



Characterization of North Coast and Cascade Network Water Quality Study Sites

Natural Resource Data Series NPS/NCCN/NRDS—2017/1097



ON THE COVER

Barnes Creek, in Olympic National Park.
NPS Photo.

Characterization of North Coast and Cascades Network Water Quality Study Sites

Natural Resource Data Series NPS/NCCN/NRDS—2017/1097

Carmen A. Welch and Ashley K. Rawhouser

National Park Service
North Cascades National Park
810 State Route 20
Sedro-Woolley, WA 98284

April 2017

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the [North Coast and Cascades Network Inventory and Monitoring website](#) and the [Natural Resource Publications Management website](#). To receive this report in a format that is optimized to be accessible using screen readers for the visually or cognitively impaired, please email irma@nps.gov.

Please cite this publication as:

Welch, C. A., and A. K. Rawhouser. 2017. Characterization of North Coast and Cascades Network water quality study sites. Natural Resource Data Series NPS/NCCN/NRDS—2017/1097. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	v
Tables.....	viii
Abstract.....	xiv
Acknowledgments.....	xv
Introduction.....	1
Methods.....	3
Sample Reach Characteristics	3
Watershed Characteristics	4
Stream Location Characterization.....	6
Ebey’s Landing National Historical Reserve	6
Ebey’s Watercourse.....	6
Lewis and Clark National Historic Park.....	12
Colewort Creek.....	14
Skipanon River	20
Megler Creek.....	24
Mount Rainier National Park.....	29
Nisqually River at Park Boundary.....	32
Nisqually River at Longmire	37
Nisqually River at Glacier Bridge	41
Paradise River.....	45
Ohanapecosh River.....	49
White River at the National Park Service Boundary.....	54
White River at Littorals	60
North Cascades National Park.....	64
Stehekin River	66
Bridge Creek.....	71
Company Creek.....	75
Goodell Creek.....	80

Contents (continued)

	Page
Newhalem Creek	86
North Fork Cascade River	91
Ruby Creek	96
Olympic National Park	101
Barnes Creek	104
Umbrella Creek	110
Ozette River	115
Kalaloch Creek	120
Matheny Creek	126
South Fork Calawah River	130
Sol Duc River	136
Summary of NCCN Watershed Characteristics	141
Watershed Area	141
Elevation	141
Precipitation	142
Literature Cited	144
Appendix A: NCCN Watershed Elevation and Precipitation Analysis	148
Appendix B: NCCN Watershed Stressor Analysis	149
Appendix C: Comprehensive List of Stressors and Associated Sources	150

Figures

	Page
Figure 1. Regional map of northwest Washington and Oregon identifies the seven NPS park units within the North Coast and Cascades Network.....	1
Figure 2. Map of the Ebey’s Watercourse stream location and watershed in Ebey’s Landing National Historical Reserve.....	7
Figure 3. Ebey’s Watercourse stream location and watershed.....	8
Figure 4. Looking upstream into the sample reach in Ebey’s Watercourse.....	10
Figure 5. Map of the stream locations and associated watersheds in Lewis and Clark National Historical Park.....	13
Figure 6. Colewort Creek and the Skipanon River water quality stream locations and delineated watersheds.	15
Figure 7. Looking upstream into the sample reach in Colewort Creek.....	19
Figure 8. Skipanon River, upstream from the stream location	23
Figure 9. Megler Creek stream location and watershed.....	25
Figure 10. Megler Creek, looking downstream from the reference point.....	28
Figure 11. Map of the stream locations and associated watersheds for Mount Rainier National Park	30
Figure 12. Nisqually River stream locations and watersheds, including: Nisqually River at Park boundary, Nisqually River at Longmire, Nisqually River at Glacier Bridge and the Paradise River.	31
Figure 13. Photograph of the Nisqually River at Park boundary sample reach illustrating the broad floodplain and braided channel characteristics	35
Figure 14. Looking downstream into the sample reach in the Nisqually River at Longmire.....	37
Figure 15. The Nisqually River at Glacier Bridge sample reach braided within its floodplain and constrained by steep valley walls.....	44
Figure 16. Looking upstream into the Paradise River sample reach.....	48
Figure 17. The Ohanapecosh River stream location and watershed.	50
Figure 18. Bedrock and boulder constraints are evident, looking downstream to the start of the Ohanapecosh sample reach.....	53
Figure 19. The White River stream locations and watersheds: White River at Park boundary and White River at littorals.	55
Figure 20. The White River at Park boundary sample reach, showing a braided channel within its floodplain.	59

Figures (continued)

	Page
Figure 21. The White River at littorals sample reach, showing braided channel within its broad valley.....	63
Figure 22. Map of the stream locations and associated watersheds in the North Cascades National Park Service Complex.....	65
Figure 23. Stehekin River, Bridge Creek, and Company Creek stream locations and watersheds.....	67
Figure 24. Looking upstream into the Stehekin River sample reach.	71
Figure 25. Representative habitat in the Bridge Creek sample reach.	75
Figure 26. Looking down stream in the Company Creek sample reach	80
Figure 27. The Goodell Creek stream location and watershed.	81
Figure 28. Braided habitat and exposed gravel bars in the Goodell Creek sample reach.	85
Figure 29. Nehalem Creek stream location and watershed.....	87
Figure 30. Technician measuring water depth at the water temperature monitoring station in Newhalem Creek.....	91
Figure 31. North Fork Cascade River stream location and watershed.....	92
Figure 32. Sample reach reference point, North Fork Cascade River.....	95
Figure 33. The Ruby Creek stream location and watershed.	97
Figure 34. Looking upstream into the Ruby Creek sample reach.....	101
Figure 35. Map of the stream locations and associated watersheds for Olympic National Park.	103
Figure 36. Barnes Creek stream location and watershed.	105
Figure 37. Photograph showing typical habitat and stressors within Barnes Creek	108
Figure 38. The Ozette River and Umbrella Creek stream locations and watersheds.....	111
Figure 39. Photograph showing typical habitat and gravel deposition within the Umbrella Creek sample reach.	115
Figure 40. Uniform habitat conditions in the Ozette River sample reach.....	120
Figure 41. Kalaloch Creek stream location and watershed.....	121
Figure 42. Kalaloch Creek, looking downstream into the sample reach.....	125
Figure 43. The Matheny Creek stream location and watershed.....	126
Figure 44. Habitat representative of the sample reach within Matheny Creek.....	130

Figures (continued)

	Page
Figure 45. The South Fork Calawah River stream location and watershed.....	131
Figure 46. South Fork Calawah River habitat, showing bedrock constraints on right side of photograph.	135
Figure 47. The Sol Duc River stream location and watershed.....	137
Figure 48. Distribution of North Coast and Cascade Network sample site watershed areas, rank ordered smallest to largest.	141
Figure 49. Mean elevation values in meters above sea level for each North Coast and Cascade Network watershed (colored squares)	142
Figure 50. Average precipitation rates (cm/year) for each North Coast and Cascade Network watershed.	143

Tables

	Page
Table 1. Amphibian species documented and potentially present in the Ebey’s Watercourse sample reach and watershed.	9
Table 2. Physical habitat characteristics measured in 2013 for the sample reach in Ebey’s Watercourse.	11
Table 3. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach conducted in 2013 for Ebey’s Watercourse	11
Table 4. Fish species documented and potentially present in Colewort Creek.	16
Table 5. Amphibian species documented in the Colewort Creek sample reach and watershed.	17
Table 6. Physical habitat characteristics measured in 2012 for the sample reach in Colewort Creek.	18
Table 7. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the sample reach in Colewort Creek	19
Table 8. Fish species documented and potentially present in the Skipanon River sample reach and watershed.	20
Table 9. Amphibian species documented and potentially present in the Skipanon River sample reach and watershed.....	21
Table 10. Physical habitat characteristics measured in 2012 for the sample reach in the Skipanon River.....	22
Table 11. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Skipanon River.....	24
Table 12. Fish species potentially present in the Megler Creek sample reach and watershed.	26
Table 13. Amphibian species potentially present in the Megler Creek sample reach and watershed.	26
Table 14. Physical habitat characteristics measured in 2012 for the sample reach in Megler Creek.	27
Table 15. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Megler Creek.....	29
Table 16. Fish species documented and potentially present in the Nisqually River at Park boundary sample reach and watershed.....	33
Table 17. Amphibian species documented and potentially present in the Nisqually River at Park boundary sample reach and watershed.	33

Tables (continued)

	Page
Table 18. Physical habitat characteristics measured in 2012 for the Nisqually River at Park boundary sample reach.	35
Table 19. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Nisqually River at Park boundary sample reach	36
Table 20. Fish species documented and potentially present in the Nisqually River at Longmire sample reach and watershed.	38
Table 21. Amphibian species documented within the Nisqually River at Longmire sample reach and watershed.	38
Table 22. Physical habitat characteristics measured in 2012 for the Nisqually River at Longmire sample reach.	40
Table 23. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Nisqually River at Longmire reach	41
Table 24. Fish species documented and potentially present in the Nisqually River at Glacier Bridge sample reach and watershed.	42
Table 25. Species of amphibians documented and potentially present in the Nisqually River at Glacier Bridge sample reach and watershed.	42
Table 26. Physical habitat characteristics measured in 2012 for the sample reach at Nisqually River at Glacier Bridge.	43
Table 27. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Nisqually River at Glacier Bridge reach	45
Table 28. Fish species documented and potentially present in the Paradise River sample reach and watershed.	46
Table 29. Species of amphibians documented and potentially present in the Paradise River sample reach and watershed.	46
Table 30. Physical habitat characteristics measured in 2012 for the Paradise River sample reach.	47
Table 31. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Paradise River.	49
Table 32. Fish species documented and potentially present in the Ohanapecosh River sample reach and watershed.	51
Table 33. Amphibian species documented and potentially present in the Ohanapecosh River sample reach and watershed.	51
Table 34. Physical habitat characteristics measured in 2012 for the sample reach in the Ohanapecosh River.	52

Tables (continued)

	Page
Table 35. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Ohanapecosh River	54
Table 36. Fish species documented and potentially present in the White River at Park boundary sample reach and watershed.....	55
Table 37. Amphibian species documented and potentially present in the White River at Park boundary sample reach and watershed.	56
Table 38. Physical habitat characteristics measured in 2012 for the sample reach in the White River at Park boundary.....	58
Table 39. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the White River at Park boundary sample reach	59
Table 40. Fish species documented and potentially present in the White River at littorals sample reach and watershed.....	60
Table 41. Amphibian species documented and potentially present in the White River at littorals sample reach and watershed.	61
Table 42. Physical habitat characteristics measured in 2012 for the sample reach in the White River at littorals.....	62
Table 43. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach 2012 for the White River at littorals sample reach	64
Table 44. Fish species documented and potentially present within the Stehekin River sample reach and watershed.....	68
Table 45. Amphibian species documented and potentially present in the Stehekin River sample reach and watershed.....	68
Table 46. Physical habitat characteristics measured in 2012 for the sample reach in the Stehekin River.....	70
Table 47. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Stehekin River sample reach	70
Table 48. Fish species documented and potentially present in the Bridge Creek watershed and sample reach.....	72
Table 49. Amphibian species documented and potentially present in the Bridge Creek sample reach and watershed.....	72
Table 50. Physical habitat characteristics measured in 2012 for the sample reach in Bridge Creek.	74
Table 51. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Bridge Creek	75

Tables (continued)

	Page
Table 52. Fish species documented and potentially present in the Company Creek sample reach and watershed.	76
Table 53. Amphibian species potentially present in the Company Creek sample reach and watershed.	77
Table 54. Physical habitat characteristics measured in 2012 for the sample reach in Company Creek.	78
Table 55. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Company Creek.....	79
Table 56. Fish species documented and potentially present in the Goodell Creek sample reach and watershed.	82
Table 57. Amphibian species documented and potentially present in the Goodell Creek sample reach and watershed.....	82
Table 58. Physical habitat characteristics measured in 2012 for the sample reach in Goodell Creek.	84
Table 59. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Goodell Creek	85
Table 60. Fish species documented and potentially present in the Newhalem Creek sample reach and watershed.....	88
Table 61. Amphibian species documented and potentially present in the Newhalem Creek sample reach and watershed.	88
Table 62. Physical habitat characteristics measured in 2012 for the sample reach in Newhalem Creek.....	90
Table 63. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Newhalem Creek	90
Table 64. Fish species documented and potentially present in the North Fork Cascade River sample reach and watershed.....	92
Table 65. Amphibian species potentially present in the North Fork Cascade River sample reach and watershed.	93
Table 66. Physical habitat characteristics measured in 2012 for the sample reach in the North Fork of the Cascade River.	94
Table 67. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the North Fork Cascade River	95
Table 68. Fish species documented and potentially present in the Ruby Creek sample reach and watershed.	98

Tables (continued)

	Page
Table 69. Amphibian species documented and potentially present in the Ruby Creek sample reach and watershed.....	98
Table 70. Physical habitat characteristics measured in 2012 for the sample reach in Ruby Creek.....	100
Table 71. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Ruby Creek.....	100
Table 72. Fish species documented and potentially present in the Barnes Creek sample reach and watershed.....	106
Table 73. Amphibian species documented and potentially present within the Barnes Creek sample reach and watershed.	106
Table 74. Physical habitat characteristics measured in 2012 for the sample reach in Barnes Creek.....	109
Table 75. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Barnes Creek	109
Table 76. Fish species documented and potentially present in the Umbrella Creek sample reach and watershed.....	112
Table 77. Amphibian species potentially present within the Umbrella Creek sample reach and watershed.....	112
Table 78. Physical habitat characteristics measured in 2012 for the sample reach in Umbrella Creek.....	114
Table 79. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Umbrella Creek	115
Table 80. Fish species documented and potentially present in the Ozette River sample reach and watershed.....	116
Table 81. Amphibian species documented and potentially present within the Ozette River sample reach and watershed.....	117
Table 82. Physical habitat characteristics measured in 2012 for the sample reach in the Ozette River.	118
Table 83. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Ozette River.....	119
Table 84. Fish species documented and potentially present in the Kalaloch Creek sample reach and watershed.....	122
Table 85. Amphibian species documented and potentially present within the Kalaloch Creek sample reach and watershed.	122

Tables (continued)

	Page
Table 86. Physical habitat characteristics measured in 2012 for the sample reach in Kalaloch Creek.....	124
Table 87. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Kalaloch Creek.....	125
Table 88. Fish species documented and potentially present in the Matheny Creek sample reach and watershed.	127
Table 89. Amphibian species documented and potentially present within the Matheny Creek sample reach and watershed.	127
Table 90. Physical habitat characteristics measured in 2012 for the sample reach in Matheny Creek.....	129
Table 91. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Matheny Creek	129
Table 92. Fish species documented and potentially present in the South Fork Calawah River sample reach and watershed.....	132
Table 93. Amphibian species documented and potentially present within the South Fork Calawah River sample reach and watershed.....	132
Table 94. Physical habitat characteristics measured in 2012 for the sample reach in the South Fork Calawah River.....	133
Table 95. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the South Fork Calawah River	135
Table 96. Fish species potentially present and documented in the Sol Duc River sample reach and watershed.	138
Table 97. Amphibian species documented and potentially present within the Sol Duc River sample reach and watershed.....	138
Table 98. Physical habitat characteristics measured in 2012 for the sample reach in the Sol Duc River.....	139
Table 99. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Sol Duc River	140

Abstract

To monitor water quality, we assess environmental conditions of the most at-risk Wadeable Streams and Rivers in five national parks. The parks, located in the North Coast and Cascades Network (NCCN), include Ebey's Landing National Historical Reserve (EBLA), Lewis and Clark National Historical Park (LEWI), Mount Rainier National Park (MORA), North Cascades National Park Service Complex (NOCA), and Olympic National Park (OLYM). The purpose of the monitoring is to identify trends and abrupt change in water quality characteristics.

In this report we describe the environmental conditions and human activities that influence water quality at 25 stream (or river) locations selected in NCCN's Water Quality monitoring protocol (Rawhouser et al. 2012). Seven stream locations were selected in each of the three largest parks, MORA, NOCA, and OLYM; one in EBLA; and three in LEWI. At each location, a stream reach was chosen to collect site specific data (Rawhouser et al. 2012). In addition, the watershed surrounding each stream location is characterized by the amount of precipitation, elevation gradients, type of dominant vegetation (Ecoregions), road and trail density, number of mines, land-use type, land ownership, and other factors such as hydropower generation facilities and sewage treatment plants above the sample reaches. Information in this report can serve as a reference to implement NCCN's Water Quality monitoring protocol and interpret results, and to inform management decisions to maintain and, or improve water quality.

Acknowledgments

This report was prepared with cartographic assistance from Natasha Antonova and technical editing assistance from Lise Grace. Natural resource managers Chris Clatterbuck, Pat Crain, Barbara Samora, Rebecca Lofgren, and Ben Wright provided content to characterize the biological resources and stressors at the different sample locations within their respective parks as well as provided valuable reviews of this report. Additional NCCN and park staff that contributed include: Jennifer Bell, Margaret Taylor, Hugh Anthony, Madeline Eckmann, John Box, Kelly Martin and Rose Ablug.

Introduction

The high abundance of rivers and streams is a defining characteristic of the North Coast and Cascades Network (NCCN) (Figure 1). Ninety-four percent of NCCN land area is federally-designated wilderness and contains some of the highest quality remaining aquatic habitat in the Pacific Northwest. The prevalence of these resources gives water quality a high ecological, management, and legal significance for the network. The aquatic resources within the NCCN support 38 native fish, including unique stocks within these species, and 17 native amphibian species. They also support human uses, including contact and non-contact recreation and water supply.



Figure 1. Regional map of northwest Washington and Oregon identifies the seven NPS park units within the North Coast and Cascades Network.

The significance of these aquatic resources, in combination with their vulnerability to environmental stressors, highlights the importance of water quality monitoring. Aquatic systems integrate the physical, chemical, and biological characteristics of the watersheds they drain, putting them at an increased risk to a variety of environmental stressors. These stressors may include atmospheric pollution, changes in flow regimes due to climate change, and more localized disturbances related to past and present land management activities and recreational use. Monitoring can help inform managers about the condition of aquatic resources, which will ultimately reduce the risk future environmental stressors pose. The NCCN Water Quality monitoring project (Rawhouser et al. 2012) was designed to provide a cost-efficient, comprehensive approach to assess the current conditions in the most at risk wadeable streams and rivers in the NCCN, establish trends, and identify any abrupt changes.

Execution of the NCCN Water Quality monitoring project involves yearly visits to 25 stream locations across the NCCN. Stream locations are distributed across Ebey's Landing National Historical Reserve (EBLA), Lewis and Clark National Historical Park (LEWI), Mount Rainier National Park (MORA), North Cascades National Park Service Complex (NOCA), and Olympic National Park (OLYM). One location was selected in EBLA, three locations were selected in LEWI, and seven locations were selected in each of the three large parks, MORA, NOCA, and OLYM. The rivers and streams that are sampled within the NCCN consist of locations that were first determined to be at the highest risk of impairment based on a network-wide process of ranking waters considered to be at risk. A detail description of that ranking process can be found in the NCCN Water Quality monitoring protocol (Rawhouser et al. 2012). From that list, an additional informed risk ranking by park resource managers identified the final 25 locations in the NCCN to be selected for monitoring on an annual basis. This report presents detailed descriptions of each location chosen, as well as the biological resources and influential stressors that led to their selection. Although Fort Vancouver National Historic Site (FOVA) and San Juan Island National Historical Park (SAJH) are park units in the NCCN, neither will be sampled, as they do not contain any wadeable rivers or streams.

