities of groundwater discharge (springs) to support summer instream flows. This lack of late-season baseflow, in conjunction with the braided and highly dynamic stream channel and limited riparian vegetation in the lower reaches, combine to create a situation in which the water that is present is subject to abundant solar heating, and thus elevated water temperatures, throughout the summer. In this case, ongoing water temperature monitoring by the EKCD is serving to establish a baseline condition for the watershed. Although it is difficult to definitively attribute the observed high water temperatures to natural versus anthropogenic causes, we are not aware of evidence indicating it is a result of anthropogenic causes.

Based on the findings of this study, the statewide default temperature standard may not be applicable for Rock Creek. We recommend further evaluation of the natural water temperature condition for Rock Creek. It should be recognized that this could be an involved assessment with uncertainties persisting because of lack of data. If it were determined that current Rock Creek water temperatures represent the natural condition, the state water quality standard for Rock Creek becomes the natural condition. Exceedence of that water temperature standard (based on protecting aquatic life) would then be identified as human actions that cause the 7-DADMax temperate to increase more than 0.54 °F (WAC 173-201A-200[1][c]).

It is uncertain from this study the extent to which livestock grazing may be adversely affecting streamside vegetation and shade, but the overall extent of vegetation across the Rock Creek valley bottom as a whole has increased dramatically over the past 65 years. Continued implementation of best management practices (e.g. preventing livestock access in the riparian zone) is nonetheless recommended to minimize potential land use effects on Rock Creek.

Chapter 173-201A WAC requires continuous monitoring probes to be set at an interval at 30 minutes or less to identify daily maximum temperatures. Therefore, we recommend that EKCD shorten their temperature recording interval from 1 hour to 30 minutes. We have coordinated with EKCD on this, and understand it will be implemented for the 2005 monitoring season.

5.3 Riparian Vegetation and Channel Alignment

The aerial photograph analysis of historical riparian vegetation indicates that the areal extent of vegetation across the Rock Creek valley bottom has been increasing and becoming more stable since 1938. This is likely a result of active fire suppression conducted over the past century. However, there are localized riparian areas that have very little vegetative cover, and where the stream channel is shallow, rocky, and braided. Ehinger (1996) recommended that establishing a single, deeper channel where shallow braided channels currently exist in the lower stream reaches could help lower water temperatures and facilitate riparian vegetation growth that would reduce temperatures even more. The findings of this study do not support this approach to revegetation, because the Rock Creek channel changes course regularly in its lower reaches which limits the establishment of vegetation. Because of this highly dynamic character, it does not appear that it would be practical or even possible to confine the shallow, braided areas of Rock Creek in its lower reaches into a single channel. In areas of the Rock Creek subbasin where the stream channel is more defined and stable (e.g., upstream of RC-06), riparian plantings might be able to be established to increase stream shade. However, prior to undertaking such plantings, it should be confirmed that there is adequate late-season water in such areas to ensure that a benefit to fish would be achieved. This could warrant additional discussion and assessment as part of Phase 3 watershed planning.

6 References

Aspect Consulting, LLC and WPN 2004. *Level 1 Watershed Assessment WRIA 31 (Rock-Glade Watershed)*. November 12, 2004.

Aspect Consulting, LLC 2004. Quality *Assurance Project Plan, WRIA 31 Supplemental Water Quality Project.* September 27, 2004.

Brown, J. C. 1979. *Geology and Water Resources of Klickitat County*. Washington State Department of Ecology Water Supply Bulletin No. 50. August 1979.

Ehinger, W. 1996. *Evaluation of High Temperature in Rock Creek (Klickitat County)*, Ecology Report No. 96-308. February 1996.

ESRI 2000. *ArcView Image Analysis*, ESRI Press.

IRZ Consulting 2004. *Land Use Classification and Crop Rotation Study for WRIA 31*. July 6, 2004.

V:\030009 WRIA 31\Draft Rock Report\Draft Rock Report.doc