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Robin K. Leferink
Portland State University

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Riparian Shade Assessment and Restoration Priorities Analysis in the Damascus Urban Growth Boundary Expansion Area

Robin K. Leferink

Prepared for
Metro

June 2007
Portland State University
Portland, Oregon

Riparian Shade Assessment and Restoration Priorities Analysis in the Damascus Urban Growth Boundary Expansion Area

Robin K. Leferink

A project report submitted in partial fulfillment of the requirements
for the degree of

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in
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Portland, Oregon

Abstract

An important component of progressive urban planning is the protection and restoration of riparian environments, particularly in the Pacific Northwest where increasing stream temperatures threaten the survival of endangered salmonids and other cold-water biota. Restoration projects are often led by watershed councils or other grassroots organizations with limited resources, and it is essential that these groups have an efficient and effective approach to determine priority areas where their efforts can be directed to achieve the greatest ecological benefit. The purpose of this project was to quantify existing riparian shade levels and identify priority reaches for shade restoration on Clackamas River basin streams in the Damascus area expansion of the Portland, Oregon urban growth boundary. Additionally, potential errors in the Metro Regional Land Information System (RLIS) Lite geographic information system (GIS) coverage of the area's streams were identified and corrected where possible. Riparian shade levels were quantified through interpretation of digital aerial photographs using GIS. At the start of the shade analysis six 50 m reaches in the study area were surveyed using a spherical densiometer to calibrate the aerial photo interpretation. Following the analysis, the method accuracy was assessed by comparing GIS-derived shade classes with field data from 25 sites in the study area that were surveyed in 2003. Stream reaches were identified and prioritized for restoration based on riparian shade level, presence or absence of late-summer flow (as determined through field investigations), and GIS-evaluated stream aspect (i.e. the direction of stream flow). Generally, the headwaters were found to have less shade than the downstream areas and many of the headwater reaches were identified as the highest restoration priority. Of the 60.5 km of streams

assessed in the riparian shade analysis, 24.7 km were identified as potential restoration reaches based on shade levels and late-summer flow conditions. These 24.7 km were further broken into five priority ranks, with 4.1 km of stream reaches assigned to the highest shade restoration priority class. Potential errors in the GIS stream coverage were identified in conjunction with the riparian shade assessment. Where possible, these errors were corrected based on the aerial photographs. Although in many cases access was limited, a total of 18 site visits were made to verify stream locations.

The results of this watershed-scale restoration priorities analysis are being used by Clackamas River Basin Council and others to guide restoration planning in the new urban area. While focusing on the high priority stream reaches identified, restoration managers will also need to consider reach-scale factors including land use plans, riparian continuity, parcel size, and landowner cooperation in the final selection of restoration sites. The GIS stream layer corrections were provided to Metro and to the City of Damascus for use in their 2007 natural resource inventory.

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Graduate Committee

J. Alan Yeakley – Major Advisor
Associate Professor of Environmental Science, Portland State University
yeakley@pdx.edu

Lori Hennings – External Advisor
Senior Regional Planner – Ecologist, Metro
hennings@metro.dst.or.us

Joseph Maser – Committee Member
Assistant Professor of Environmental Science, Portland State University
maserj@pdx.edu

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Project Objectives

The primary objectives of this project were to quantify current riparian shade levels on streams in and around the Damascus area expansion of the Portland, Oregon urban growth boundary (UGB) and to identify priority reaches for shade restoration. This information was provided to Clackamas River Basin Council (CRBC), Metro, Clackamas County, and others to guide restoration planning in the new urban area. An additional objective of the project was to identify potential errors in Metro's Regional Land Information System (RLIS) Lite geographic information system (GIS) stream coverage of the area (i.e. shapefiles that show stream locations), perform field investigations where necessary, and provide Metro with corrections. These data were also provided to the City of Damascus to aid in the stream mapping that will be conducted as part of their 2007 natural resource inventory.