This document presents a detailed characterization of the 25 watersheds and stream reaches that are sampled as part of the NCCN Water Quality monitoring project. It also provides a characterization of the potential stressors affecting each of the monitoring locations. This characterization is based on the methods developed for monitoring water quality in the wadeable rivers and streams in the NCCN using the Water Quality monitoring protocol (Rawhouser et al. 2012). The information in this report will aid in interpreting future Water Quality monitoring results and serve as a reference for staff involved with the long-term implementation of this project.

Methods

The information presented in this report was collected during development and implementation of the North Coast and Cascades Network Water Quality monitoring protocol (Rawhouser et al. 2012). The methods described in the following section are a brief summary of the methods and concepts originally presented in full detail in the North Coast and Cascades Network Water Quality monitoring protocol (Rawhouser et al. 2012).

Water quality monitoring of a given stream location involved collecting information about the stream itself and the watershed it lies within. The watershed of a stream or river is defined as the area of land where all water drains to a common point. Characteristics of a watershed influence the physical, chemical, and biological properties of the river or stream it feeds. This information will aid in understanding the factors that influence the water quality of a stream and the biological resources that it supports.

Sample Reach Characteristics

For each of the 25 stream locations, a sample reach has been delineated. A series of characteristics was developed to describe each sample reach.

Sample reach length is defined as a reach length (in meters) of 40 times the average wetted width, starting at the stream location and going upstream. Minimum and maximum reach lengths were predetermined to be 150 and 500 m, respectively (Rawhouser et al. 2012). Once established in the first year of sampling, sample reach length remains unchanged from year to year.

Stream location elevation is determined for each stream location using a global positioning system unit at the stream location. Elevations are reported here in meters above sea level. After the initial determination, elevation for each stream location remains unchanged from year to year.

Wetted width is the width (m) of wetted stream channel between the right and left stream banks, perpendicular to the flow. Wetted width data are collected on an annual basis.

Bankfull width is the width (m) of stream channel between the right and left stream banks, perpendicular to flow, at the point where over-bank flow begins during a flood event. Indicators to identify the over-bank flow point on each bank include vegetation/moss lines, leaf depositions, and scour lines. This measurement was made in straight, low-gradient riffles with uniform banks. Bankfull width data are collected on an annual basis.

Thalweg depth is the depth (m) of water at the deepest part of a stream channel cross section, as measured with a measuring rod. Thalweg depth data are collected on an annual basis.

Valley width is the distance (m) between valley walls on either side of the stream channel, measured with a laser range finder. In situations where valley widths are greater than 100 m, the widths are estimated visually or using topographical maps or GIS. Valley width data are collected on an annual basis.

Channel constraint assessment determines if the stream or river channel is a single (one predominate channel), anastomosing (channel is split by large vegetated islands) or braided (channel is split frequently by un-vegetated gravel bars) channel; whether the channel is constrained, and if so, what the constraining feature is (bedrock, boulder, incision, hill slope, or human alteration) and what percent of the channel is affected by the constraining feature. Channel constraint data are collected on an annual basis.

Torrent evidence involves qualitative evaluation of the reach for indications of scour and deposition. These indicators include bank and gravel bar scour, vegetation removal, large woody debris deposits, fine sediment deposition in large quantities, and vegetation deposits above bankfull level. Torrent evidence data are collected on an annual basis.

Rapid Habitat Assessment is a visual qualitative assessment of the riparian and in-stream habitat within the sample reach, scored from 0 to 20, ranging from lowest to highest quality habitat. This assessment has been adapted from the Environmental Monitoring and Assessment Program (EMAP) Wadeable Stream Assessment: Field Operations Manual (USEPA 2004) and Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers (Barbour et al. 1999).

Watershed Characteristics

For each of the 25 stream locations, a series of characteristics were developed to describe the, natural environmental conditions, land use, geography, and climate that occurred within the watershed delineated for that stream location. The following statistics were developed using geographic information system (GIS) data layers, processed using ArcMap v10.1 software by ESRI.

Watershed Level IV Ecoregions were ecologically and geographically defined areas with recurring environmental patterns and biological characteristics, as delineated by the U.S. Environmental Protection Agency (USEPA 2012a, 2012b). Level IV ecoregions were of a resolution that most of the designated watersheds were composed of at least two different ecoregions. Ecoregions were determined using GIS data layers and ArcMap v10.1 software by ESRI (ORD NHEEL 2012, USEPA 2012a, 2012b).

Human activity was assessed as a combination of land management activities such as commercial forestry, agriculture, and recreational use, and more permanent developments such as roads, hydropower facilities, and recreational infrastructure. For each watershed, human activity was qualitatively and quantitatively assessed. The qualitative assessment was based on existing knowledge of human activity and developments, field-based observations, and interpretation of aerial photographs. The quantitative assessment used road, trail, and mining development data for each of the watersheds (Rawhouser et al. 2012).

Total distance of roads was defined as the total length (km) of roads within a watershed.

Road density (km/km²) was calculated by dividing the total length of roads within a watershed by the watershed area.

Road crossings were defined as the total number of times a road crosses a stream within a watershed.

Total distance of trails represented the total length of trails (km) within a watershed.

Trail density (km/km²) was calculated by dividing the total length of trails within a watershed by the watershed area.

Trail crossings were defined as total number of times a trail crosses a stream within a watershed.

Mines represented the total number of mines present in a watershed.

Watershed area was calculated as the surface area (km²) of the landscape that drains to the water quality stream location. The size of the watershed influences the amount of runoff and flux of terrestrially derived inputs entering the stream. Watershed boundaries were delineated using the topographic divides visible at the 1:24,000 scale.

Watershed elevation was summarized as minimum, maximum, and mean elevation above sea level in meters (m) for each watershed, using data derived from a digital elevation model with a cell size of 10 m². The minimum elevation points were typically located at the stream locations and the maximum elevations were found on ridge tops or peaks along the perimeters of the watersheds. The mean elevation statistics were derived using zonal analysis tools in ArcMap v10.1 software by ESRI.

Watershed precipitation was derived from PRISM precipitation data (PRISM 2012). These data were based on records from 1981 to 2010 and represent the average precipitation (cm/year) in each watershed.

Stream Location Characterization

Ebey's Landing National Historical Reserve

Freshwater resources within EBLA are limited to Lake Pondilla, a few small wetlands, and Ebey's Watercourse, which is the only source of running fresh water within the Reserve. The remaining aquatic resources within EBLA are marine and brackish waters, composed of Penn Cove, as well as marine shorelines along the eastern Strait of Juan de Fuca, Admiralty Inlet, and Admiralty Bay (Figure 2).

Ebey's Watercourse

Watershed Description

One stream, Ebey's Watercourse, is sampled in Ebey's Landing National Historical Reserve as part of the NCCN Water Quality monitoring protocol (Figure 2). The Ebey's Watercourse watershed encompasses 8.5 km², ranges in elevation from 13 to 67 m above sea level, and receives an average precipitation of 54 cm/year. The stream is seasonally intermittent and is fed primarily by surface runoff of rain and groundwater inflow. Small wetlands found in the watershed (Larrabee 2011) likely help to recharge groundwater inflow. Contained within the Olympic Rainshadow Level IV Ecoregion; the watershed is composed of mixed forest, coastal coniferous forest, restored natural grassland, as well as agricultural lands used for crop production and pasture (Omernick 2010). The stream drains directly into Admiralty Inlet on the west side of Whidbey Island.

Whidbey Island, including the watershed surrounding Ebey's Watercourse, is designated as a sole source aquifer, requiring Washington State's highest level of regulatory protection (Island County 2004). The majority of the watershed is privately owned and has been significantly modified by human activity over the years. Several small isolated holdings are managed by the NPS (Figure 3). Land use within the Ebey's Watercourse watershed includes urban and rural development, agriculture, mining, and recreation. The watershed contains 20.2 km of roads, and 2.9 km of trails. Road density in the watershed is 2.37 km/km² placing it in the 90th percentile of NCCN watersheds and the trail density is 0.34 km/km² placing it in the 75th percentile of NCCN watersheds (Rawhouser et al. 2012).



Figure 2. Map of the Ebey's Watercourse stream location and watershed in Ebey's Landing National Historical Reserve.

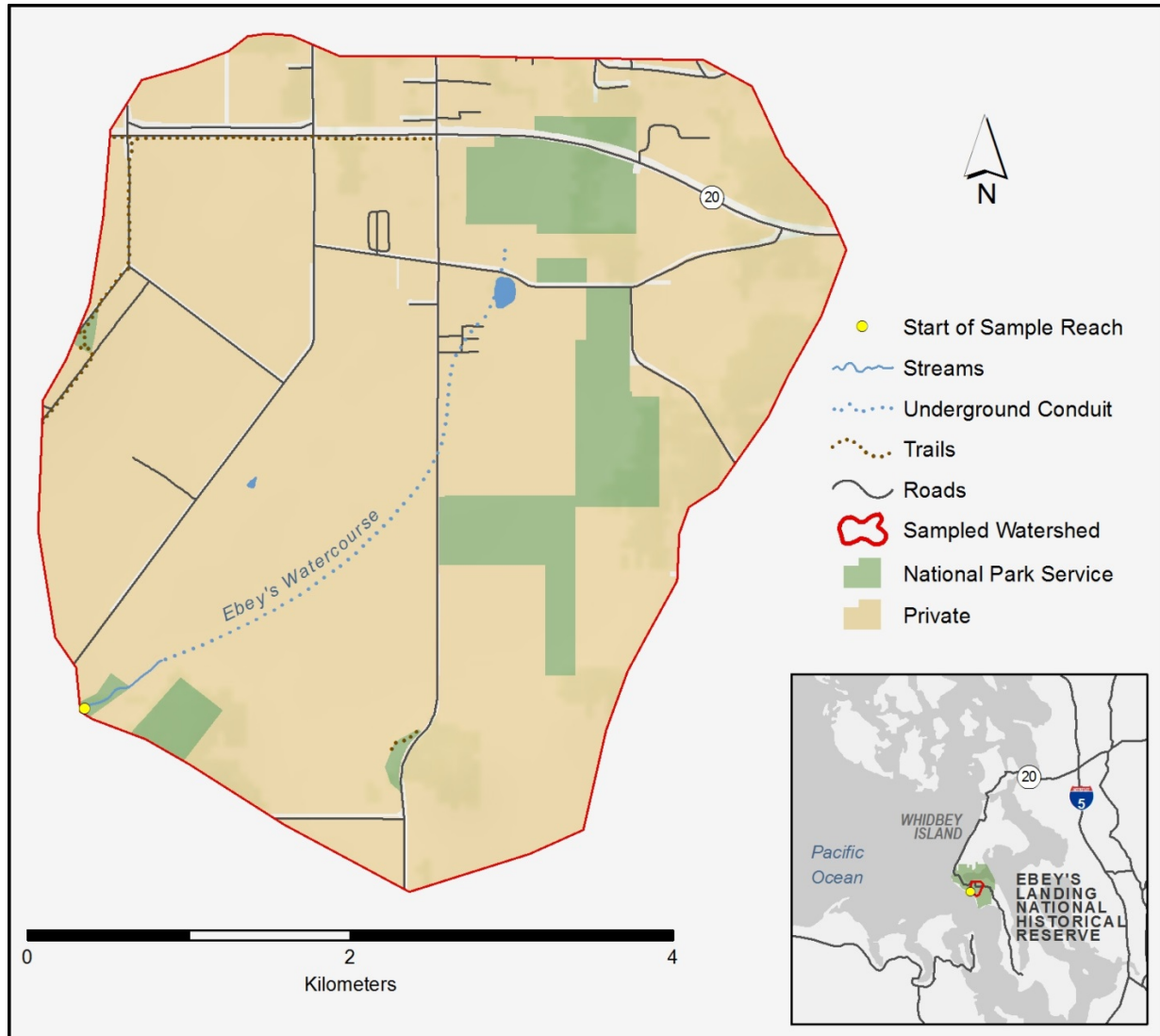


Figure 3. Ebey's Watercourse stream location and watershed.

Biological Resources

At this time, no amphibian or fish species have been documented in the Ebey's Watercourse sample reach (Samora et al. 2013a, b). However, five amphibian species have been documented within EBLA boundaries, and three species have been documented in the Ebey's Watercourse watershed (Table 1) (Samora et al. 2013a). Although their presence is unconfirmed at this time, two additional amphibian species, western toad (*Anaxyrus boreas*) and bull frog (*Rana catesbeiana*) are believed to occur in the area (Table 1) (Leonard et al. 1993, WNHP WDFW BLM 2005).

Table 1. Amphibian species documented and potentially present in the Ebey's Watercourse sample reach and watershed.

Common Name	Scientific Name	Documented in Watershed	Potentially Present
Northwest salamander ¹	<i>Ambystoma gracile</i>		X ²
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>	X ²	
Western toad ¹	<i>Anaxyrus boreas</i>		X
Pacific (Chorus) tree frog ¹	<i>Pseudacris regilla</i>	X ²	
Red-legged frog ¹	<i>Rana aurora</i>		X ²
Bull frog ¹	<i>Rana catesbeiana</i>		X
Rough skinned newt ¹	<i>Taricha granulosa</i>	X ²	

¹Facultative stream dwelling species.

²Species documented within Ebey's Landing National Historical Reserve.

Stressors of Water Quality

The greatest threats to water quality in Ebey's Watercourse come from hydrologic modifications related to a network of buried drainage tiles and the channelization of the stream in its lower reaches to facilitate the drainage of the associated agricultural lands (Larrabee 2011). These conditions are compounded by urban and rural development, current agricultural practices, gravel mining, and high densities of roads and trails. See comprehensive list below of stressors that may present a risk to water quality in the Ebey's Watercourse watershed.

- Increased fine sediment deposition from surface runoff.
- Increased turbidity from surface runoff.
- Introduction of chemicals and pollutants from roads and surface run off.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Habitat fragmentation.
- Barriers to aquatic organism passage.
- Increased rate of non-native plant and animal invasions.
- Increased maximum water temperatures.
- Decreased minimum water temperatures.
- Runoff of herbicides and pesticides.
- Accidental toxic spills.
- Increased introduction of pathogens from animal and human waste.
- Increased nutrient delivery.
- Introduction of chemicals from pharmaceutical waste.
- Increased amounts of organic matter.

Sample Reach Characterization

The sample reach in Ebey's Watercourse is 150 m long, starts at an elevation of 13 m above sea level, and begins approximately 200 m upstream from the confluence with Admiralty Inlet. The sample reach is a 1st order intermittent stream (Strahler 1952) occupying a single channel that is constrained by incision into the surrounding terrace (Figure 4 and Table 2). This incision is considered to be severe and has greatly reduced habitat complexity and degraded habitat quality (Tables 2 and 3).

The channel was dry in August of 2012 during the first annual site visit therefore the stream was revisited in the spring when water was expected. The visit in Figure 4 occurred in May of 2013, and since the sample reach was watered at this time, future sample events will occur in May.



Figure 4. Looking upstream into the sample reach in Ebey's Watercourse.

Table 2. Physical habitat characteristics measured in 2013 for the sample reach in Ebey's Watercourse.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTM)	–
Easting	521848.6
Northing	5337556.1
Reach length (m)	150
Average Wetted Width(m)	0.81
Minimum (m)	0.2
Maximum (m)	1.6
Average Bankfull Width (m)	1.7
Minimum (m)	1.4
Maximum (m)	2.0
Average Thalweg Depth (m)	0.06
Minimum (m)	0.02
Maximum (m)	0.09
Valley Width (m)	>1000 ¹
Channel Pattern	One channel
Channel Constraint	Broad valley but constrained by incision
Constraining Feature	Human alteration/incision
Contact with constraining feature	100%
Torrent Evidence	• Substrate not imbricate and/or angular. • Channel has little evidence of pool-rifle structure.

¹Valley width was estimated as total distance observer could see.

Table 3. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach conducted in 2013 for Ebey's Watercourse. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	3
Embeddedness	0
Velocity/Depth Regime	1
Sediment Deposition	2
Channel Flow Status	12
Channel Alteration	0
Frequency of Riffles (or bends)	5
Bank Stability	0
Vegetative Protection	12
Riparian Vegetated Zone Width	0

Lewis and Clark National Historic Park

Three streams are sampled in Lewis and Clark National Historical Park as part of the NCCN Water Quality monitoring protocol (Figure 5). These streams and their delineated watersheds all lie within the Coastal Upland Level IV Ecoregion, which is characterized as having low gradient, meandering, hold high amounts of wood tannins, surrounded by forests that typically contain Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), and Douglas-fir (*Pseudotsuga menziesii*). Forest undergrowth is composed of salal (*Gaultheria shallon*), sword fern (*Polystichum munitum*), vine maple (*Acer circinatum*), and Oregon grape (*Mahonia aquifolium*) (Omernick 2010).

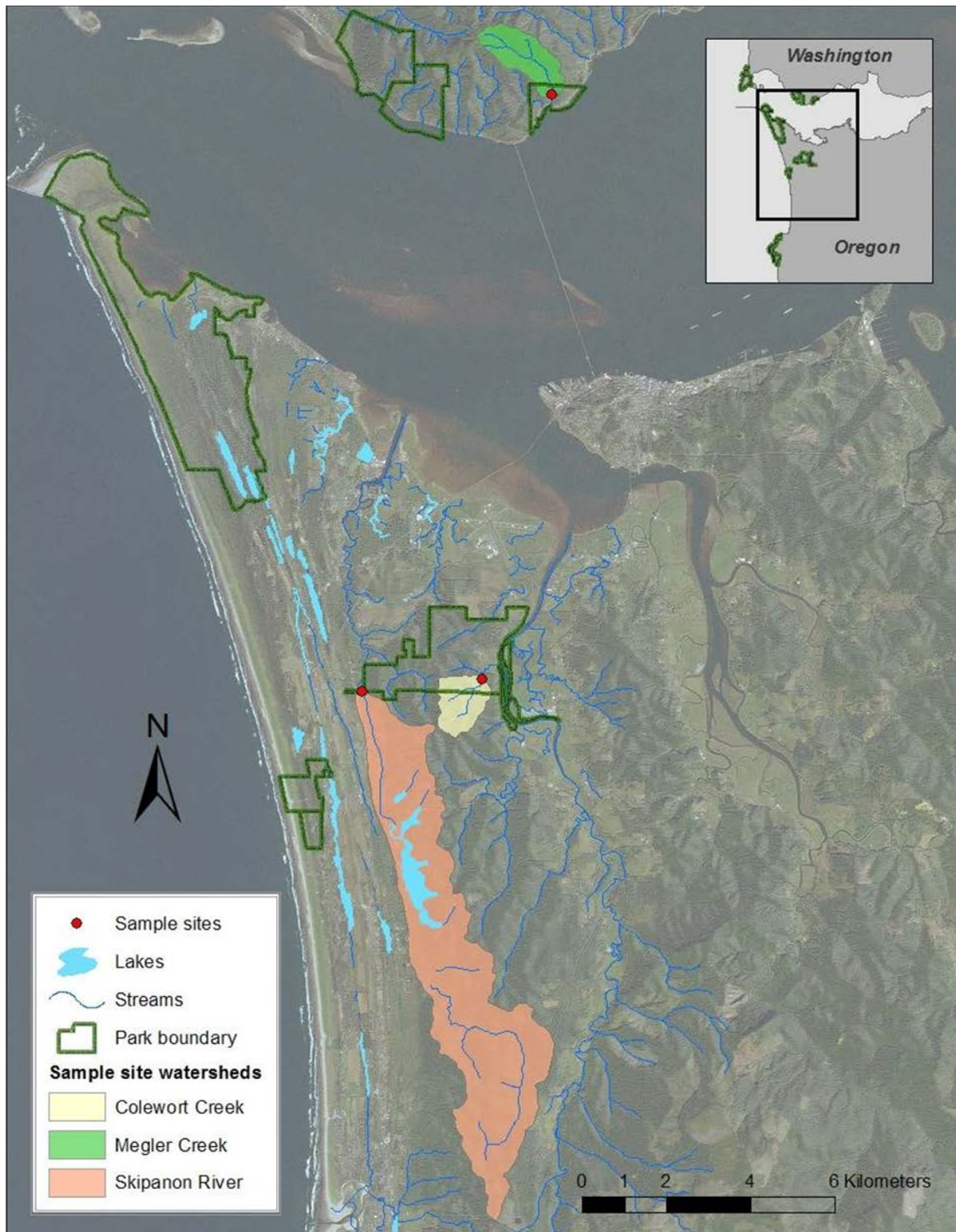


Figure 5. Map of the stream locations and associated watersheds in Lewis and Clark National Historical Park.

Colewort Creek

Watershed Description

Located in the Oregon portion of LEWI, Colewort Creek is a small perennial stream that drains into the Lewis and Clark River (Figure 5). The Colewort Creek watershed encompasses 1.4 km² and ranges in elevation from 3 to 127 m. The average annual precipitation in the watershed is 202 cm/year. Colewort Creek is primarily feed by surface runoff of rain and groundwater inflow.

Roughly 35% of the Colewort Creek watershed is managed by the NPS, and the remaining land is privately owned (Figure 6). Human activity within the watershed consists of commercial forestry and recreational use. The road density in the watershed is 1.61 km/km² placing it in the 75th percentile of NCCN watersheds and the trail density is 0.22 km/km² placing it in the 60th percentile of NCCN watersheds (Rawhouser et al. 2012).

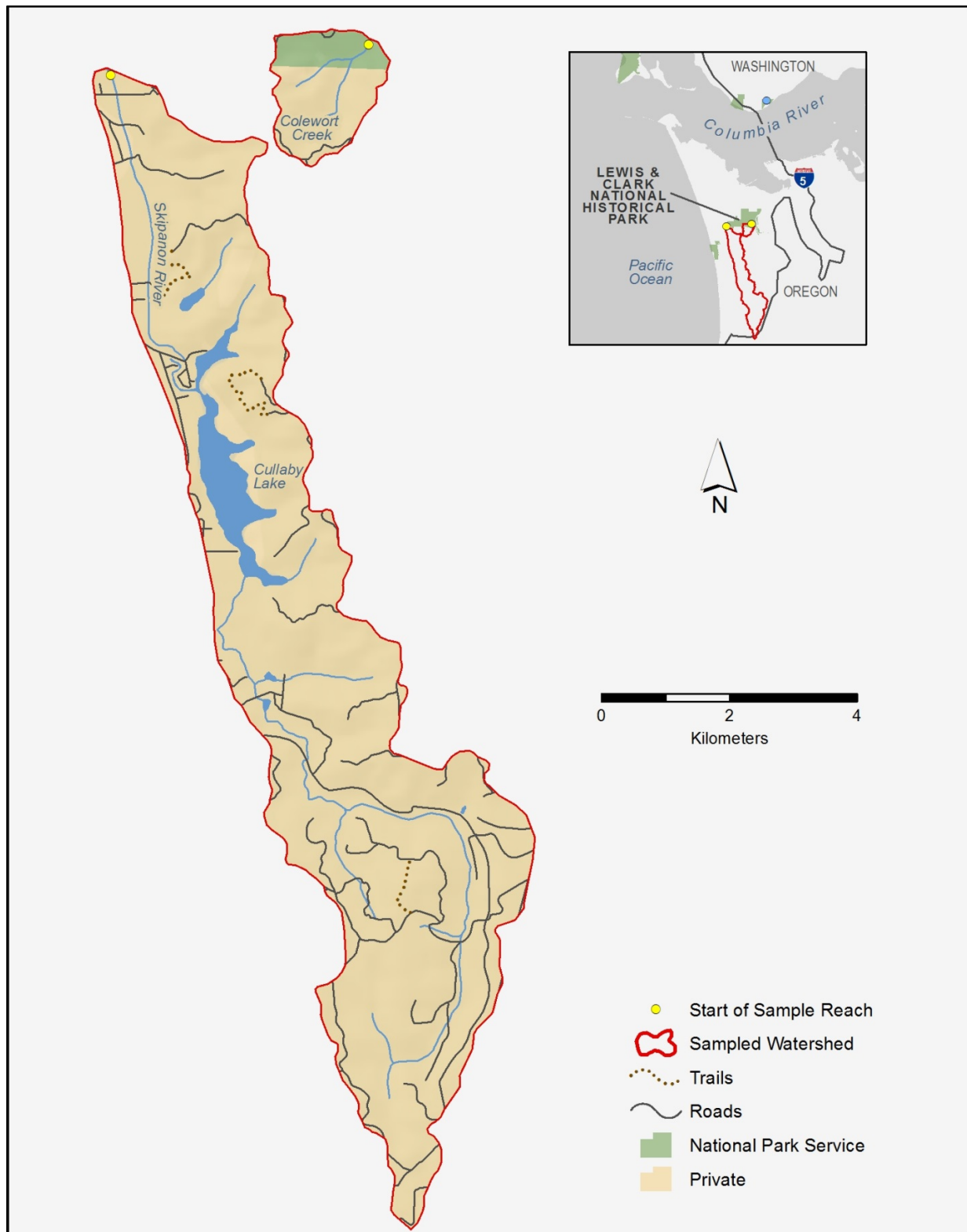


Figure 6. Colewort Creek and the Skipanon River water quality stream locations and delineated watersheds.

Biological Resources

Three species of fish, including one Federally Threatened species, have been documented in the sample reach in Colewort Creek. Sixteen additional species have been documented in other sections of Colewort Creek (Brenkman 2008, Schwartz 2013, Samora et al. 2015). Based on regional distribution data and habitat requirements, it is possible that this stream supports up to 23 different species of fish (Table 4) (Wydoski and Whitney 2003).

Five species of amphibians were documented in the Colewort Creek sample reach during an amphibian survey in 2005 (Table 5) (Samora et al. 2015). Other surveys have been conducted upstream and downstream from the sample reach, documenting six additional species in the Colewort Creek watershed (Table 5) (Samora et al. 2015, Galvan et al. 2005).

Table 4. Fish species documented and potentially present in Colewort Creek.

Common Name	Scientific Name	Documented in Sample Reach	Documented in Colewort Creek	Potentially Present	Native
American shad	<i>Alosa sapidissima</i>		X		No
Coastrange sculpin	<i>Cottus aleuticus</i>		X		
Prickly sculpin	<i>Cottus asper</i>			X	Yes
Riffle sculpin	<i>Cottus gulosus</i>		X		Yes
Reticulate sculpin	<i>Cottus perplexus</i>		X		Yes
Pacific staghorn sculpin	<i>Leptocottus armatus</i>		X		Yes
Unidentified Sculpin	<i>Cottus spp</i>	X			Yes
Shiner surfperch	<i>Cymatogaster aggregate</i>		X		Yes
Pumpkin seed sunfish	<i>Lepomis gibbosus</i>		X		No
Largemouth bass	<i>Micropterus salmoides</i>		X		No
Black crappie	<i>Pomoxis nigromaculatus</i>		X		No
Peamouth	<i>Mylocheilus caurinus</i>		X		Yes
Chiselmouth	<i>Acrocheilus alutaceus</i>			X	Yes
Banded killifish	<i>Fundulus diaphanous</i>		X		No
Threespine stickleback	<i>Gasterosteus aculeatus</i>	X			Yes
Longfin smelt	<i>Spirinchus thaleichthys</i>		X		Yes
Eulachon	<i>Thaleichthys pacificus</i>			X	Yes
Western brook lamprey	<i>Lampetra richardsoni</i>			X	Yes
Coastal cutthroat trout	<i>Oncorhynchus clarkii clarkii</i>		X		Yes
Chum salmon	<i>Oncorhynchus keta</i>		X		Yes
Coho salmon	<i>Oncorhynchus kisutch</i>	X			Yes
Rainbow trout/Steelhead	<i>Oncorhynchus mykiss</i>		X		Yes
Chinook salmon	<i>Oncorhynchus tshawytscha</i>		X		Yes

Table 5. Amphibian species documented in the Colewort Creek sample reach and watershed.

Common name	Species name	Documented in Sample Reach	Documented in Watershed
Northwestern salamander ¹	<i>Ambystoma gracile</i>	X	
Cope's giant salamander ²	<i>Dicamptodon copei</i>		X ³
Pacific giant salamander ²	<i>Dicamptodon tenebrosus</i>		X
Ensatina ¹	<i>Ensatina eschscholtzii</i>		X ³
Dunn's salamander ²	<i>Plethodon dunni</i>	X	
Western redback salamander ¹	<i>Plethodon vehiculum</i>		X ³
Pacific (Chorus) tree frog ¹	<i>Pseudacris regilla</i>		X ^{3,4}
Red-legged frog ¹	<i>Rana aurora</i>	X	
Bull frog ¹	<i>Rana catesbeiana</i>		X ⁴
Columbia torrent salamander ²	<i>Rhyacotriton kezeri</i>	X	
Rough-skinned newt ¹	<i>Taricha granulosa</i>	X	

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

³Species detected in downstream tributary.

⁴Species detected immediately below sample reach.

Stressors of Water Quality

High road density and related commercial forest management activities, combined to a lesser degree with trails and recreational use, are the primary sources of stress to aquatic resources within the Colewort Creek watershed. See comprehensive list below of stressors that may present a risk to water quality in the Colewort Creek watershed.

- Increased sediment deposition from mass failures.
- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Habitat fragmentation.
- Barriers to aquatic organism passage.
- Increased rate of non-native plant and animals invasions.
- Increased water temperature.
- Decreased dissolved oxygen.
- Runoff of applied herbicides and pesticides.

- Runoff of applied road chemicals.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).
- Increased nutrient delivery.
- Increased introduction of pathogens from animal and human waste.

Sample Reach Characterization

The sample reach in Colewort Creek starts approximately 700 m upstream from its confluence with the Lewis and Clark River and is 10 m above sea level. The sample reach is 150 m long and is a 2nd order stream (Strahler 1952), occupying a single channel located in an unconstrained broad valley (Table 6).

Table 6. Physical habitat characteristics measured in 2012 for the sample reach in Colewort Creek.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	–
Easting	431,761
Northing	5,108,414
Reach Length (m)	150
Average Wetted Width (m)	1.55
Minimum (m)	0.80
Maximum (m)	2.2
Average Bankfull Width (m)	2.25
Minimum (m)	1.85
Maximum (m)	3.00
Average Thalweg Depth (m)	0.10
Minimum (m)	0.05
Maximum (m)	0.20
Valley Width (m)	65.8
Channel Pattern	One channel
Channel Constraint	Broad valley and unconstrained
Constraining Feature	None
Contact with constraining feature	n/a
Torrent Evidence	No evidence of torrent scouring or torrent deposits.

Rapid Habitat Assessment scores for Colewort Creek indicated poor to moderate habitat quality (Table 7 and Figure 7). Though minimal channel alteration was present, channel sinuosity and pool variability were low, failing to provide diverse and stable habitat. Poor habitat quality was also indicated by the large amounts of sediment deposition present in the sample reach.

Table 7. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the sample reach in Colewort Creek. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	7
Pool Substrate Characterization	14
Pool Variability	4
Sediment Deposition	4
Channel Flow Status	18
Channel Alteration	16
Channel Sinuosity	8
Bank Stability	14
Vegetative Protection	20
Riparian Vegetated Zone Width	20



Figure 7. Looking upstream into the sample reach in Colewort Creek. Note: Two-meter stadia rod for scale.

Skipanon River

Watershed Description

The Skipanon River is located in the Oregon portion of LEWI. The Skipanon River is tidally-influenced and flows into Youngs Bay along the Columbia River (Figure 5). The Skipanon River watershed encompasses 19.1 km², ranges in elevation from 7 to 133 m, and has an average annual precipitation of 203 cm/year. Surface runoff of rain and groundwater inflow primarily feed the Skipanon River.

The only federal land within the Skipanon River watershed consists of a trail right-of-way that is approximately 200 m² and is where the stream location is located (Figure 6). Human activity within the watershed includes commercial forestry, agriculture, rural and urban development, and recreational use. These uses have resulted in the development of 43.8 km of roads, and 3.2 km of trails within the watershed. The road density in the watershed is 2.29 km/km² placing it in the 80th percentile of NCCN watersheds and the trail density is 0.17 km/km² placing it in the 50th percentile of NCCN watersheds (Rawhouser et al. 2012).

Biological Resources

The Skipanon River may contain up to a total of seventeen species of fish (Wydoski and Whitney 2003). However, the only fish documented in the sample reach are the threespine stickleback (*Gasterosteus aculeatus*) and an unidentified sculpin (Table 8) (Brenkman et al. 2008).

Eight species of amphibian are believed to occur in the Skipanon watershed (Table 9) (Leonard et al. 2003). However, only the rough skinned newt (*Taricha granulosa*) has been documented in the Skipanon River sample reach (Brenkman et al. 2008).

Table 8. Fish species documented and potentially present in the Skipanon River sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
White sturgeon	<i>Acipenser transmontanus</i>		X	Yes
American shad	<i>Alosa sapidissima</i>		X	No
Sculpin sp.	<i>Cottus sp.</i>	X		Yes
Prickly sculpin	<i>Cottus asper</i>		X	Yes
Riffle sculpin	<i>Cottus gulosus</i>		X	Yes
Reticulate Sculpin	<i>Cottus perplexus</i>		X	Yes
Pacific staghorn Sculpin	<i>Leptocottus armatus</i>		X	Yes
Chiselmouth	<i>Acrocheilus alutaceus</i>		X	Yes
Peamouth	<i>Mylocheilus caurinus</i>		X	Yes
Banded killifish	<i>Fundulus diaphanous</i>		X	No
Threespine stickleback	<i>Gasterosteus aculeatus</i>	X		Yes
Longfin smelt	<i>Spirinchus thaleichthys</i>		X	Yes

Table 8 (continued). Fish species documented and potentially present in the Skipanon River sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Eulachon	<i>Thaleichthys pacificus</i>		X	Yes
Western brook lamprey	<i>Lampetra richardsoni</i>		X	Yes
Coastal cutthroat trout	<i>Oncorhynchus clarkii clarkii</i>		X	Yes
Coho salmon	<i>Oncorhynchus kisutch</i>		X	Yes
Rainbow trout/Steelhead	<i>Oncorhynchus mykiss</i>		X	Yes
Chinook salmon	<i>Oncorhynchus tshawytscha</i>		X	Yes

Table 9. Amphibian species documented and potentially present in the Skipanon River sample reach and watershed.

Common name	Species name	Documented in Sample Reach	Potentially Present
Northwestern salamander ¹	<i>Ambystoma gracile</i>		X
Cope's giant salamander ²	<i>Dicamptodon copei</i>		X
Dunn's salamander ²	<i>Plethodon dunni</i>		X
Western red-backed salamander ¹	<i>Plethodon veniculus</i>		X
Pacific (Chorus) tree frog ¹	<i>Pseudacris regilla</i>		X
Red-legged frog ¹	<i>Rana aurora</i>		X
Bull frog ¹	<i>Rana catesbeiana</i>		X
Columbia torrent salamander ²	<i>Rhyacotriton kezeri</i>		X
Rough-skinned newt ¹	<i>Taricha granulosa</i>	X	

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

Elevated road densities, commercial forest management activities, agriculture, as well as rural and urban development within the watershed are the primary activities with the potential to impact water quality in the Skipanon River. While recreational use also has the potential to impact water quality, it is not believed to be a significant contributor given the magnitude of the previously mentioned sources of environmental stress. See comprehensive list below of stressors that may present a risk to water quality in the Skipanon River watershed.

- Increased sediment deposition from mass failures.
- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.

- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Habitat fragmentation.
- Barriers to aquatic organism passage.
- Increased rate of non-native plant and animal invasions.
- Increased water temperature.
- Decreased dissolved oxygen.
- Runoff of applied road chemicals and deicing compounds.
- Runoff of applied herbicides and pesticides.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).

Sample Reach Characterization

The Skipanon River at the sample reach is a 2nd order river (Strahler 1952) (Table 10). The sample reach is 103 m in length and occupies a single channel that is highly constrained by incision within the coastal plain (Figure 8). The length of the sample reach was restricted to less than the recommended 150 m minimum because of limited access (Rawhouser et al. 2012). The stream location is approximately 8.5 km from Youngs Bay, and it is unclear if there is any saltwater intrusion to the sample reach, but water level rises and falls dramatically in response to tidal fluctuations.

Table 10. Physical habitat characteristics measured in 2012 for the sample reach in the Skipanon River.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	–
Easting	428,900
Northing	5,108,113
Reach Length (m)	103
Average Wetted Width (m)	5.1
Minimum (m)	4.6
Maximum (m)	5.9
Average Bankfull Width (m)	6.5
Minimum (m)	5.6
Maximum (m)	8.2
Average Thalweg Depth (m)	0.58 ¹
Minimum (m)	0.53
Maximum (m)	0.79

Table 10 (continued). Physical habitat characteristics measured in 2012 for the sample reach in the Skipanon River.

Physical Habitat Characterization Parameters	Values
Valley Width (m)	281
Channel Pattern	One channel
Channel Constraint	Broad valley but constrained by incision
Constraining Feature	Human alteration
Contact with constraining feature.	100%
Torrent Evidence	Channel has little evidence of pool-riffle structure.

¹Depth measurements were taken during low tide.



Figure 8. Skipanon River, upstream from the stream location (which is also the foot bridge across the river).

The Rapid Habitat Assessment conducted for the Skipanon River in 2012 indicated that the sample reach was in marginal condition, chiefly due to channelization (Table 11). The banks were stable, but the dominance of non-native and invasive reed canary grass (*Phalaris arundinacea*) and Himalayan blackberry (*Rubus armeniacus*) provided for poor riparian zone cover and minimized the potential for large woody debris recruitment (Figure 8).

Table 11. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Skipanon River. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	7
Pool Substrate Characterization	12
Pool Variability	0
Sediment Deposition	19
Channel Flow Status	12
Channel Alteration	8
Channel Sinuosity	8
Bank Stability	12
Vegetative Protection	14
Riparian Vegetated Zone Width	0

Megler Creek

Watershed Description

Megler Creek is a small perennial stream that drains into the Columbia River and is located in the Washington portion of LEWI (Figure 5). The Megler Creek watershed encompasses 1.8 km² and ranges in elevation from 29 to 362 m. Average annual precipitation in the watershed is 256 cm/year. Surface runoff of rain and groundwater inflow primarily feed Megler Creek.

Roughly 20% of the Megler Creek watershed is managed by the NPS, and the remaining land is privately owned and managed for commercial forestry (Figure 9). The Megler Creek watershed contains 2.8 km of roads and has no trails. A road density of 1.54 km/km², places it in the 75th percentile of NCCN watersheds (Rawhouser et al. 2012).