Introduction

In recent years, the Portland, Oregon metropolitan region's rapid population growth has spurred local governments to expand the UGB surrounding Portland and adjacent suburbs and to pass directives guiding future development. The State of Oregon mandates that jurisdictions maintain a 20-year land supply to meet the needs of the projected population. As part of the largest expansion since its creation in 1980, over 12,000 acres (roughly 5,000 ha) in the Damascus area were added to Portland's UGB in December of 2002 (Figure 1; Metro 2002). This area, which includes the Rock Creek and Richardson Creek watersheds in the lower Clackamas River basin, will experience significant urban development in the coming decades.

Historically, development practices have done little to address negative effects to water quality resulting from the loss of riparian habitat (Naiman and Décamps 1997, Oregon Department of Environmental Quality (ODEQ) 2005). In an effort to improve environmental sustainability in the region, Metro has created requirements for habitat-friendly development practices as part of its regional fish and wildlife habitat protection program (Title 13; Metro 2005a). These requirements, intended for implementation by city and county governments, include designating zones of restricted development in riparian areas and other sensitive environments essential to fish and wildlife (Metro 2005b). The need to address water quality in the region has been elevated by ODEQ's release of the Willamette River basin Total Maximum Daily Load (TMDL), which identifies portions of the Clackamas River and its tributaries as exceeding acceptable limits for water temperature (ODEQ 2006). It is important that any plans to bring the basin's streams and rivers into compliance with water temperature standards address riparian shade in the Damascus area.

Riparian shading, defined primarily as stream water shading by tree and shrub vegetation in riparian areas, is a critical factor in water temperature regulation (Quinn et al. 1992; Rutherford et al. 1997; Naiman et al. 2005). Riparian vegetation affects stream temperature in a number of ways. It absorbs a portion of the incoming short-wave radiation, resulting in cooler water temperatures, particularly on hot summer days (Rutherford et al. 1997). Riparian vegetation can also alter the air temperature, wind speed, and/or humidity in the micro-climate surrounding the stream, which in turn can affect evaporation, conduction, and ground and water temperature (e.g. increased evapotranspiration by tree vegetation can lower the air temperature surrounding the

stream through evaporative cooling, which can lead to cooler water temperatures). In addition, loss of riparian vegetation can render streambanks unstable, leading to increased erosion and altered channel morphology. Such physical changes in a stream can also influence the temperature regime through diminished hyporheic zone exchange (caused by decreased streambed permeability) and disconnection from cooler groundwater inputs, or an increase in the volume of surface water flowing through the stream (Poole and Berman 2001). Altered hydrology can also lead to further vegetation loss, both through the erosion of vegetated stream banks or through channelization, in which the stream no longer provides water to the floodplain vegetation. Stream temperature influences the life cycles, physiology, and metabolic rates of aquatic biota, and many cold-water species cannot persist in temperatures above their normal range (Allen 1995).

Urban development encroaches on riparian areas, which can lead to reduction, disconnection, or elimination of riparian buffers (May et al. 1997; Booth and Jackson 1997; Ozawa and Yeakley in press). When riparian zones are degraded they may cease to perform important ecosystem functions that, in addition to regulating stream temperature, include slowing and reducing runoff from impervious surfaces and the associated sediment, nutrients, and contaminants, providing large woody debris for structure and habitat, and providing energy input to the stream in the form of leaves and other organic matter (Naiman et al. 2005). In one study of urban areas in Oregon, progressive planning and stringent regulations were demonstrated to be effective at decreasing, although not completely stopping, the rate of riparian habitat loss due to urbanization (Ozawa and Yeakley in press).

Figure 1. Damascus UGB Expansion Area. The shaded region depicts the Damascus area included in the December, 2002 expansion of the Portland, Oregon urban growth boundary (UGB).

Methods

Approach

To address the project objectives, existing riparian shade levels were characterized using existing remotely sensed data and GIS. Field-collected data were used to calibrate the analysis and evaluate the overall accuracy. Corrections to the GIS stream coverage were performed in conjunction with the riparian shade assessment and site visits were conducted when stream presence or location could not be determined from aerial photographs. Data from the riparian shade assessment and the field investigations were used to exclude highly shaded and intermittent reaches from the group of potential restoration sites. The remaining sites were broken into three classes based on their aspect (i.e. the direction of streamflow), an essential factor in determining the potential shade that could be provided by vegetation planted on the streambank. The riparian shade level and aspect classification were then used to rank the potential restoration reaches into five classes based on their restoration priority level.