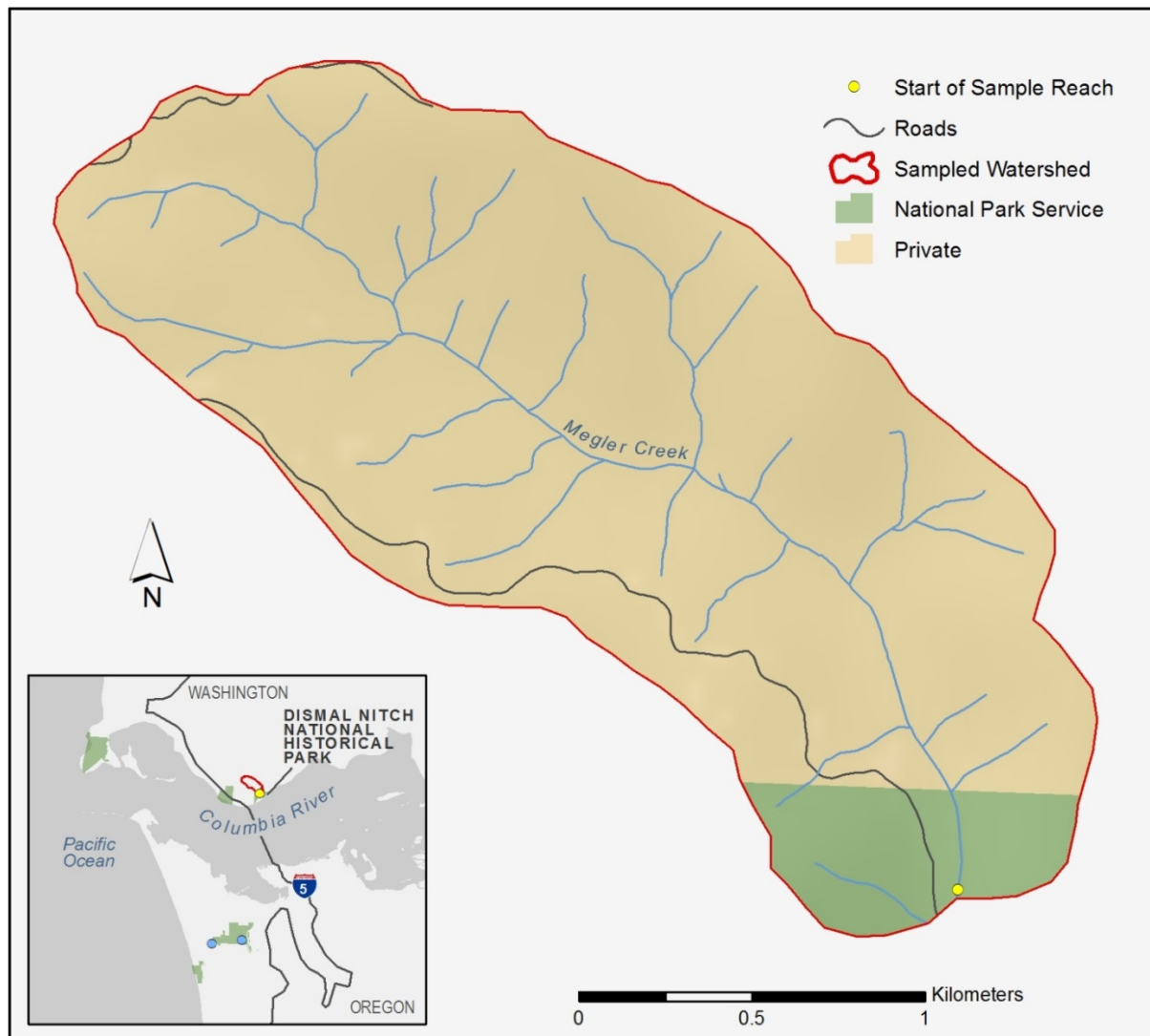


Figure 9. Megler Creek stream location and watershed.

Biological Resources

Four species of fish have been documented downstream from the sample reach in Megler Creek (Columbia River Estuary Study Taskforce, unpublished data), but none have been documented within the sample reach itself (Table 12). A perched 48" culvert routes Megler Creek under State Route 401 and has been evaluated as only 15% passable to salmonids (Chris Clatterbuck, Chief of Resource Management, Lewis and Clark National Historical Park, email communication 5/16/2014). All four species have been found above the culvert with densities been between 75 and 91% lower than densities below the culvert (Columbia River Estuary Study Taskforce, unpublished data). Based on regional distribution data and habitat requirements, this section of stream should support up to 12 species of fish (Table 12).

Table 12. Fish species potentially present in the Megler Creek sample reach and watershed.

Common Name	Scientific Name	Potentially Present	Native
American shad	<i>Alosa sapidissima</i>	X	No
Coastrange sculpin	<i>Cottus aleuticus</i>	X	Yes
Prickly sculpin	<i>Cottus asper</i>	X	Yes
Riffle sculpin	<i>Cottus gulosus</i>	X	Yes
Reticulate sculpin	<i>Cottus perplexus</i>	X	Yes
Pacific staghorn sculpin	<i>Leptocottus armatus</i>	X	Yes
Chiselmouth	<i>Acrocheilus alutaceus</i>	X	Yes
Peamouth	<i>Mylocheilus caurinus</i>	X	Yes
Threespine stickleback	<i>Gasterosteus aculeatus</i>	X	Yes
Eulachon	<i>Thaleichthys pacificus</i>	X	Yes
Western brook lamprey	<i>Lampetra richardsoni</i>	X	Yes
Coastal cutthroat trout	<i>Oncorhynchus clarkii clarkii</i>	X ¹	Yes
Chum salmon	<i>Oncorhynchus keta</i>	X ¹	Yes
Coho salmon	<i>Oncorhynchus kisutch</i>	X ¹	Yes
Rainbow trout/Steelhead	<i>Oncorhynchus mykiss</i>	X	Yes
Chinook salmon	<i>Oncorhynchus tshawytscha</i>	X ¹	Yes

¹Species documented in Megler Creek downstream from the sample reach.

Eight species of amphibians potentially occur in the area (Table 13) (Leonard et al. 2003, OSU), but no amphibians have been documented in the sample reach or the surrounding watershed.

Table 13. Amphibian species potentially present in the Megler Creek sample reach and watershed.

Common name	Species name	Potentially Present
Cope's giant salamander ¹	<i>Dicamptodon copei</i>	X
Dunn's salamander ¹	<i>Plethodon dunni</i>	X
Western red-backed salamander ²	<i>Plethodon veniculum</i>	X
Pacific (Chorus) tree frog ²	<i>Pseudacris regilla</i>	X
Red-legged frog ²	<i>Rana aurora</i>	X
Bull frog ²	<i>Rana catesbeiana</i>	X
Columbia torrent salamander ¹	<i>Rhyacotriton kezeri</i>	X
Rough-skinned newt ²	<i>Taricha granulosa</i>	X

¹Obligate stream dwelling species.

²Facultative stream dwelling species.

Stressors of Water Quality

Commercial forest management and associated access roads are the primary human activities within the Megler Creek watershed and have the greatest potential to impact water quality. See comprehensive list below of stressors that may present a risk to water quality in the Megler Creek watershed.

- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Habitat fragmentation.
- Barriers to aquatic organism passage.
- Increased rate of non-native plant and animals invasions.
- Increased water temperature.
- Decreased dissolved oxygen.
- Runoff of applied herbicides and pesticides.
- Runoff of applied road chemicals.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).
- Increased nutrient delivery.

Sample Reach Characterization

The Megler Creek sample reach is a total of 150 m long, beginning approximately 100 m upstream from the confluence with the Columbia River at 42 m above sea level. The sample reach is a 2nd order stream (Strahler 1952) occupying a single channel, which is minimally constrained within its floodplain by debris aprons (Table 14 and Figure 10).

Table 14. Physical habitat characteristics measured in 2012 for the sample reach in Megler Creek.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	–
Easting	433,434
Northing	5,122,375
Reach Length (m)	150
Average Wetted Width (m)	2.17
Minimum (m)	0.8
Maximum (m)	4.2
Average Bankfull Width (m)	5.0
Minimum (m)	4.4
Maximum (m)	6.2

Table 14 (continued). Physical habitat characteristics measured in 2012 for the sample reach in Megler Creek.

Physical Habitat Characterization Parameters	Values
Average Thalweg Depth (m)	0.11
Minimum (m)	0.04
Maximum (m)	0.25
Valley Width (m)	37
Channel Pattern	One Channel
Channel Constraint	Narrow valley but not very constrained
Constraining Feature	Hill slope
Contact with constraining feature.	0%
Torrent Evidence	• Substrate not imbricated and/or angular. • Channel has little evidence of pool-riffle structure.



Figure 10. Megler Creek, looking downstream from the reference point.

The Rapid Habitat Assessment conducted for Megler Creek in 2012 indicated that the sample reach was in sub-optimal condition due to the lack of in-stream cover and a low diversity of velocity and depth regimes (Table 15).

Table 15. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Megler Creek. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	10
Embeddedness	12
Velocity/Depth Regime	8
Sediment Deposition	14
Channel Flow Status	15
Channel Alteration	17
Frequency of Riffles or Bends	18
Bank Stability	20
Vegetative Protection	11
Riparian Vegetated Zone Width	20

Mount Rainier National Park

Seven locations are sampled in MORA as part of the NCCN Water Quality monitoring protocol (Figure 11). The Nisqually River is sampled in four locations; three separate sample reaches are in the main stem of the Nisqually River, and one sample reach is in the Paradise River, a tributary of the Nisqually River (Figure 12). In the Nisqually River, the lowest elevation stream location is Nisqually River at Park boundary (NIBO). Located at the National Park Service boundary, this stream location has the largest watershed, which contains the other three sample watersheds within its boundaries (Figure 12). The Nisqually River at Longmire (NILO) stream location is 26 km upstream of NIBO. The NILO watershed is the second largest of the Nisqually samples and contains both the Nisqually River at Glacier Bridge (NIGB) and the Paradise River sample watersheds. Similar in their nested nature, the NCCN also monitors two stream locations in the main stem of the White River. One of these locations is at the NPS boundary, or White River at NPS boundary (WIBO), and the other location is 10 km upstream in an area referred to by NPS staff as the “littorals”, or the White River at littorals (WILI) (Figure 11). The final MORA stream location is in the Ohanapecosh River and it is not associated with any of the other sample watersheds.

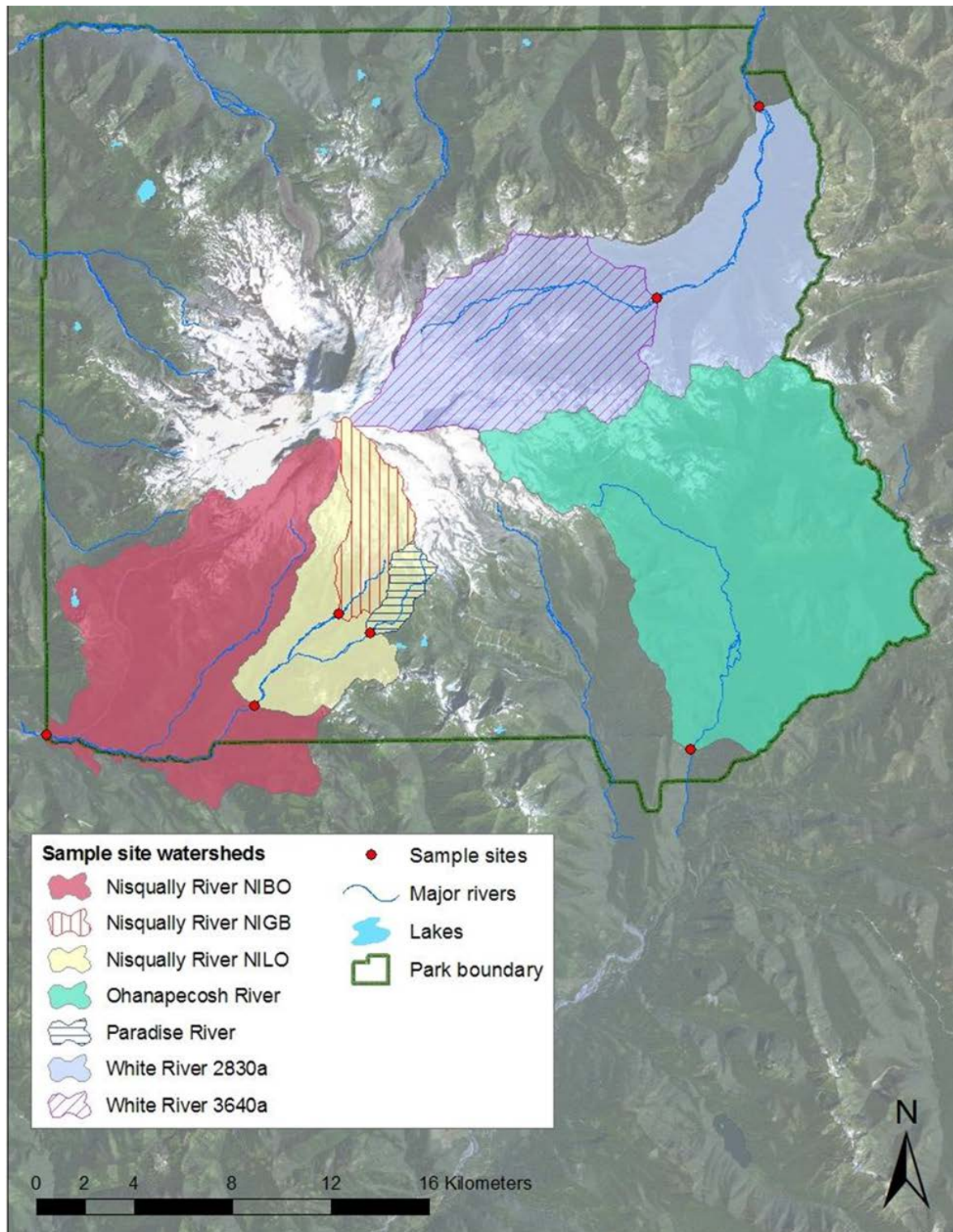


Figure 11. Map of the stream locations and associated watersheds for Mount Rainier National Park (NIBO is Nisqually River at Boundary location, NIGB is Nisqually River at Glacier Bridge location and NILO is Nisqually River at Longmire location).

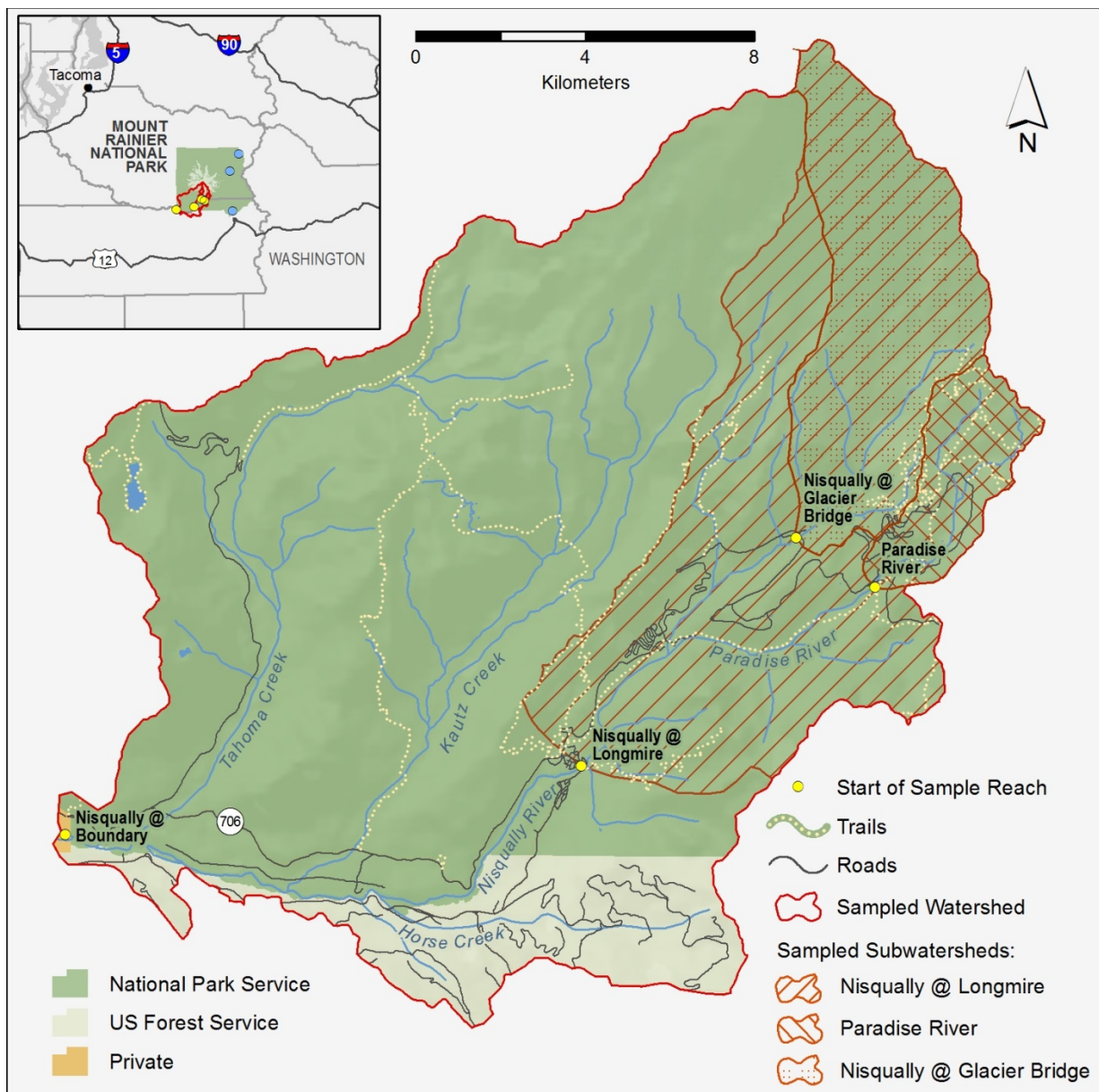


Figure 12. Nisqually River stream locations and watersheds, including: Nisqually River at Park boundary, Nisqually River at Longmire, Nisqually River at Glacier Bridge and the Paradise River.

The watersheds delineated above the NCCN Water Quality monitoring reaches are composed of three Level IV Ecoregions, consisting of the Western Cascades Lowlands and Valleys, Western Cascades Montane and Highlands, and the Cascade Subalpine/Alpine Ecoregions. Located at lower elevations, the Western Cascades Lowlands and Valleys Ecoregion are characterized by networks of steep ridges and narrow valleys that contain medium to high gradient rivers. The mild and wet climate here gives rise to lush forests dominated by western hemlock and Douglas-fir. Found at higher elevations with colder climatic conditions and more snow, the Western Cascades Montane Highlands Ecoregion shares the physiographic and vegetation characteristics of the Western Cascades Lowlands and Valleys Ecoregion. The highest elevation and coldest Ecoregion, the

Cascade Subalpine/Alpine Ecoregion, consists of subalpine meadows vegetated with herbaceous shrubs, mountain hemlock (*Tsuga mertensiana*), subalpine fir (*Abies lasiocarpa*), and whitebark pine (*Pinus albicaulis*) that are adapted to cold winter temperatures, a short growing season, and deep snow pack. Additionally, most of the higher Cascade Subalpine/Alpine Ecoregion is also covered with glaciers and permanent snow fields (Omernik 2010).

Nisqually River at Park Boundary

Watershed Description

The watershed delineated for NIBO encompasses 148.1 km² and ranges in elevation from 609 to 4,392 m at the summit of Mount Rainier. Average annual precipitation in the watershed is 258 cm/year. Surface runoff from snow pack and glacial melt and seven mountain lakes primarily feed NIBO. The watershed is composed of the Western Cascades Lowlands and Valleys, Western Cascades Montane and Highlands, and the Cascade Subalpine/Alpine Level IV Ecoregions.