Study Area

The study area for the GIS-based riparian shade assessment, shade restoration priorities analysis, and stream layer corrections includes the Rock Creek and Richardson Creek watersheds in the lower Clackamas River basin. All of the Rock Creek watershed and most of the Richardson Creek watershed are located within the 2002 expansion of Portland's UGB (Figure 2). A few small, unnamed streams that drain directly to the Clackamas River between these two watersheds were also included in the analysis. In total, 60.5 km of streams were included in the riparian shade assessment. This area contains a mix of land uses. In general, the headwaters and higher reaches are dominated

by agricultural and low-density suburban use, and the riparian zones in these areas are narrow or non-existent. The stream valleys become increasingly steeper in the lower reaches and these areas contain generally intact riparian zones (Hollis 2006).

Although a portion of Noyer Creek extends into the southeastern edge of the UGB expansion area, Noyer Creek and Deep Creek were included in a 2004 riparian shade assessment conducted by CRBC (2004). Therefore, these streams were not included in this analysis. The Clackamas River was excluded from this analysis to due to the limited role of riparian vegetation in producing shade on a river of its size.

Figure 2. Study Area. Located in the lower Clackamas River basin in northwestern Oregon, the Rock Creek and Richardson Creek watersheds and several small Clackamas River tributaries were included in the riparian shade assessment, shade restoration priorities analysis, and stream layer corrections.

Riparian Shade Assessment

Aerial Photograph Interpretation

Riparian vegetation estimates were based on interpretation of Metro's July 2005 ortho-rectified digital aerial photographs, a high-quality raster data set in natural color with 6-inch (15.2 cm) resolution. Using ESRI ArcGIS 9.1, the aerial photos were overlaid with Metro's RLIS Lite stream line layer, a vector data set that is based on United States Geological Survey (USGS) 7.5 minute quadrangles that have been visually adjusted from aerial photos at approximately 1:10,000 resolution. All estimates were done at a viewing scale of approximately 1:1,500, and streams were broken into segments having similar riparian shading using the classification guidelines established by the Washington Forest Practices Board (WFPB) and summarized in Table 1. These classification guidelines were also used in the riparian shade assessment conducted by CRBC on Noyer Creek and North Fork Deep Creek watersheds, which adjoin the east side of the study area. The Oregon Watershed Assessment Manual (OWAM; Watershed Professionals Network 1999) used by ODEQ also uses an aerial photograph interpretation method based on WFPB guidelines; however, their simplified method combines shade classes 1 and 2 from Table 1 to create a 'low' shade class, shade class 3 represents the 'medium' shade class, and shade classes 4 and 5 are combined to create a 'high' shade class.

Table 1. Shade Estimation Criteria for Aerial Photograph Interpretation (WFPB 1997).

Class	Indicator	% Shade
1	Stream surface and banks visible	<20%
2	Stream surface visible and banks visible at times	20-40%
3	Stream surface visible but banks not visible	40-70%
4	Stream surface slightly visible or visible in patches	70-90%
5	Stream surface not visible	>90%

Calibration

The OWAM recommends field-verifying initial riparian vegetation estimates made by aerial photo interpretation. At the start of the riparian shade assessment, six sites in the study area were surveyed for this purpose. Due to access limitations, these survey sites were all located on public lands. A 50 meter reach was surveyed at each site. In-stream measurements of canopy cover were collected using a spherical densiometer at five transects evenly spaced throughout the sample reach. At each transect, canopy cover was measured at six points (left bank, right bank, center upstream, center left, center downstream, and center right). These values were then averaged to generate a percent shade value for the sample reach, which was then compared to the percent shade range obtained using GIS. This was a valuable step in calibrating the aerial photo interpretation that followed.

Accuracy Evaluation

To evaluate the accuracy of the riparian shade assessment after it was completed, the GIS-based classifications were compared with a more extensive set of canopy measurements collected in the field. In a 2003 Metro study, ABR collected physical habitat data, including canopy cover, at 35 sites in and around the Damascus area UGB expansion (Cole and Hennings 2004). In reaches ranging from 75 to 100 meters in length, canopy cover was measured with a spherical densiometer at six points (left bank, right bank, center upstream, center left, center downstream, and center right) for each regularly spaced transect. These measurements were then averaged to produce a percent shade value for the surveyed reaches. Of the 35 sites surveyed, 25 were randomly selected for this accuracy assessment. The GIS shade classification method was applied to Metro's

July 2003 ortho-rectified digital aerial photos for the 25 randomly selected sites. The results of the GIS-based classification were then compared with the field-measured values to determine the accuracy of the GIS method.

Stream Layer Corrections

GIS-based Corrections

Inaccuracies in the RLIS Lite stream line layer (November 2005 release) were identified in conjunction with the GIS-based riparian shade assessment. In areas where the actual location of the stream channel shown in the aerial photographs clearly deviated from the GIS stream layer (e.g. the GIS layer shows the stream running through a building, the layer is offset from the visible stream surface by several meters or more, or what is shown by the GIS layer as a stream is clearly a pond), the stream layer was corrected based on the aerial photographs. In areas where stream presence or location was questionable based on examination of the aerial photographs, shade classes from Table 1 were still assigned, as was an additional notation identifying those reaches as needing further investigation. These streams were then visited during the field surveys (where access was permitted).

Field Investigations

Streams in the GIS stream layer were visited when the stream's existence or exact location could not be verified based on the aerial photographs. A total of 18 sites were visited for this purpose (Figure 3); however, due to access constraints, most of these visits occurred at road crossings. To ensure accurate navigation, the RLIS Lite stream line layer was loaded onto a Trimble GeoXT Global Positioning System (GPS) unit that was taken into the field. At each stream location in question, the presence or absence of a stream

channel or water (in the stream channel or elsewhere) was recorded, as was any relevant information on possible diversions or other conditions that could be viewed from the point of access was noted. This information was documented in an associated GIS file.

Figure 3. Stream Presence/Location Check Sites. These sites were visited to verify the existence or location of streams in the Damascus, Oregon area when the information could not be determined from aerial photographs.

Stream Aspect Calculation

Using GIS, stream reaches were broken into three classes based on their direction of flow (Figure 4). This method was designed based on the Whittaker Index adaptation used by Day and Monk (1974). Class I represents streams with aspect values ranging from 82.5° to 142.5° and from 262.5° to 322.5°; riparian vegetation on these streams has the potential to generate the most shade with the greatest influence on stream temperature (when planted on the southern bank). Class III represents streams with aspect values ranging from 172.5° to 232.5° and from 353.5° to 52.5°. These streams flow perpendicular to those in Aspect Class I, and riparian vegetation planted on the banks of these streams will generally produce the least stream shade. Aspect Class II contains the remainder of the stream aspect values, and riparian vegetation planted on these stream banks will generally have an intermediate effect on stream shade. All aspect values are based on true north. The analysis was performed at a viewing scale of approximately 1:1,500, and streams were broken into segments based on their natural meanders (as opposed to a standard segment length) and assigned an aspect class value that was recorded in the associated GIS file.

Figure 4. Stream Aspect Classes. Figure (a) depicts the three aspect classes for the riparian shade assessment in the Damascus area expansion of the Portland, Oregon urban growth boundary. Streams with aspect values from 263.5° to 322.5° or 82.5° to 142.5° were assigned to Aspect Class I (b); streams with aspect values from 352.5° to 52.5° or 172.5° to 232.5° were assigned to Aspect Class III (c). The remaining streams were assigned to Aspect Class II.