Approximately 90% of the NIBO watershed is managed by the NPS. The remaining 10% is composed of land managed by the U.S. Forest Service (USFS) and small sections of private land adjacent to the sample reach (Figure 12). Human activity within the watershed consists of trails, roads, campgrounds, and NPS maintenance facilities such as a sewage treatment plant and water supply, storage areas, offices, visitor centers, and concessions. Additionally road operations that involve dumping plowed snow directly into the river also occur in the NIBO watershed. The watershed has 105.3 km of roads and 93.4 km of trails. Road and trail densities are 0.71 km/km² and 0.63 km/km², in the 70th and 90th percentiles of NCCN watersheds (Rawhouser et al. 2012). A popular area for recreation use, close to 200,000 vehicles passed through the Nisqually entrance station in 2013 (NPS 2014). Numerous recreational opportunities available in the Nisqually River area include: sightseeing, camping, day hiking, backpacking, and mountaineering, backcountry skiing, snowshoeing, sledding, and fishing.

Biological Resources

Fish, amphibians, and a rare insect of interest, are all found within the NIBO watershed. Three species of fish have been documented in the NIBO sample reach and based on species distributions and habitat requirements, four additional fish species are potentially present (Table 16) (Wydoski and Whitney 2003, Samora et al. 2013b, Barbara Samora, Biologist, Mount Rainier National Park, email communication, 02-15-201. Five species of amphibians have been documented in the NIBO sample reach (Table 17) (Tyler et al. 2003, Galvan et al. 2005, Samora and Anderson 2010, Samora et al. 2013a), and an additional six species are located within the greater NIBO watershed (Galvan et al. 2005 and Samora et al. 2013a). Cope's giant salamander (*Dicamptodon copei*) is an additional amphibian species which has not been detected in the NIBO sample reach but is potentially present based on presence nearby, regional distribution data, and habitat requirements (Leonard et al. 1993, WNHP WDFW BLM 2005, Samora et al. 2013a). Also present in the NIBO watershed is the Fender's soliperlan stonefly (*Soliperla fenderi*), a federal species of concern that is only found in two locations in Washington State (Kondratieff and Lechleitner 2002, WNHP WDFW 2014).

Table 16. Fish species documented and potentially present in the Nisqually River at Park boundary sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Shorthead sculpin	<i>Cottus confusus</i>	X		Yes
Torrent sculpin	<i>Cottus rhotheus</i>		X	Yes
Coastal cutthroat trout	<i>Oncorhynchus clarkii clarkii</i>	X		Yes
Rainbow trout/Steelhead	<i>Oncorhynchus mykiss</i>		X	Yes
Kokanee salmon	<i>Oncorhynchus nerka</i>		X	No
Mountain whitefish	<i>Prosopium williamsoni</i>		X	Yes
Brook trout	<i>Salvelinus fontinalis</i>	X		No

Table 17. Amphibian species documented and potentially present in the Nisqually River at Park boundary sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Documented in Watershed	Potentially Present
Northwestern salamander ¹	<i>Ambystoma gracile</i>		X	
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>		X	
Cope's giant salamander ²	<i>Dicamptodon copei</i>			X
Pacific/Coastal giant salamander ²	<i>Dicamptodon tenebrosus</i>		X	
Larch mountain salamander ¹	<i>Plethodon larselli</i>		X	
Van Dyke's salamander ¹	<i>Plethodon vandykei</i>	X		
Tailed frog ²	<i>Ascaphus truei</i>	X		
Western toad ¹	<i>Anaxyrus boreas</i>	X		
Cascade frog ²	<i>Rana cascadae</i>	X		
Pacific (Chorus) tree frog ¹	<i>Pseudacris regilla</i>		X	
Red-legged frog ¹	<i>Rana aurora</i>	X		
Rough-skinned newt ¹	<i>Taricha granulosa</i>		X	

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

According to park managers, water quality in the Nisqually River is potentially impacted by numerous sources that include roads, trails, NPS infrastructure, and recreational use (Barbara Samora, Biologist, Mount Rainier National Park, email communication, 02-15-2014). Specific examples include road maintenance such as winter road sanding, plowed snow being directly dumped into the Nisqually River; installation and maintenance of flood protection structures such as levees, log crib walls, rip rap revetments and rock barbs; water withdrawal from two mountain streams to supply the Longmire and Paradise facilities; channel dredging at Longmire and the Tahoma Creek Bridge; and the discharge of treated waste from the Paradise sewage treatment plant

in to the Nisqually River. See comprehensive list below of stressors that may present a risk to water quality in the Nisqually River at Park boundary watershed.

- Increased sediment deposition from mass failures.
- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Habitat fragmentation.
- Barriers to aquatic organism passage.
- Increased rate of non-native plant and animal invasions.
- Increased average and maximum water temperatures.
- Decreased minimum water temperatures.
- Decreased dissolved oxygen.
- Runoff of applied herbicides and pesticides.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use and snow dumping operations.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust) and from snow dumping operations.
- Increased nutrient delivery.
- Increased introduction of pathogens from animal and human waste.
- Introduction of chemicals from pharmaceutical waste.
- Increased amounts of organic matter.

Sample Reach Characterization

The NIBO sample reach is 500 m long and is a 4th order river (Strahler 1952) that occupies a braided channel in an unconstrained broad floodplain (Figure 13). Torrent evidence strongly suggests that both scouring and deposition occur in this reach (Table 18). Beason et al. (2014) determined average aggradation for the NIBO sample reach to range from -0.17 m/year in 2005 to 0.36 m/year in 2012. The high amounts of silt deposition, channel alteration, and low variety of velocity and depth regimes contributed to the sub-optimal habitat rating in the Rapid Habitat Assessment conducted for the NIBO sample reach in 2012 (Table 19).



Figure 13. Photograph of the Nisqually River at Park boundary sample reach illustrating the broad floodplain and braided channel characteristics. Note: Bank armoring/rip-rap in the foreground.

Table 18. Physical habitat characteristics measured in 2012 for the Nisqually River at Park boundary sample reach.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	
Easting	582,547
Northing	5,176,721
Reach Length(m)	500
Average Wetted Width (m)	40.4
Minimum (m)	25.5
Maximum(m)	56.5
Average Bankfull Width (m)	161*
Minimum (m)	—
Maximum (m)	—

Table 18 (continued). Physical habitat characteristics measured in 2012 for the Nisqually River at Park boundary sample reach.

Physical Habitat Characterization Parameters	Values
Average Thalweg Depth (m)	0.68
Minimum (m)	0.30
Maximum (m)	>1.0
Valley Width (m)	>700 ¹
Channel Pattern	Braided Chanel
Channel Constraint	Broad valley and unconstrained
Constraining Feature	Human alteration
Contact with constraining feature	2%
Torrent Evidence	• Recently de-vegetated area $\geq 2x$ wider than the wetted width. • Substrate not imbricated and/or angular. • Channel has little evidence of pool-riffle structure. • Channel scoured to bedrock. • Gravel and cobble berms above bankfull level. • Downstream contains large amounts of debris, logs a/or sediment. • Massive deposits of debris, logs and/or sediment w/in reach. • Stream eroding newly laid matrix supported deposits.

¹Bank full and valley widths were estimated.

Table 19. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Nisqually River at Park boundary sample reach. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter (Optimal – Poor)	Score
Epifaunal Substrate/Available Cover	18
Embeddedness	5
Velocity/Depth Regime	11
Sediment Deposition	1
Channel Flow Status	10
Channel Alteration	11
Frequency of Riffles (or bends)	16
Bank Stability	0
Vegetative Protection	0
Riparian Vegetated Zone Width	18

Nisqually River at Longmire

Watershed Description

The watershed above the NILO stream location encompasses 48.6 km² and ranges in elevation from 837 to 4,392 m at the summit of Mount Rainier. Average annual precipitation in the watershed is 277 cm/year. Surface runoff of snow pack and glacial melt and two mountain lakes primarily feed NILO. The watershed is composed of the Western Cascades Lowlands and Valleys, Western Cascades Montane and Highlands, and the Cascade Subalpine/Alpine Level IV Ecoregions.

The entire NILO watershed lies within the boundaries of MORA (Figure 12). The watershed contains 35.8 km of roads and 51.7 km of trails. Road and trail densities are 0.74 km/km² and 1.06 km/km² and are above the 70th and 90th percentiles for NCCN watersheds (Rawhouser et al. 2012). The NPS maintenance compound at Longmire is located on the banks of the Nisqually River within the floodplain (Figure 14). Common recreational activities include: sight-seeing, camping, day hiking, backpacking, and mountaineering, backcountry skiing, sledding, snowshoeing, and fishing.



Figure 14. Looking downstream into the sample reach in the Nisqually River at Longmire. The MORA service compound can be seen to the right in the photograph.

Biological Resources

The NILO sample reach supports an assemblage of fish and amphibians similar to the NIBO sample reach. Three species of fish have been documented in the NILO sample reach (Samora et al. 2013b, Barbara Samora, Biologist, Mount Rainier National Park, email communication, 02-15-2014) and, according to regional distribution and habitat requirements, three additional species may be present (Table 20) (Wydoski and Whitney 2003). Six amphibian species have been documented in the NILO sample reach, and an additional five have been documented within the watershed (Table 21) (Tyler et al. 2003, Galvan et al. 2005, Samora and Anderson 2010, Samora et al. 2013a).

Table 20. Fish species documented and potentially present in the Nisqually River at Longmire sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Shorthead sculpin	<i>Cottus confusus</i>	X		Yes
Coastal cutthroat trout	<i>Oncorhynchus clarkii clarkii</i>	X		Yes
Rainbow trout/Steelhead	<i>Oncorhynchus mykiss</i>		X	Yes
Kokanee salmon	<i>Oncorhynchus nerka</i>		X	No
Mountain whitefish	<i>Prosopium williamsoni</i>		X	Yes
Brook trout	<i>Salvelinus fontinalis</i>	X		No

Table 21. Amphibian species documented within the Nisqually River at Longmire sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Documented in Watershed
Northwestern salamander ¹	<i>Ambystoma gracile</i>		X
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>		X
Pacific/Coastal giant salamander ²	<i>Dicamptodon tenebrosus</i>		X
Larch mountain salamander ¹	<i>Plethodon larselli</i>		X
Van Dyke's salamander ¹	<i>Plethodon vandykei</i>	X	
Tailed frog ²	<i>Ascaphus truei</i>	X	
Western toad ¹	<i>Anaxyrus boreas</i>	X	
Cascade frog ²	<i>Rana cascadae</i>	X	
Pacific (Chorus) tree frog ¹	<i>Pseudacris regilla</i>	X	
Red-legged frog ¹	<i>Rana aurora</i>	X	
Rough-skinned newt ¹	<i>Taricha granulosa</i>		X

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

According to park managers, water quality in the Nisqually River is potentially impacted by numerous sources that include roads, trails, NPS infrastructure, and recreational use Barbara Samora,

Biologist, Mount Rainier National Park, email communication, 02-15-2014). The NPS compound at Longmire, which is adjacent to the sample reach and open to the public year round, consists of NPS administrative offices; NPS maintenance facilities such as auto and carpenter shops, fuel and hazardous waste storage areas, water treatment facilities, and sewage treatment plant; the Longmire Museum; the Wilderness Information Center; and the National Park Inn. Specific examples of impacts to water quality include water withdrawal from a mountain stream within the watershed to supply Longmire facilities, channel dredging in the Longmire sample reach to protect structures, and discharge of treated waste from the Paradise sewage treatment plant into the Nisqually River. See comprehensive list below of stressors that may present a risk to water quality in the Nisqually River at Longmire watershed.

- Increased sediment deposition from mass failures.
- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Habitat fragmentation.
- Barriers to aquatic organism passage.
- Increased rate of non-native plant and animal invasions.
- Increased average and maximum water temperatures.
- Decreased minimum water temperatures.
- Decreased dissolved oxygen.
- Runoff of applied road chemicals.
- Runoff of applied herbicides and pesticides.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use and from snow dumping operations.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust) and from snow dumping operations.
- Increased nutrient delivery.
- Increased introduction of pathogens from animal and human waste.
- Introduction of chemicals from pharmaceutical waste.
- Increased amounts of organic matter.

Sample Reach Characterization.

The NILO sample reach is 500 m long and starts at 837 m above sea level. The sample reach is located in the bottom of a classic U-shaped glacial valley in a narrow flood plain that is constrained by debris aprons. The sample reach is a 3rd order river (Strahler 1952) that occupies a braided channel, constrained by incision due to dredging (Figure 14). Torrent evidence strongly suggests that both scouring and deposition occur in this sample reach (Table 22). Average annual aggradation rates from 1997 to 2012 range from -0.00079 m/year to 0.14 m/year (Beason et al. 2014). The Rapid Habitat Assessment conducted for the NILO sample reach in 2012 indicated poor habitat quality (Table 23), primarily due to silt deposition and channel alteration that have decreased the diversity of velocity and depth regimes.

Table 22. Physical habitat characteristics measured in 2012 for the Nisqually River at Longmire sample reach.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	—
Easting	591,000
Northing	5,117,907
Reach Length(m)	500
Average Wetted Width (m)	19.9
Minimum(m)	7.4
Maximum (m)	34.9
Average Bankfull Width (m)	78
Minimum (m)	61
Maximum (m)	89
Average Thalweg Depth (m)	0.53
Minimum (m)	0.40
Maximum (m)	0.9
Valley Width (m)	1000 ¹
Channel Pattern	Braided channel
Channel Constraint	Broad valley and unconstrained
Constraining Feature	Human alteration
Contact with constraining feature	100%
Torrent Evidence	• Recently de-vegetated area ≥2x wider than the wetted width. • Substrate not imbricated and/or angular. • Channel has little evidence of pool-riffle structure. • Gravel and cobble berms above bankfull level. • Downstream contains large amounts of debris, logs a/or sediment. • Trees have fallen into channel due to scouring. • Massive deposits of debris, logs and/or sediment w/in reach. • Stream eroding newly laid matrix supported deposits.

¹Bankfull and valley widths were estimated as the distance you can see.

Table 23. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Nisqually River at Longmire reach. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	10
Embeddedness	6
Velocity/Depth Regime	5
Sediment Deposition	3
Channel Flow Status	7
Channel Alteration	0
Frequency of Riffles (or bends)	16
Bank Stability	0
Vegetative Protection	0
Riparian Vegetated Zone Width	0

Nisqually River at Glacier Bridge

Watershed Description

The watershed delineated for the NIGB sample reach encompasses 16.4 km² and ranges in elevation from 1,159 to 4,392 m at the summit of Mount Rainier. Average annual precipitation in the watershed is 309 cm/year. Surface runoff of snow pack and glacial melt primarily feed NIGB. The watershed is composed of the Western Cascades Montane and Highlands and Cascade Subalpine/Alpine Level IV Ecoregions.

The entire NIGB watershed lies within the boundaries of MORA and is managed by the NPS (Figure 12). Human activity within the watershed primarily consists of NPS infrastructure and recreational use. The watershed has 1.9 km of roads and 7.3 km of trails, with a road density of 0.11 km/km² and trail density of 0.45 km/km². These densities are above the 50th and 80th percentiles for NCCN watersheds (Rawhouser et al. 2012). Common recreational activities include: sight-seeing, camping, day hiking, backpacking, mountaineering, rock climbing, snowshoeing, sledding, and cross country skiing.

Biological Resources

Since there are no barriers to aquatic organism passage up to this point in the Nisqually River the NIGB sample reach supports an assemblage of fish and amphibians similar to the NIBO and NILO sample reaches. Documented taxa include two species of fish (Table 24) (Samora et al. 2013b, Barbara Samora, Biologist, Mount Rainier National Park, email communication, 02-15-2014) and two species of amphibians (Galvan et al. 2005, Samora et al. 2013a, Barbara Samora, Biologist, Mount Rainier National Park, email communication, 02-15-2014) have been documented in the NIGB sample reach. Three additional species of amphibians have been documented in the watershed, and four different species have the potential to be present within the sample reach and watershed (Table 25).

Table 24. Fish species documented and potentially present in the Nisqually River at Glacier Bridge sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Shorthead sculpin	<i>Cottus confusus</i>	X		Yes
Coastal cutthroat trout	<i>Oncorhynchus clarkii clarkii</i>	X		Yes
Westslope cutthroat trout	<i>Oncorhynchus clarkii lewisi</i>		X	No ¹

¹Species is native to the NCCN, but introduced to MORA.

Table 25. Species of amphibians documented and potentially present in the Nisqually River at Glacier Bridge sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Documented in Watershed	Potentially Present
Northwestern salamander ¹	<i>Ambystoma gracile</i>		X	
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>		X	
Van Dyke's salamander ¹	<i>Plethodon vandykei</i>		X	
Larch mountain salamander ¹	<i>Plethodon larselli</i>			X
Tailed frog ²	<i>Ascaphus truei</i>	X		
Cascades frog ²	<i>Rana cascadae</i>	X		
Western toad ¹	<i>Anaxyrus boreas</i>			X
Pacific (Chorus) tree frog ¹	<i>Pseudacris regilla</i>			X
Rough-skinned newt ¹	<i>Taricha granulosa</i>			X

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

According to park managers, water quality in the Nisqually River at the Glacier Bridge is potentially impacted by numerous sources that include roads, the Highway 706 crossing at Glacier Bridge, trails, NPS infrastructure, river bank protection structures, and recreational use (Barbara Samora, Biologist, Mount Rainier National Park, email communication, 02-15-2014). Specific examples include water withdrawal from a tributary to the Paradise River to supply the Paradise Visitor Complex, discharge of treated waste from the Paradise sewage treatment plant into the Nisqually River, storm water runoff from roads and bridges, and road maintenance practices that include disposing of fallen rock material into the Nisqually River. See comprehensive list below of stressors that may present a risk to water quality in the Nisqually River at Glacier Bridge watershed.

- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Increased rate of non-native plant and animal invasions.

- Increased average and maximum water temperatures.
- Decreased minimum water temperatures.
- Decreased dissolved oxygen.
- Runoff of applied road chemicals.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).
- Increased nutrient delivery.
- Increased introduction of pathogens from animal and human waste.
- Introduction of chemicals from pharmaceutical waste.
- Increased amounts of organic matter.

Sample Reach Characterization

The NIGB sample reach is 400 m long and starts at 1,158 m above sea level, extending up to 4392 m on the flanks of Mount Rainier. The sample reach is a 2nd order stream (Strahler 1952) that occupies a braided channel and is located in the bottom of a narrow valley, constrained by debris aprons. Torrent evidence strongly suggests that both scouring and deposition occur in this sample reach (Table 26, Figure 15). The Rapid Habitat Assessment conducted for the NIGB reach in 2012 indicated poor habitat conditions (Table 27). The substrate was highly affected by silt deposition and channel alteration, which has led to a low variety of velocity and depth regimes.

Table 26. Physical habitat characteristics measured in 2012 for the sample reach at Nisqually River at Glacier Bridge.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	—
Easting	594,426
Northing	5,181,640
Reach Length(m)	400
Average Wetted Width (m)	11.03
Minimum(m)	5.0
Maximum (m)	19.2
Average Bankfull Width (m)	105
Minimum (m)	89
Maximum (m)	116
Average Thalweg Depth (m)	0.95
Minimum (m)	0.50
Maximum (m)	2.0 ⁺
Valley Width (m)	183
Channel Pattern	Braided channel
Channel Constraint	Narrow valley but not very constrained
Constraining Feature	Hill slope

Table 26 (continued). Physical habitat characteristics measured in 2012 for the sample reach at Nisqually River at Glacier Bridge.

Physical Habitat Characterization Parameters	Values
Contact with constraining feature	5%
Torrent Evidence	• Recently de-vegetated area $\geq 2x$ wider than the wetted width. • Substrate not imbricated and/or angular. • Channel has little evidence of pool-riffle structure. • Channel scoured to bedrock. • Gravel and cobble berms above bankfull level. • Downstream contains large amounts of debris, logs a/or sediment. • Riparian trees scarred will above bankfull level. • Trees have fallen into channel due to scouring. • Massive deposits of debris, logs and/or sediment w/in reach. • Stream eroding newly laid matrix supported deposits.



Figure 15. The Nisqually River at Glacier Bridge sample reach braided within its floodplain and constrained by steep valley walls.

Table 27. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Nisqually River at Glacier Bridge reach. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	5
Embeddedness	0
Velocity/Depth Regime	2
Sediment Deposition	2
Channel Flow Status	6
Channel Alteration	20
Frequency of Riffles (or bends)	16
Bank Stability	0
Vegetative Protection	0
Riparian Vegetated Zone Width	18

Paradise River

Watershed Description

The Paradise River watershed encompasses 5.2 km² and ranges in elevation from 1,341 to 2,241 m. Average annual precipitation in the watershed is 311 cm/year. The Paradise River is primarily feed by surface runoff of snow pack and glacial melt. The watershed is composed of the Western Cascades Montane and Highlands and Cascade Subalpine/Alpine Level IV Ecoregions.

The entire Paradise River watershed lies within the boundaries of MORA and is managed by the NPS (Figure 12). Human activity within the watershed consists of 9.7 km of roads and 15.9 km of trails. The road and trail densities are 1.87 km/km² and 3.05 km/km², which are above the 90th and 80th percentiles for NCCN watersheds (Rawhouser et al. 2012). National Park Service infrastructure and recreational use are also prevalent human activities within the watershed. Common recreational activities include camping, day hiking, backpacking, backcountry skiing, and snowshoeing.

Biological Resources

A 57 m high waterfall lies just below the start of the Paradise sample reach and blocks all fish passage. Below these falls four species of fish have been documented Samora et al. 2013b, Barbara Samora, Biologist, Mount Rainier National Park, email communication, 02-15-2014), and two additional species have the potential to be present (Table 28) (Wydoski and Whitney 2003). Five amphibian species have been documented in the Paradise River sample reach (Samora et al. 2013a, Barbara Samora, Biologist, Mount Rainier National Park, email communication, 02-15-2014), and an additional four species have the potential to be present (Table 29) (Leonard et al. 1993, WNHP WDFD BLM 2005).

Table 28. Fish species documented and potentially present in the Paradise River sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Shorthead sculpin	<i>Cottus confusus</i>	X		Yes
Coastal cutthroat trout	<i>Oncorhynchus clarkii clarkii</i>	X		Yes
Westslope cutthroat trout	<i>Oncorhynchus clarkii lewisi</i>		X	No ¹
Rainbow trout	<i>Oncorhynchus mykiss</i>	X ²		Yes
Mountain whitefish	<i>Prosopium williamsoni</i>		X	Yes
Brook trout	<i>Salvelinus fontinalis</i>	X		No

¹Species is native to the NCCN, but introduced to MORA.

²Rainbow trout and Coastal Cutthroat hybrids exist in this reach.

Table 29. Species of amphibians documented and potentially present in the Paradise River sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present
Northwestern salamander ¹	<i>Ambystoma gracile</i>	X	
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>	X	
Van Dyke's salamander ¹	<i>Plethodon vandykei</i>		X
Pacific/Coastal giant salamander ²	<i>Dicamptodon tenebrosus</i>	X	
Western toad ¹	<i>Anaxyrus boreas</i>		X
Tailed frog ²	<i>Ascaphus truei</i>	X	
Cascade frog ²	<i>Rana cascadea</i>	X	
Pacific (Chorus) tree frog ¹	<i>Pseudacris regilla</i>		X
Rough-skinned newt ¹	<i>Taricha granulosa</i>		X

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

According to park managers, water quality in the Paradise River is potentially impacted by numerous sources that include roads, trails, NPS infrastructure, and recreational use (Barbara Samora, Biologist, Mount Rainier National Park, email communication, 02-15-2014). The network of roads within the Paradise River watershed ends at Paradise, which is one of the most popular visitor destinations in MORA. The visitor complex at Paradise is composed of: the Jackson Visitor Center; the Paradise Inn; the Guide House; the Paradise Ranger Station; a network of paved access roads, paved trails and large paved areas for parking; and a water supply dam on Edith creek which requires occasional sediment excavation to maintain. Also within the watershed, the Narada Falls area has storage sheds used for road maintenance equipment and materials. See comprehensive list below of stressors that may present a risk to water quality in the Paradise River watershed.

- Increased sediment deposition from mass failures.
- Increased fine sediment deposition from surface runoff.

- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Habitat fragmentation.
- Barriers to aquatic organism passage.
- Increased rate of non-native plant and animal invasions.
- Increased average and maximum water temperatures.
- Decreased minimum water temperatures.

Sample Reach Characterization

The Paradise River sample reach is 150 m long and starts at 1,354 m above sea level, extending up to 2,241 m in elevation. The sample reach is a single channel 2nd order stream (Strahler 1952), located in the bottom of a narrow valley, and constrained by bedrock and boulder walls and debris aprons (Table 30, Figure 16). The Rapid Habitat Assessment conducted for the Paradise River in 2012 indicated that the sample reach was in optimal condition (Table 31).

Table 30. Physical habitat characteristics measured in 2012 for the Paradise River sample reach.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	—
Easting	595,716
Northing	5,180,958
Reach Length(m)	150
Average Wetted Width (m)	5.47
Minimum(m)	3.0
Maximum (m)	9.8
Average Bankfull Width (m)	8.4
Minimum (m)	7.0
Maximum (m)	9.1
Average Thalweg Depth (m)	0.48
Minimum (m)	0.1
Maximum (m)	2.0 ¹
Valley Width (m)	20
Channel Pattern	One channel
Channel Constraint	Very constrained in V-shaped valley

Table 30 (continued). Physical habitat characteristics measured in 2012 for the Paradise River sample reach.

Physical Habitat Characterization Parameters	Values
Constraining Feature	Bedrock
Contact with constraining feature	90%
Torrent Evidence	• Substrate not imbricated and/or angular. • Channel scoured to bedrock.

¹Maximum thalweg depth is likely deeper, but was estimated for this site.



Figure 16. Looking upstream into the Paradise River sample reach.

Table 31. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Paradise River. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	11
Embeddedness	18
Velocity/Depth Regime	20
Sediment Deposition	20
Channel Flow Status	19
Channel Alteration	20
Frequency of Riffles (or bends)	20
Bank Stability	20
Vegetative Protection	20
Riparian Vegetated Zone Width	16

Ohanapecosh River

Watershed Description

The Ohanapecosh River watershed encompasses 164.1 km² and ranges in elevation from 533 to 2,821 m. Average annual precipitation in the watershed is 199 cm/year. Snow pack combined with glacial melt, ground water, and approximately 15 mountain lakes are the primary water sources for the Ohanapecosh River sample reach. The watershed is composed of the Western Cascades Lowlands and Valleys, Western Cascades Montane and Highlands, and Cascade Subalpine/Alpine Level IV Ecoregions.

The entire watershed lies within the boundaries of MORA and is managed by the NPS (Figure 17). Human activity within the watershed consists of roads, trails, a campground, and other NPS infrastructure and recreational use. The watershed contains 37.7 km of roads and 79.3 km of trails. The road and trail densities are 0.23 km/km² and 0.48km/km² and are above the 80th and 50th percentiles for NCCN watersheds (Rawhouser et al. 2012). Common recreational activities include camping, day hiking, backpacking, limited stock use, backcountry skiing, and fishing.

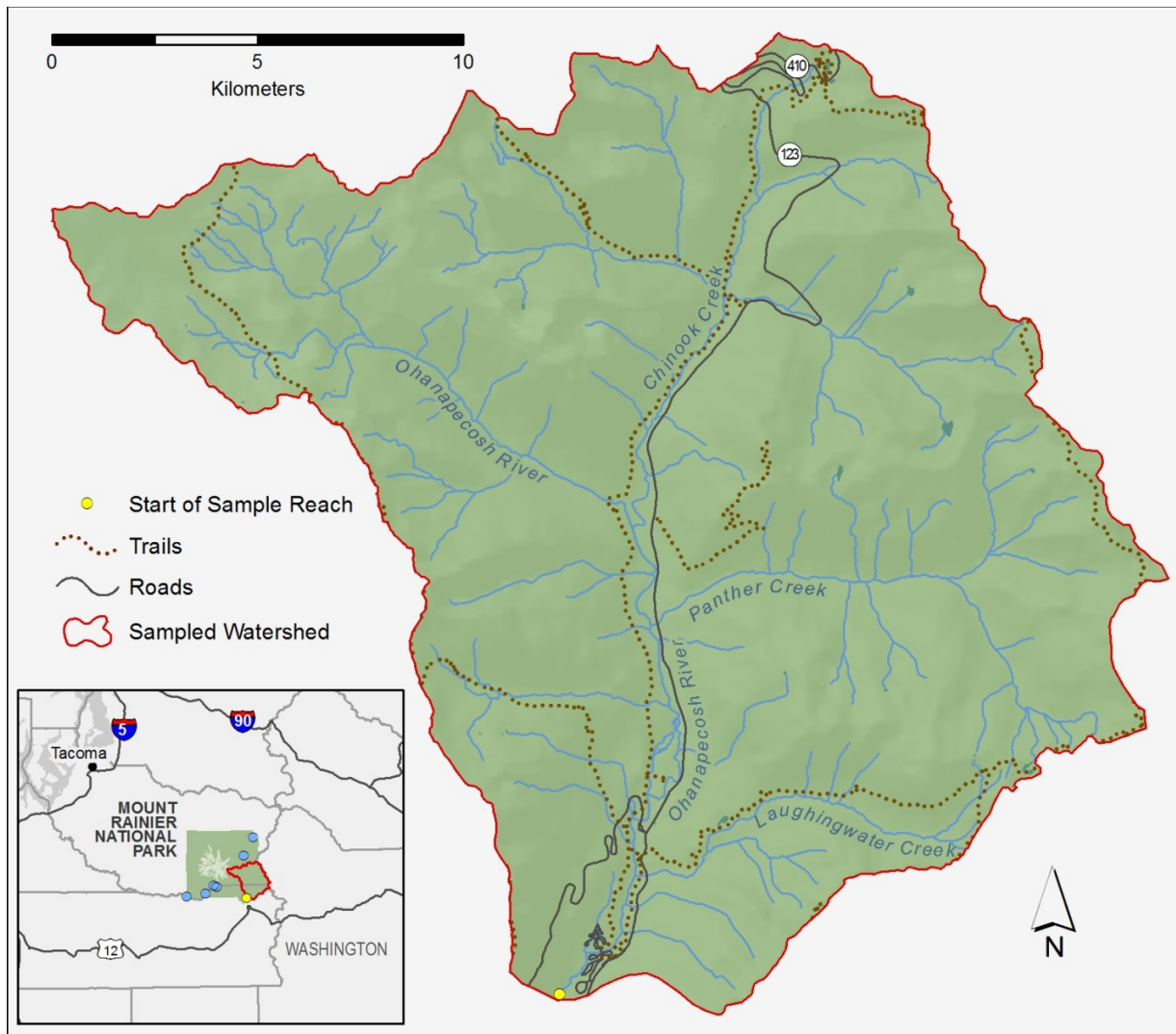


Figure 17. The Ohanapecosh River stream location and watershed.

Biological Resources

Two species of fish have been documented (Samora et al 2013b), and, another five species may be present but have not been documented (Table 32) (Wydoski and Whitney 2003). Six different species of amphibians have been documented in the Ohanapecosh River sample reach, and an additional five have been documented in the watershed (Table 33) (Galvan et al. 2005, Samora et al. 2013a, Barbara Samora, Biologist, Mount Rainier National Park, email communication, 02-15-2014).

Table 32. Fish species documented and potentially present in the Ohanapecosh River sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Coastal cutthroat trout	<i>Oncorhynchus clarkii clarkii</i>	X		
Yellowstone cutthroat trout	<i>Oncorhynchus clarkii bouvieri</i>		X	No
Westslope cutthroat trout	<i>Oncorhynchus clarkii lewisi</i>		X	No ¹
Rainbow trout	<i>Oncorhynchus mykiss</i>		X	Yes
Mountain whitefish	<i>Prosopium williamsoni</i>		X	Yes
Bull trout	<i>Salvelinus confluentus</i>		X	Yes
Brook trout	<i>Salvelinus fontinalis</i>	X		No

¹Species is native to the NCCN, but introduced to MORA

Table 33. Amphibian species documented and potentially present in the Ohanapecosh River sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Documented in Watershed
Northwestern salamander ¹	<i>Ambystoma gracile</i>	X	
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>		X
Pacific/Coastal giant salamander ²	<i>Dicamptodon tenebrosus</i>	X	
Larch mountain salamander ¹	<i>Plethadon larselli</i>	X	
Van Dyke's salamander ¹	<i>Plethadon vandykei</i>	X	
Tailed frog ²	<i>Ascaphus truei</i>	X	
Western toad	<i>Anaxyrus boreas</i>	X	
Pacific (Chorus) tree frog ¹	<i>Pseudacris regilla</i>		X
Cascade frog ²	<i>Rana cascadea</i>		X
Red-legged frog ¹	<i>Rana aurora</i>		X
Rough-skinned newt ¹	<i>Taricha granulosa</i>		X

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

Water quality in the OHCA watershed is potentially impacted by numerous sources related to NPS infrastructure, roads and trails, and visitor use (Figure 17). Specific examples include the Ohanapecosh Visitor Center and campground, ranger and maintenance stations, paved access roads, paved areas for parking, waste treatment facilities, and water withdrawal from Laughingwater Creek and an unnamed creek in the watershed to supply the Ohanapecosh complex and Grove of the patriarchs, respectively. See comprehensive list below of stressors that may present a risk to water quality in the Ohanapecosh River watershed.

- Increased sediment deposition from mass failures.
- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.

- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Habitat fragmentation.
- Barriers to aquatic organism passage.
- Increased rate of non-native plant and animal invasions.
- Increased average and maximum water temperatures.
- Decreased minimum water temperatures.
- Decreased dissolved oxygen.
- Runoff of applied road chemicals and potential deicing compounds.
- Runoff of applied herbicides and pesticides.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).
- Increased nutrient delivery.
- Increased introduction of pathogens from animal and human waste.
- Introduction of chemicals from pharmaceutical waste.
- Increased amounts of organic matter.

Sample Reach Characterization

The Ohanapecosh River sample reach is 500 m long and starts at 583 m above sea level. The sample reach is located in the bottom of a narrow valley in a river canyon. The sample reach is a 5th order stream (Strahler 1952) that occupies one channel and is constrained by bedrock and boulders (Table 34, Figure 18). The Rapid Habitat Assessment conducted for the Ohanapecosh River in 2012 indicated that the sample reach was in optimal condition (Table 35).

Table 34. Physical habitat characteristics measured in 2012 for the sample reach in the Ohanapecosh River.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	–
Easting	609,110
Northing	5,176, 549
Reach Length (m)	500
Average Wetted Width (m)	14.8
Minimum (m)	10.9

Table 34 (continued). Physical habitat characteristics measured in 2012 for the sample reach in the Ohanapecosh River.

Physical Habitat Characterization Parameters	Values
Maximum (m)	21.0
Average Bankfull Width (m)	23.4
Minimum (m)	19.7
Maximum (m)	28.9
Average Thalweg Depth (m)	0.89
Minimum (m)	0.5
Maximum (m)	>2.0
Valley Width (m)	30
Channel Pattern	One channel
Channel Constraint	Very constrained in V-shaped valley
Constraining Feature	Bedrock
Contact with constraining feature	50%
Torrent Evidence	Downstream contains large amounts of debris, logs and or sediment.



Figure 18. Bedrock and boulder constraints are evident, looking downstream to the start of the Ohanapecosh sample reach.

Table 35. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Ohanapecosh River. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	19
Embeddedness	19
Velocity/Depth Regime	18
Sediment Deposition	18
Channel Flow Status	17
Channel Alteration	19
Frequency of Riffles (or bends)	17
Bank Stability	17
Vegetative Protection	16
Riparian Vegetated Zone Width	18

White River at the National Park Service Boundary

Watershed Description

The watershed delineated for WIBO is 127 km² and ranges in elevation from 860 to 4,330 m at the summit of Mount Rainier. Average annual precipitation in the WIBO watershed is 221 cm/year and the White River is primarily feed by runoff from snow pack and glacial melt and approximately 13 mountain lakes.

The entire watershed lies within the boundaries of MORA and is managed by the NPS (Figure 19). Human activity within the watershed consists of roads, trails, NPS infrastructure, and recreational use. The watershed contains 42.3 km of roads and 66.4 km of trails. The road and trail densities are 0.33 km/km² and 0.52 km/km² and are above the 90th and 60th percentiles for NCCN watersheds (Rawhouser et al. 2012). Common recreational activities include camping, day hiking, backpacking, snowshoeing, backcountry skiing, and snowmobile use along State Highway 410 in the winter.

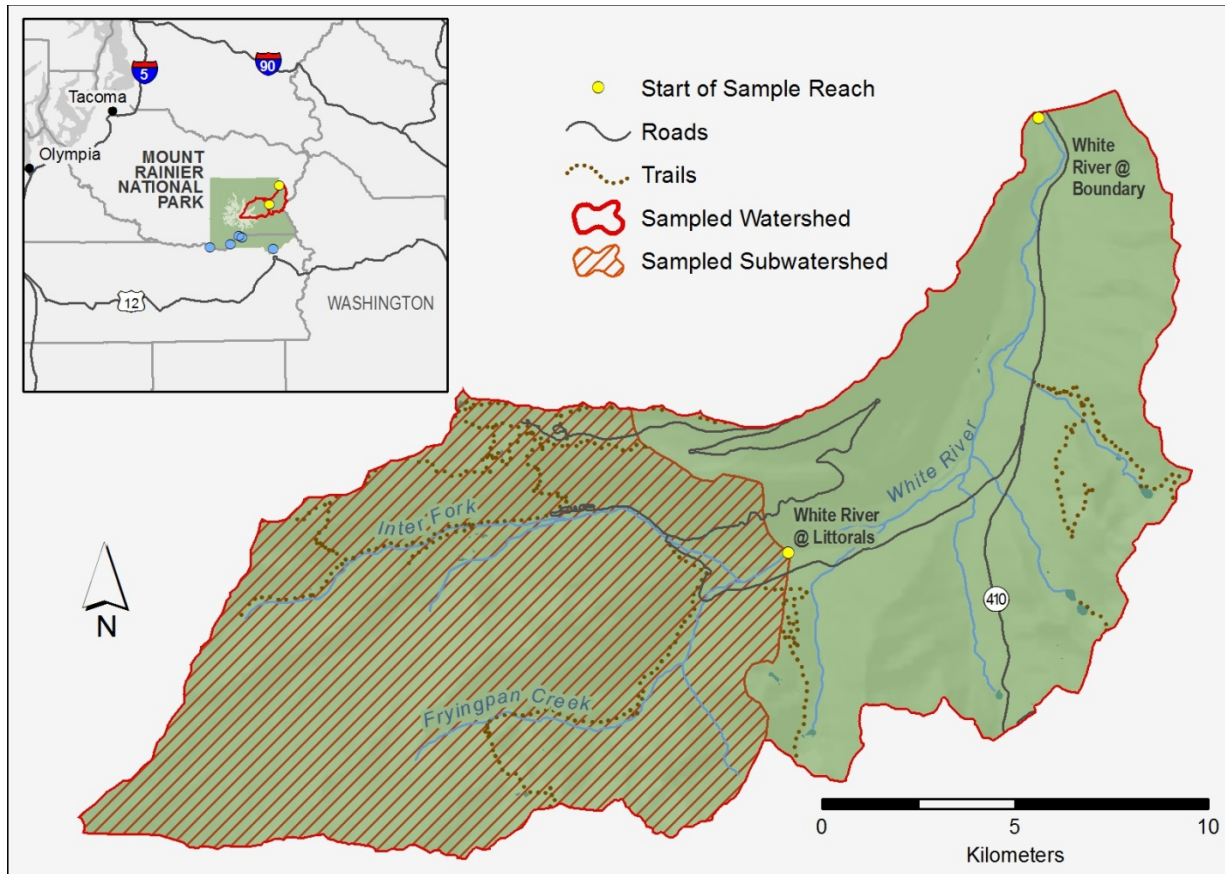


Figure 19. The White River stream locations and watersheds: White River at Park boundary and White River at littorals.