Identification of Priority Shade Restoration Areas

Three steps were used to select and prioritize stream reaches for shade restoration. In each step, a portion of the streams were eliminated from the group of potential priority reaches. In the first step, stream reaches with greater than 70 percent shade (as determined in the riparian shade assessment) were eliminated. In the second step, stream segments that were dry during late August – early September site visits were excluded, as these reaches are assumed to be contributing little or no water during critical high water temperature months. In the third step, the remaining reaches were prioritized according to the combined weight of their shade and aspect classifications, as is shown in Table 2.

Table 2. Shade Restoration Priority Classification.

Shade Restoration Priority Rank I
Aspect Class I + Shade Class 1
Shade Restoration Priority Rank II
Aspect Class I + Shade Class 2
Aspect Class II + Shade Class 1
Shade Restoration Priority Rank III
Aspect Class I + Shade Class 3
Aspect Class II + Shade Class 2
Aspect Class III + Shade Class 1
Shade Restoration Priority Rank IV
Aspect Class II + Shade Class 3
Aspect Class III + Shade Class 2
Shade Restoration Priority Rank V
Aspect Class III + Shade Class 3

Results

Riparian Shade Assessment

Aerial Photograph Interpretation

The Riparian Shade Classification Map shows the results of the GIS shade analysis (Figure 5). In general, it appears that the headwater reaches have less riparian shade than the downstream areas. Relative shade levels in Rock Creek and Richardson Creek appear to be roughly equal (Figure 6). Table 3 provides the total reach length in each Riparian Shade Class as well as the total length of reaches identified as Piped/Other, Ponds, or No Stream Present (which generally occurred in headwater areas). Reaches that have been piped, impounded, or otherwise diverted (e.g. a portion of Rock Creek at the Pleasant Valley Golf Course) appear in gray on the Riparian Shade Classification Map.

Figure 5. Riparian Shade Classification. Stream shading on Rock Creek and Richardson Creek watersheds in the Damascus area expansion of the Portland, Oregon urban growth boundary. Reaches in Riparian Shade Class 1 are shown in red and represent segments with less than 20 percent of the stream surface shaded by adjacent riparian vegetation.

Table 3. GIS Classification Totals.

Classification	Attribute Table Code	No. of Reaches	Length (meters)	%
Riparian Shade Class 1	1	94	15560	25.72
Riparian Shade Class 2	2	38	6060	10.03
Riparian Shade Class 3	3	54	9900	16.37
Riparian Shade Class 4	4	101	22900	37.87
Riparian Shade Class 5	5	31	6060	10.02
RSC subtotal		318	60480	100.00
Piped/Other	66	3	1,510	
Ponds	98	33	5370	
No stream present	99	33	10540	
Grand Total		387	77900

Figure 6. Riparian Shade Levels by Watershed. Proportion of assessed stream reaches in each riparian shade class for Rock Creek and Richardson Creek watersheds in the Damascus area expansion of the Portland, Oregon urban growth boundary.

Accuracy Evaluation

Of the 25 verification sites, 20 were correctly assessed (i.e. the field-measured value was within the shade class assigned in the GIS assessment). For the remaining five sites, the difference between the field-measured value and the GIS-based classification was generally quite small; the values ranged from 3 to 11 percent out of the Riparian Shade Class (e.g. a site measured at 67 percent canopy cover in the field and assigned a GIS-based Riparian Shade Class of 4 (70 – 90%) would be 3 percent out of the Riparian Shade Class). The individual site results appear in Appendix A. Although the OWAM recommends checking shade classifications based on aerial photos against field measured shade values, it does not establish any accuracy targets or other numeric criteria for the comparisons.

Stream Layer Corrections

Approximately 12 km of streams were corrected based on the aerial photographs. The vast majority of these corrections consisted of removing non-existent headwater stream reaches, generally in areas of agricultural, residential, or commercial land use. Additional corrections included adjusting stream locations (some streams have been re-routed around buildings or parking lots), and delineating ponds that were shown as streams in the original GIS layer. Another 3 km of streams were identified as potential inaccuracies in the stream layer, but the existence or location of these reaches could not be verified based on the aerial photographs. Information on these additional reaches was collected during the site visits and recorded in the associated GIS files.