Biological Resources

Eight species of fish have been documented in the White River at Park boundary sample reach (Samora et al 2013b), and another three species may be present but have not been documented (Table 36) (Wydoski and Whitney 2003). Seven different species of amphibians have been documented in the sample reach, and an additional two have been documented in the watershed (Table 37) (Galvan et al. 2005, Samora et al. 2013a, Barbara Samora, Biologist, Mount Rainier National Park, email communication, 02-15-2014).

Table 36. Fish species documented and potentially present in the White River at Park boundary sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Shorthead sculpin	<i>Cottus confusus</i>	X		Yes
Torrent sculpin	<i>Cottus rhotheus</i>		X	Yes
Coastal cutthroat trout	<i>Oncorhynchus clarkii clarkii</i>	X		
Pink salmon	<i>Oncorhynchus gorbuscha</i>	X		
Coho salmon	<i>Oncorhynchus kisutch</i>	X		Yes

Table 36 (continued). Fish species documented and potentially present in the White River at Park boundary sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Rainbow trout/Steelhead	<i>Oncorhynchus mykiss</i>	X		Yes
Sockeye salmon	<i>Oncorhynchus nerka</i>	X		Yes
Chinook salmon	<i>Oncorhynchus tshawytscha</i>	X		Yes
Mountain whitefish	<i>Prosopium williamsoni</i>		X	Yes
Bull trout	<i>Salvelinus confluentus</i>	X		Yes
Brook trout	<i>Salvelinus fontinalis</i>		X	No

Table 37. Amphibian species documented and potentially present in the White River at Park boundary sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Documented in Watershed
Northwestern salamander ¹	<i>Ambystoma gracile</i>	X	
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>		X
Pacific/Coastal giant salamander ²	<i>Dicamptodon tenebrosus</i>	X	
Van Dyke's salamander ¹	<i>Plethodon vandykei</i>	X	
Tailed frog ²	<i>Ascaphus truei</i>	X	
Western toad ¹	<i>Anaxyrus boreas</i>	X	
Cascade frog ¹	<i>Rana cascadea</i>	X	
Pacific (Chorus) tree frog ¹	<i>Pseudacris regilla</i>		X
Rough-skinned newt ¹	<i>Taricha granulosa</i>	X	

¹Facultative stream dwelling species

²Obligate stream dwelling species.

Stressors of Water Quality

Water quality in the WIBO sample reach is potentially impacted by numerous sources related to roads, trails, NPS infrastructure, and recreational use. A network of roads within the watershed leads to the Sunrise recreation site. The Sunrise recreation site is composed of the Sunrise Visitor Center, the Sunrise Day Lodge, and a network of paved access roads large parking areas. Within the watershed, water is withdrawn from Klickitat Creek, and two unnamed creeks (w19-00b, w19-00a), to supply the White River entrance facilities and housing complex, the Sunrise visitor complex, and the White River Campground. Additionally, the Washington Department of Transportation waste transfer facilities at the White River 'littorals' site poses a moderate hazard due to water flowing through materials stored on-site for road and facility maintenance. Lastly, within the watershed, there are multiple areas along the road network that require flood protection structures. Rip rap revetments, rock barbs, levees and road-stream crossings require frequent maintenance and stream disturbance, and many are not designed for aquatic biological connectivity. See comprehensive list below of stressors that may present a risk to water quality in the White River at Park boundary watershed.

- Increased sediment deposition from mass failures.
- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Habitat fragmentation.
- Barriers to aquatic organism passage.
- Increased rate of non-native plant and animal invasions.
- Increased average and maximum water temperatures.
- Decreased minimum water temperatures.
- Decreased dissolved oxygen.
- Runoff of applied road chemicals and potential deicing compounds.
- Runoff of applied herbicides and pesticides.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).
- Increased nutrient delivery.
- Increased introduction of pathogens from animal and human waste.
- Introduction of chemicals from pharmaceutical waste.
- Increased amounts of organic matter.

Sample Reach Characterization

The WIBO sample reach is 500 m long and starts at 863 m above sea level. The sample reach is a 4th order river (Strahler 1952) and occupies an unconstrained braided channel in the bottom of a broad valley. Torrent evidence suggests that both scouring and deposition occur in this sample reach (Table 38, Figure 20). The Rapid Habitat Assessment conducted for the sample reach in 2012 indicated that the substrate was highly affected by silt depositions and a low variety of velocity and depth regimes, suggesting sub-optimal habitat quality (Table 39).

Table 38. Physical habitat characteristics measured in 2012 for the sample reach in the White River at Park boundary.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	–
Easting	611,813
Northing	5,202,230
Reach Length (m)	500
Average Wetted Width (m)	13.6
Minimum (m)	8.2
Maximum (m)	17.6
Average Bankfull Width (m)	90
Minimum (m)	69
Maximum (m)	106
Average Thalweg Depth (m)	0.61
Minimum (m)	0.45
Maximum (m)	1.30
Valley Width (m)	700 ¹
Channel Pattern	Braided channel
Channel Constraint	Broad valley and unconstrained
Constraining Feature	Human alteration (rip/rap)
Contact with constraining feature	>5%
Torrent Evidence	• Recently de-vegetated area (less than or equal to) 2x wider than the wetted width. • Substrate not imbricated and/or angular. • Channel has little evidence of pool-riffle structure. • Downstream contains large amounts of debris, logs and/or sediment. • Trees have fallen into channel due to scouring. • Massive deposits of debris, logs and/or sediment within reach.

¹Valley widths were estimated as the distance you can see.

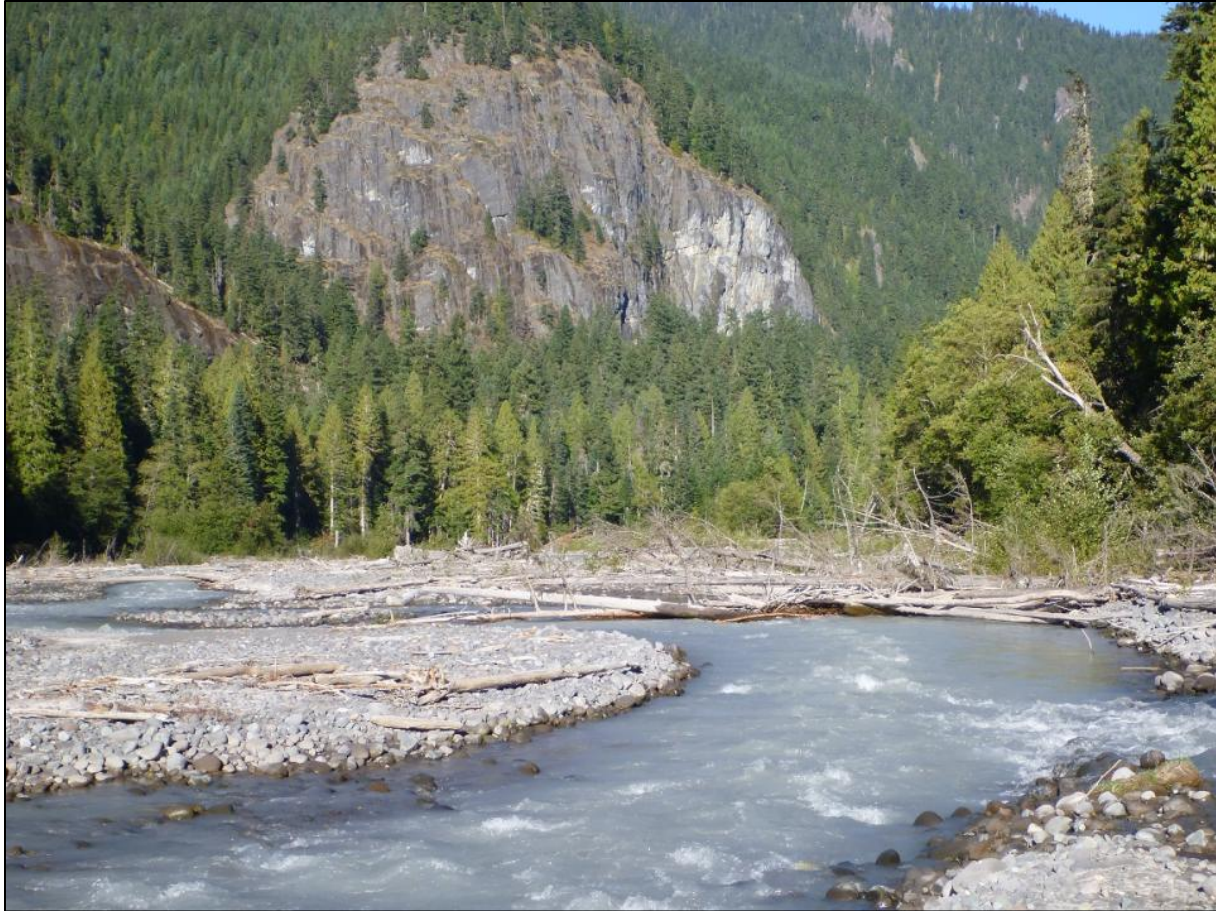


Figure 20. The White River at Park boundary sample reach, showing a braided channel within its floodplain.

Table 39. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the White River at Park boundary sample reach. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	16
Embeddedness	2
Velocity/Depth Regime	7
Sediment Deposition	8
Channel Flow Status	7
Channel Alteration	16
Frequency of Riffles (or bends)	12
Bank Stability	16
Vegetative Protection	18
Riparian Vegetated Zone Width	14

White River at Littorals

Watershed Description

Higher in elevation than the WIBO sample reach, WILI sample reach is the second location in the main stem of the White River. It encompasses 68.4 km² and ranges in elevation from 1,101 to 4,330 m at the summit of Mount Rainier. Average annual precipitation in the watershed is 253 cm/year and the river is primarily feed by the runoff from melting snow pack and glaciers and approximately five mountain lakes. The watershed is composed of Western Cascades Montane and Highlands and Cascade Subalpine/Alpine Ecoregions.

The entire White River at littoral watershed lies within the boundaries of MORA and is managed by the NPS (Figure 19). Human activity within the watershed primarily consists of NPS infrastructure, roads and trails. The watershed contains 12.1 km of roads and 45.3 km of trails and. The road and trail densities of 0.18 km/km² and 0.66 km/km² are above the 50th and 90th percentiles for NCCN watershed (Rawhouser et al. 2012). Common recreational activities include camping, day hiking, backpacking, mountaineering, snowshoeing, and backcountry skiing.

Biological Resources

Much like the White River at Park boundary sample reach, many species of fish and amphibians are found in the White River at littorals sample reach. Five species of fish have been documented in the White River at littorals sample reach (Samora et al 2013b), and based on regional distribution data and habitat requirements, another five species may be present but have not been documented (Table 40) (Wydoski and Whitney 2003). Five species of amphibians have been documented in the in the White River at littorals sample reach, and an additional two have been documented in the watershed (Table 41) (Galvan et al. 2005, Samora et al. 2013a, Barbara Samora, Biologist, Mount Rainier National Park, email communication, 02-15-2014).

Table 40. Fish species documented and potentially present in the White River at littorals sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Shorthead sculpin	<i>Cottus confusus</i>	X		
Torrent sculpin	<i>Cottus rhotheus</i>	X		
Coastal cutthroat trout	<i>Oncorhynchus clarkii clarkii</i>	X		
Coho salmon	<i>Oncorhynchus kisutch</i>		X	Yes
Rainbow trout/Steelhead	<i>Oncorhynchus mykiss</i>		X	Yes
Sockeye salmon	<i>Oncorhynchus nerka</i>	X		Yes
Chinook salmon	<i>Oncorhynchus tshawytscha</i>		X	Yes
Mountain whitefish	<i>Prosopium williamsoni</i>		X	Yes
Bull trout	<i>Salvelinus confluentus</i>	X		Yes
Brook trout	<i>Salvelinus fontinalis</i>		X	No

Table 41. Amphibian species documented and potentially present in the White River at littorals sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Documented in Watershed	Potentially Present
Northwestern salamander ¹	<i>Ambystoma gracile</i>	X		
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>		X	
Coastal giant salamander ²	<i>Dicamptodon tenebrosus</i>			X
Tailed frog ²	<i>Ascaphus truei</i>	X		
Western toad ¹	<i>Anaxyrus boreas</i>	X		
Pacific (Chorus) tree frog ¹	<i>Pseudacris regilla</i>		X	
Cascade frog ¹	<i>Rana cascadea</i>	X		
Rough-skinned newt ¹	<i>Taricha granulosa</i>	X		

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

Water quality in the White River at littorals watershed is potentially impacted by numerous sources related to roads, trails, NPS infrastructure, and recreational use (Table 52). The network of roads within the White River at littorals watershed ends at Sunrise where the previously described visitor complex is located. Water is withdrawn from an unnamed creek (w19-00b) in the watershed to supply the Sunrise visitor complex. Additionally, WILI is located immediately downstream from the Washington Department of Transportation waste transfer facilities which poses a moderate hazard due to water flowing through materials stored on-site for road and facility maintenance. See comprehensive list below of stressors that may present a risk to water quality in the White River at littorals watershed.

- Increased sediment deposition from mass failures.
- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Habitat fragmentation.
- Barriers to aquatic organism passage.
- Increased rate of non-native plant and animal invasions.
- Increased average and maximum water temperatures.
- Decreased minimum water temperatures.

- Decreased dissolved oxygen.
- Runoff of applied road chemicals.
- Runoff of applied herbicides and pesticides.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).
- Increased nutrient delivery.
- Increased introduction of pathogens from animal and human waste.
- Introduction of chemicals from pharmaceutical waste.
- Increased amounts of organic matter.

Sample Reach Characterization

The WILI sample reach is 400 m long and starts at 1,160 m above sea level. The sample reach is a 4th order river (Strahler 1952) and occupies an unconstrained braided channel in the bottom of a broad valley. Torrent evidence suggests that both scouring and deposition occur in this sample reach (Table 42, Figure 21). The Rapid Habitat Assessment conducted for the White River at littorals sample reach in 2012 indicated that the substrate was highly affected by silt depositions and a low variety of velocity and depth regimes, suggesting sub-optimal habitat quality (Table 43).

Table 42. Physical habitat characteristics measured in 2012 for the sample reach in the White River at littorals.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	–
Easting	607,363
Northing	5,194,530
Reach Length (m)	400
Average Wetted Width (m)	11.8
Minimum (m)	8.4
Maximum (m)	16.5
Average Bankfull Width (m)	46
Minimum (m)	44
Maximum (m)	48
Average Thalweg Depth (m)	0.57
Minimum (m)	0.45
Maximum (m)	0.70
Valley Width (m)	1000 ¹
Channel Constraint	
Channel Pattern	One channel
Channel Constraint	Broad valley and unconstrained
Constraining Feature	Hill slope

Table 42 (continued). Physical habitat characteristics measured in 2012 for the sample reach in the White River at littorals.

Physical Habitat Characterization Parameters	Values
Contact with constraining feature	5%
Torrent Evidence	• Recently de-vegetated area (less than or equal to 2x wider than the wetted width. • Substrate not imbricated and/or angular. • Channel has little evidence of pool-riffle structure. • Downstream contains large amounts of debris, logs and/or sediment. • Trees have fallen into channel due to scouring. • Massive deposits of debris, logs and/or sediment within reach.

¹Valley widths were estimated as the distance you can see.



Figure 21. The White River at littorals sample reach, showing braided channel within its broad valley.

Table 43. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach 2012 for the White River at littorals sample reach. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter (Optimal – Poor)	Score
Epifaunal Substrate/Available Cover	7
Embeddedness	2
Velocity/Depth Regime	6
Sediment Deposition	8
Channel Flow Status	7
Channel Alteration	17
Frequency of Riffles (or bends)	13
Bank Stability	14
Vegetative Protection	15
Riparian Vegetated Zone Width	20

North Cascades National Park

Seven stream reaches are sampled in NOCA as part of the NCCN Water Quality monitoring protocol (Figure 22). Three of these reaches are located on the east side of the Pacific Crest, in the Stehekin River watershed, and flow into the Columbia River. The remaining four reaches are located to the west of the Pacific Crest and flow into Puget Sound via the Skagit River.

The watersheds delineated for the stream locations within NOCA are composed of four Level IV Ecoregions, including North Cascades Lowland Forest, North Cascades Highland Forest, North Cascades Subalpine/Alpine, and Wenatchee/Chelan Highlands. The North Cascades Lowland Forest Ecoregion consists of productive western hemlock, Douglas-fir, and western red cedar (*Thuja plicata*) forests that have developed under the mild maritime climate. Located at higher elevations, the North Cascade Highland Forest Ecoregion is characterized by colder climatic conditions and the development of a deep and persistent snow pack with forests dominated with Pacific silver fir (*Abies amabilis*) and mountain hemlock. Located at the highest elevations with the coldest climate and deepest snow pack, the Subalpine/Alpine Ecoregion favors the development of alpine meadows and also contains large areas of bare rock and perennial snowfields. The Wenatchee/Chelan Highlands Ecoregion is found on the eastern side of the Pacific Crest. It shares many of the physiographic characteristics of the North Cascades Highland Forest Ecoregion; however, it experiences drier climatic conditions that have resulted in forests dominated by Douglas-fir, lodgepole pine (*Pinus contorta*), and ponderosa pine (*Pinus ponderosa*) (Omernik 2010).