Identification of Priority Shade Restoration Areas

Of the 60.5 km of streams included in the riparian shade analysis, 31.5 km (52%) of stream reaches had shade levels below 70 percent. From this 31.5 km, 6.8 km were excluded because they were determined to be intermittent. The remaining 24.7 km were assigned aspect class values and broken into five shade restoration priority ranks based on the combined weight of their shade and aspect classifications (Figure 7). Of these, a total of 4.1 km of stream reaches received the highest shade restoration priority rank. These reaches have the lowest existing shade levels and the greatest potential for restoration of stream shading based on their aspect. These stream reaches occurred primarily in the first and second order streams; almost no Shade Restoration Priority Rank I reaches occurred along the main stems. Appendix B contains additional information on the priority restoration areas.

Figure 7. Shade Restoration Priority Classification. Damascus area stream reaches in Shade Priority Rank I are the highest priority for restoration activities, followed by II, III, IV, and V. Reaches that appear in blue were not considered candidates for restoration because they are presently shaded greater than 70 percent, are intermittent, or are piped.

Discussion

In general, the headwaters and upper stream reaches were found to be less shaded than those lower in the watersheds. This result is the reverse of what was expected. Typically, headwater channels are smaller and located in steeper valleys than larger order streams, so the surface is more easily shaded by riparian vegetation and the steep slopes are not generally not conducive to land uses that would clear the riparian vegetation. As streams progress downstream and grow wider, it is increasingly difficult for the vegetation on the streambank to provide complete shade coverage, and the more gently sloping stream valleys open the land to other uses that may result in riparian deforestation (Gregory et al. 1991). However, in this study area, due to the highly erodible nature of the soils (which originated as Missoula flood deposits), the land surrounding the headwaters is generally flat, and the stream valleys grow increasingly steeper downstream. Because of this, the land surrounding the reaches lower in the watersheds is generally less suitable for the agricultural, commercial, and residential land uses that often lead to riparian deforestation.

Of the 60.5 km of streams assessed in the riparian shade analysis, 4.1 km (6.8%) received the highest stream restoration priority rank, and the additional 20.6 km in the remaining four classes are also important areas to consider for restoration of stream shade. This stream shade priority ranking can be used as an important component of restoration planning and site selection; however, the ultimate selection of restoration sites will need to incorporate additional factors including wildlife habitat needs, land use plans, and landowner cooperation.

Due to the spatial scale and scope of this analysis, the shade preservation priority ranking method did not take into account the importance of riparian continuity in stream temperature. In their study of southern Ontario trout streams, Barton et al. (1985) found that the percent of forested stream bank 2.5 km upstream of a site could explain 56 percent of the variation in water temperature. They also determined that fine particulate concentration, water temperature, and water flow variability – all factors that are detrimental to the trout populations they were studying – were inversely related to the proportion of vegetated upstream riparian areas. Restoring riparian continuity may also be an important factor to consider in the ultimate selection of stream restoration sites.

Conclusion

This study quantified existing riparian shade levels, prioritized reaches for restoration of stream shade, and provided corrections for the GIS stream coverage for Clackamas River basin streams in the Damascus area UGB expansion. Generally, the headwaters were found to have less shade than the downstream areas and many of the headwater reaches were identified as the highest restoration priority. The results of the shade restoration priorities analysis can be used to guide restoration planning in the new urban area; however, it is important that additional factors such as riparian continuity, water quality, and land use be considered in the final selection of restoration sites. To protect riparian habitat and other natural resources, it is essential to have an accurate map of the existing resources, and the stream layer corrections and subsequent natural resource inventory will aid in achieving that. Overall, this project is one key component of the progressive planning that will be needed to protect natural areas in our increasingly urban environment.

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Appendix A: Riparian Shade Assessment Accuracy Evaluation Results

The field-measured canopy cover value from the 2003 stream surveys conducted for Metro by ABR appears in Column B. Column C contains the Riparian Shade Class assigned to the same stream reaches through the GIS evaluation of the 2003 aerial photographs. A 'Pass' in Column D indicates that the GIS-based Riparian Shade Class matched the field-measured value. For the sites where the GIS-based assessment did not match the field measurement, Column E represents the difference between the field-measured value and the threshold of the assigned Riparian Shade Class – the percent out of the class (i.e. a small value means that the field measured value was close to the assigned Riparian Shade Class).

Table A-1. Riparian Shade Assessment Accuracy Evaluation Data

A. Field Survey Site Number	B. Field-Measured Canopy Cover (%)	C. Riparian Shade Class*	D. Pass/Fail	E. Percent Out of the Class
18	69	3	Pass	
33	93	5	Pass	
13	92	5	Pass	
3	91	5	Pass	
44	81	3	Fail	-11
31	92	5	Pass	
46	86	4	Pass	
49	87	4	Pass	
45	83	4	Pass	
34	73	4	Pass	
1	82	4	Pass	
21	91	5	Pass	
29	86	5	Fail	4
2	87	4	Pass	
19	75	4	Pass	
43	99	5	Pass	
27	93	5	Pass	
39	89	4	Pass	
36	93	5	Pass	
47	93	4	Fail	-4
42	98	5	Pass	
28	87	5	Fail	3
48	91	5	Pass	
23	94	4	Fail	-5
24	94	5	Pass	

*Riparian Shade Classes:

1 = <20%; 2 = 20 – 40%; 3 = 40 – 70%; 4 = 70 – 90%; 5 = >90%

Appendix B: Site Recommendations for Restoration Planning

The Shade Restoration Priority Rank I reaches appear in Figure B-1. It is important to note that any of these reaches (as well as those with lower Shade Restoration Priority Rankings) may be a good candidates for restoration and that those decisions will need to be based on site-specific information that may include flow, existing vegetation, landowner cooperation, and current and projected land use. However, to aid in the initial phases of site selection, 16 sections have been highlighted as possible restoration sites based on field observations, reach length, and other ancillary information. Additional information on these sections appears in Table B-1.

Table B-1. Site Recommendations.

Section 1	Rock Creek Tributary	603 m (multiple reaches)
<i>Notes:</i> This section comprises three Shade Restoration Priority Rank 1 stream reaches on a tributary in the upper Rock Creek watershed. The presence or locations of these streams was difficult to determine based on the aerial photo interpretation. They will require a thorough on-the-ground investigation.		
Section 2	Rock Creek Tributary	98 m
Section 3	Rock Creek and Tributary	~ 500 m (multiple reaches)
<i>Notes:</i> Identified by Michael Carlson/CRBC as a good candidate for restoration.		
Section 4	Rock Creek	112 m
Section 5	Rock Creek	~ 480 m (multiple reaches)
<i>Notes:</i> This section is downstream (or included in) the Rock Creek Fish Passage Enhancement Project. A sign upstream of the site identified Clackamas County Transportation Maintenance and U.S. Fish & Wildlife Service as partners in the project. The contact provided was Clackamas County Road Department – (503) 557-6391.		
Section 6	Rock Creek Tributary	135 m
Section 7	Rock Creek Tributary	141 m
Section 8	Rock Creek Tributary	78 m
Section 9	Richardson Creek Tributary	142 m
Section 10	Rock Creek Tributary	59 m
Section 11	Rock Creek Tributary	134 m
Section 12	Richardson Creek Tributary	60 m
Section 13	Richardson Creek	54 m
<i>Notes:</i> Site visit was done 262 m upstream. At the September visit the stream was dry, the channel had been artificially constructed or diverted and was running through a housing development with little or no shade.		
Section 14	Rock Creek Tributary	63 m
<i>Notes:</i> Site visit was done 445 m upstream – At the September visit the faint stream channel was dry, at that point the channel may have been diverted to a roadside ditch.		
Section 15	Richardson Creek Tributary	511 m
Section 16	Richardson Creek Tributary	515 m

Figure B-1. Priority Shade Restoration Areas – Potential Restoration Sites.