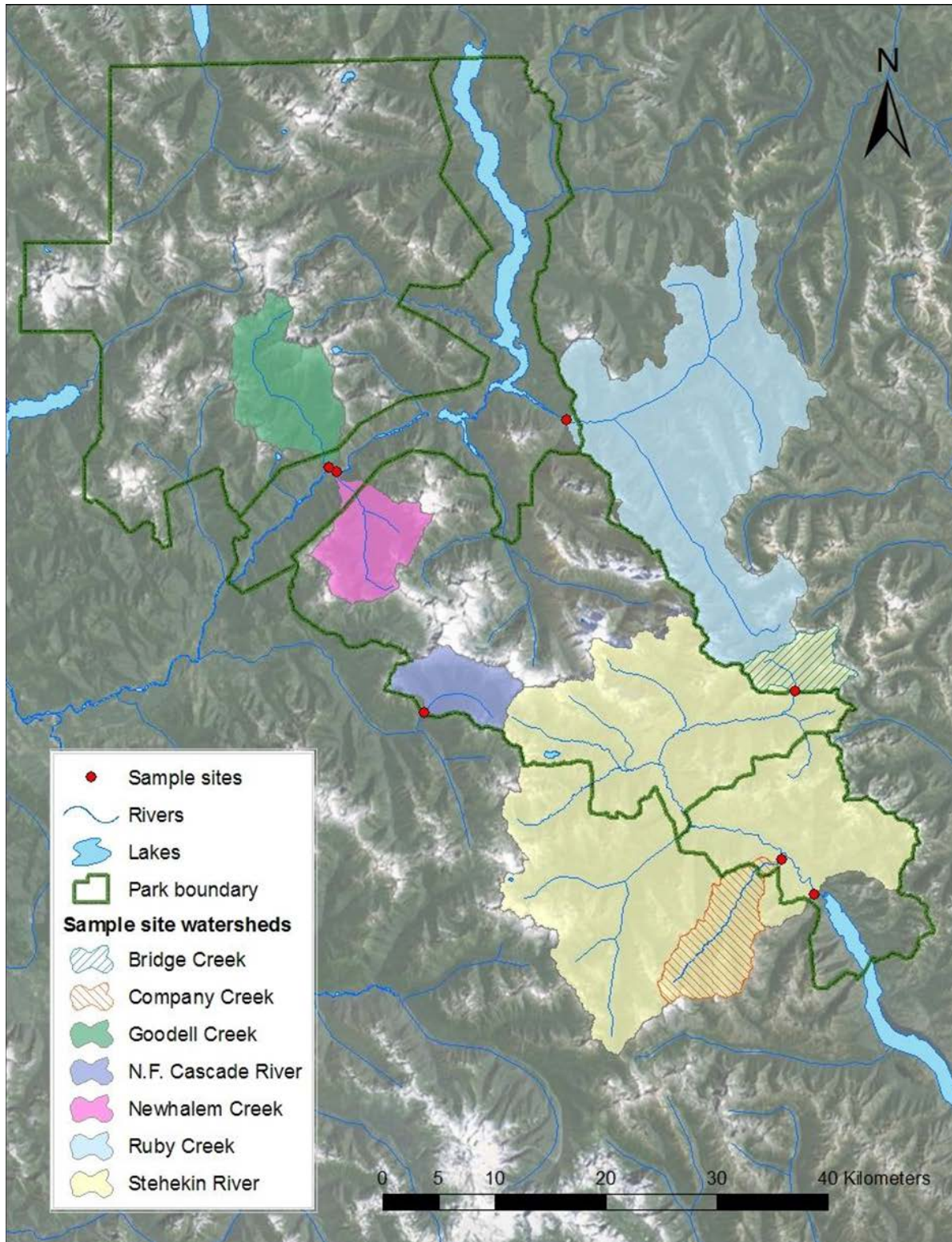


Figure 22. Map of the stream locations and associated watersheds in the North Cascades National Park Service Complex.

Stehekin River

Watershed Description

The Stehekin River watershed encompasses 883.7 km² and ranges in elevation from 340 to 2,893 m at the summit of Bonanza Peak. The average annual precipitation in the watershed is 170 cm/year. Several mountain lakes, ground water inflow, runoff of snow melt and runoff of 103 glaciers feed the Stehekin River (NPS NOCA 2012). The watershed is composed of the North Cascades Highland Forest, North Cascades Subalpine/Alpine and Wenatchee/Chelan Highlands Level IV Ecoregions.

Most of the Stehekin watershed is designated as federally protected wilderness and is managed by the NPS and the Wenatchee National Forest. In the lower reaches of the watershed 2.5 km² are either privately owned or held by the Chelan Public Utility District (Figure 23). Residential development is one of the primary human activities within the non-federally held portion of the watershed. The Stehekin Valley supports approximately 100 year-round and 80 seasonal residents. The Stehekin watershed contains access and community roads totaling 51.3 km, and a road density of 0.06 km/km².

National Park Service infrastructure and recreational use are also prevalent human activities in the lower reaches of the watershed. As one of the most popular visitor destinations in NOCA, the Stehekin/Lake Chelan area had 40,830 visitors in 2012 (NPS 2014). The Stehekin Valley offers a general store and bakery, a visitor center, concessions lodging, daily vehicle and horse tours of the valley, campgrounds, and hiking trails. The Stehekin watershed has a total of 225 km of trails, and a trail density of 0.29 km/km², which is above the 70th percentile for NCCN watersheds (Rawhouser et al. 2012). Common recreational activities include camping, day hiking, backpacking, stock use, mountaineering, rock climbing, backcountry skiing, snowmobiling, helicopter assisted skiing, rafting, fishing, and hunting. The watershed also contains 43 abandoned mines located in its headwaters.

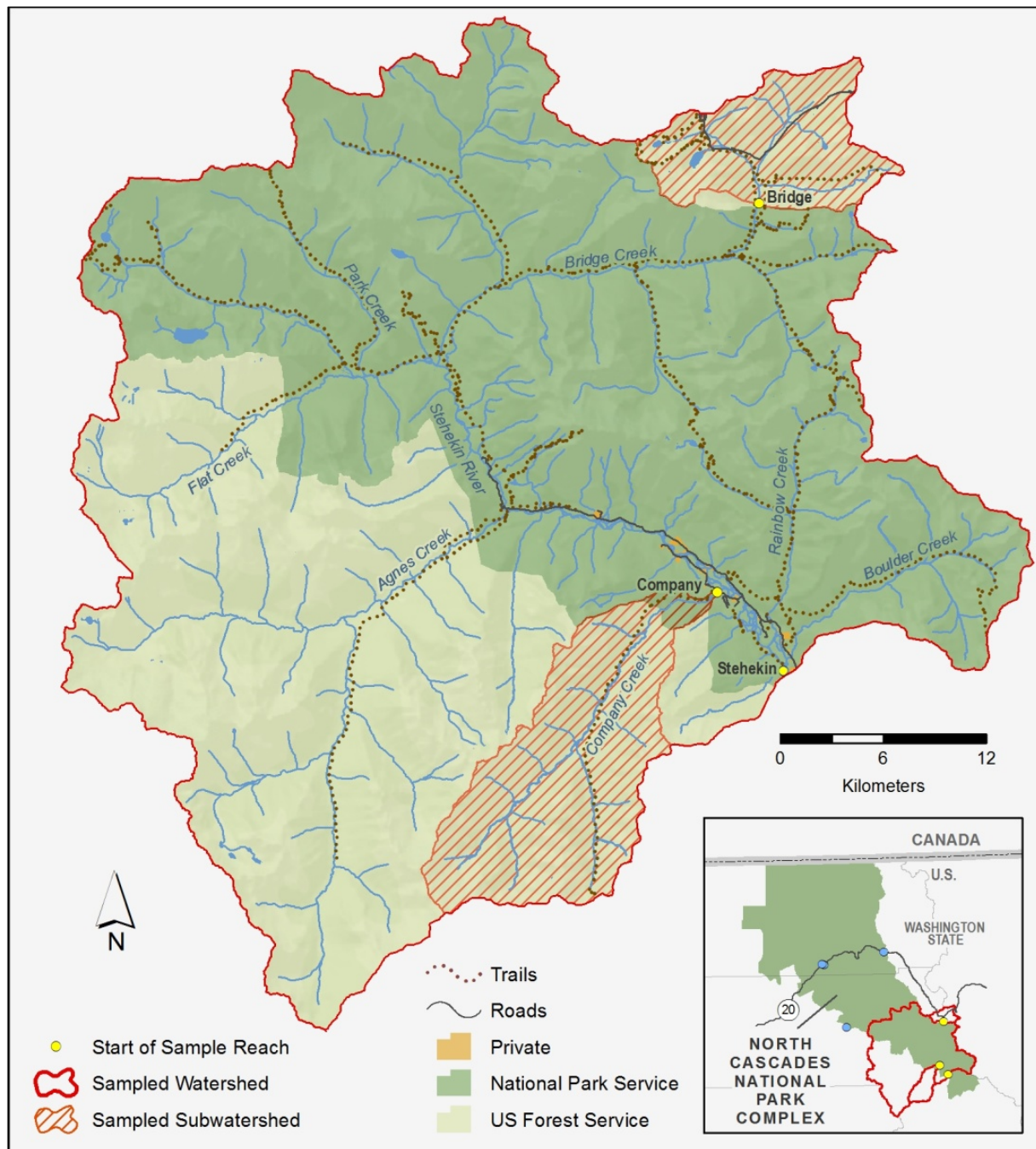


Figure 23. Stehekin River, Bridge Creek, and Company Creek stream locations and watersheds. The Bridge Creek and Company Creek watersheds are nested within the larger Stehekin River watershed.

Biological Resources

Six species of fish have been documented in the Stehekin River sample reach (Zyskowski 2007, Anthony and Glesne 2013, Hugh Anthony, Aquatic Ecologist, North Cascades National park, personal communication, 1-9-14), and according to regional distribution data and habitat requirements, it is possible that 10 additional species of fish may be present (Table 44) (Wydoski and Whitney 2003). No amphibian species have been documented in the Stehekin River sample reach,

though surveys have documented six species in the watershed (Bury and Adams 2000, WNHP WDFW BLM 2005) and an additional species could be present, according to regional distribution data and habitat requirements (Table 45) (Leonard et al. 1993).

Table 44. Fish species documented and potentially present within the Stehekin River sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Bridgelip sucker	<i>Catostomus columbianus</i>		X	Yes
Largescale sucker	<i>Catostomus macrocheilus</i>		X	Yes
Slimy sculpin	<i>Cottus cognatus</i>		X	Yes
Shorthead sculpin	<i>Cottus confusus</i>		X	Yes
Torrent sculpin	<i>Cottus rhotheus</i>		X	Yes
Northern pikeminnow	<i>Ptychocheilus oregonensis</i>		X	Yes
Longnose dace	<i>Rhinichthys cataractae</i>		X	Yes
Burbot	<i>Lota lota</i>		X	Yes
Threespine stickleback	<i>Gasterosteus aculeatus</i>		X	Yes
Westslope cutthroat trout	<i>Oncorhynchus clarkii lewisi</i>	X		Yes
Rainbow trout/Steelhead	<i>Oncorhynchus mykiss</i>	X		No
Kokanee salmon	<i>Oncorhynchus nerka</i>	X		No
Mountain whitefish	<i>Prosopium williamsoni</i>		X	Yes
Chinook salmon	<i>Oncorhynchus tshawytscha</i>	X		No
Brook trout	<i>Salvelinus fontinalis</i>	X		No
Lake trout	<i>Salvelinus namaycush</i>	X		No

Table 45. Amphibian species documented and potentially present in the Stehekin River sample reach and watershed.

Common Name	Scientific Name	Documented in Watershed	Potentially Present
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>	X	
Tailed frog ²	<i>Ascaphus truei</i>	X	
Western toad ¹	<i>Anaxyrus boreas</i>	X	
Pacific giant salamander ²	<i>Dicamptodon tenebrosus</i>		X
Pacific (Chorus) tree frog ¹	<i>Pseudacris regilla</i>	X	
Cascade frog ²	<i>Rana cascadae</i>	X	
Columbia spotted frog ²	<i>Rana luteiventris</i>	X	

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

Water quality in the Stehekin River is potentially impacted by numerous sources including trails, roads, residential development, pastoral agriculture, NPS infrastructure, recreational use, a hydropower project located on Company Creek, and the five abandoned mines in the watershed. Among those, the greatest threats to water quality in the lower reaches of the watershed are from residential development, NPS infrastructure, and road maintenance. See comprehensive list below of stressors that may present a risk to water quality in the Stehekin River watershed.

- Increased sediment deposition from mass failures.
- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Increased rate of non-native plant and animal invasions.
- Increased average and maximum water temperatures.
- Decreased minimum water temperatures.
- Decreased dissolved oxygen.
- Runoff of applied herbicides and pesticides.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).
- Increased nutrient delivery.
- Increased introduction of pathogens from animal and human waste.
- Introduction of chemicals from pharmaceutical waste.
- Increased amounts of organic matter.
- Decreased pH.
- Increased levels of dissolved metals.
- Increased levels of cyanide, petroleum products, oil, solvents, acids, and reagents.

Sample Reach Characterization

The Stehekin River sample reach is 500 m long and starts at an elevation of 366 m above sea level. The sample reach is a 5th order stream (Strahler 1952) located two km upstream of the confluence with Lake Chelan in the bottom of a classic U-shaped glacial valley. It occupies an anastomosing channel that is constrained by incision into alluvial terraces (Table 46). The Rapid Habitat Assessment conducted for the Stehekin River in 2012 indicated that the sample reach was in sub-

optimal condition chiefly due to recent flooding events that have deposited large amounts of sediment in the reach and increased bank erosion (Table 47, Figure 24).

Table 46. Physical habitat characteristics measured in 2012 for the sample reach in the Stehekin River.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	–
Easting	5354879
Northing	0671126
Reach length (m)	500
Average Wetted Width(m)	35.4
Minimum (m)	25
Maximum (m)	42
Average Bankfull Width (m)	71
Minimum (m)	48
Maximum (m)	101
Average Thalweg Depth (m)	1.47
Minimum (m)	0.9
Maximum (m)	>2.0
Valley Width (m)	1000 ¹
Channel Pattern	Anastomosing channel
Channel Constraint	Broad valley but constrained by incision
Constraining Feature	Terrace/alluvial fan
Contact with constraining feature	5%
Torrent Evidence	• Downstream contains large amounts of debris, logs and or sediment. • Trees have fallen into channel due to scouring. • Massive deposits of debris, logs and or sediment within reach.

¹Valley width was estimated as total distance observer could see.

Table 47. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Stehekin River sample reach. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	13
Embeddedness	16
Velocity/Depth Regime	17
Sediment Deposition	16
Channel Flow Status	8

Table 47 (continued). Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Stehekin River sample reach. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Channel Alteration	17
Frequency of Riffles (or bends)	17
Bank Stability	10
Vegetative Protection	20
Riparian Vegetated Zone Width	20



Figure 24. Looking upstream into the Stehekin River sample reach.

Bridge Creek

Watershed Description

The Bridge Creek watershed encompasses 36.4 km² and ranges in elevation from 1,226 to 2,451 m at the summit of Cutthroat Peak. The average annual precipitation in the watershed is 164 cm/year. Three mountain lakes, ground water inflow, and surface runoff of snow pack melt primarily feed

Bridge Creek. The watershed is composed of the North Cascades Highland Forest and North Cascades Subalpine/Alpine Level IV Ecoregions.

The majority of the watershed is managed by the Wenatchee National Forest, with the exception of the State Route 20 corridor which traverses the watershed and is managed by the Washington State Department of Transportation (Figure 23). Human activity within the watershed consists of 9.6 km of roads, 26.2 km of trails, and a few USFS facilities. The road and trail densities are 0.26 km/km² and 0.72 km/km², and are above the 50th and 90th percentiles for NCCN watersheds (Rawhouser et al. 2012). In regards to recreation, this is one of the most heavily used areas in the North Cascades, with over 320,000 vehicles traveling through the watershed on State Route 20 in 2013 (Lise Grace, Visitor Use Statistics Specialist, North Cascades National Park, email communication, 1-9-2014). Common recreational activities in the Bridge Creek watershed include day hiking, backpacking, stock use, mountaineering, rock climbing, backcountry skiing, snowmobiling, helicopter assisted skiing, fishing, and hunting.

Biological Resources

Only one fish and one amphibian species have been documented in the vicinity of the Bridge Creek sample reach (Tables 48 and 49) (Zyskowski 2007, Rawhouser et al. 2009). However, based on regional distribution data and habitat requirements, this area potentially contains an additional fish species and four additional amphibian species (Table 48 and 49) (Leonard et al. 1993, Wydoski and Whitney 2003, Galvan et al. 2005, WNHP WDFD BLM 2005).

Table 48. Fish species documented and potentially present in the Bridge Creek watershed and sample reach.

Common Name	Scientific Name	Documented in Watershed	Potentially Present	Native
Westslope cutthroat trout	<i>Oncorhynchus clarkii lewisi</i>	X		Yes
Rainbow trout	<i>Oncorhynchus mykiss</i>		X	No

Table 49. Amphibian species documented and potentially present in the Bridge Creek sample reach and watershed.

Common Name	Scientific Name	Documented in Watershed	Potentially Present
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>		X
Tailed frog ²	<i>Ascaphus truei</i>	X	
Western toad ¹	<i>Anaxyrus boreas</i>		X
Pacific giant salamander ²	<i>Dicamptodon tenebrosus</i>		X
Pacific (Chorus) tree frog ¹	<i>Pseudacris regilla</i>		X
Cascade frog ²	<i>Rana cascadae</i>		X
Columbia spotted frog ²	<i>Rana luteiventris</i>		X

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

The greatest threat to water quality in Bridge Creek comes from the State Route 20 and high trail densities within the watershed, along with high numbers of recreational users and abundant infrastructure. See comprehensive list below of stressors that may present a risk to water quality in the Bridge Creek watershed.

- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Habitat fragmentation.
- Increased rate of non-native plant and animal invasions.
- Increased average and maximum water temperatures.
- Decreased minimum water temperatures.
- Decreased dissolved oxygen.
- Runoff of applied road chemicals and deicing compounds.
- Runoff of applied herbicides and pesticides.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).
- Increased nutrient delivery.
- Increased introduction of pathogens from animal and human waste.
- Introduction of chemicals from pharmaceutical waste.
- Increased amounts of organic matter.
- Increased amounts of petroleum based toxic compounds from snowmobile use.

Sample Reach Characterization

The sample reach in Bridge Creek is 400 m long and starts an elevation of 1,216 m above sea level. This sample reach occupies a single V-shaped channel, which is constrained by bedrock and large boulders. The sample reach is a 3rd order stream (Strahler 1952), typical of mountain streams in the North Cascades (Table 50, Figure 25). The Rapid Habitat Assessment conducted for the Bridge Creek sample reach indicated optimal habitat conditions (Table 51).

Table 50. Physical habitat characteristics measured in 2012 for the sample reach in Bridge Creek.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	–
Easting	5372850
Northing	0669582
Reach Length (m)	400
Average Wetted Width (m)	5.78
Minimum (m)	2.5
Maximum (m)	11.2
Average Bankfull Width (m)	10.23
Minimum (m)	8.0
Maximum (m)	13.7
Average Thalweg Depth (m)	0.56
Minimum (m)	0.30
Maximum (m)	1.30
Valley Width (m)	200
Channel Pattern	One channel
Channel Constraint	Very constrained in a V-shaped valley
Constraining Feature	Bedrock
Contact with constraining feature	60%
Torrent Evidence	• Channel scoured to bedrock. • Downstream contains large amounts of debris, logs and/or sediment.



Figure 25. Representative habitat in the Bridge Creek sample reach.

Table 51. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Bridge Creek. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	17
Embeddedness	18
Velocity/Depth Regime	17
Sediment Deposition	16
Channel Flow Status	17
Channel Alteration	19
Frequency of Riffles (or bends)	16
Bank Stability	18
Vegetative Protection	18
Riparian Vegetated Zone Width	20

Company Creek

Watershed Descriptions

The Company Creek watershed encompasses 71.1 km² and ranges in elevation from 386 to 2,893 m at the summit of Bonanza Peak. The average annual precipitation in the watershed is 143 cm/year.

Ground water inflow and surface runoff of snow pack and glacial melt primarily feed Company Creek. The creek drains directly into the Stehekin River approximately 10 km upstream from Lake Chelan (Figure 23). The watershed is composed of the North Cascades Highland Forest, North Cascades Subalpine/Alpine and Wenatchee/Chelan Highlands Level IV Ecoregions.

Less than 10% of the Company Creek watershed is managed by the NPS. However, the remainder of the watershed is managed as federally protected Wilderness by the Wenatchee National Forest. Development consists of 16.1 km of trails in the Wilderness portion of the watershed, with a trail density of 0.23 km/km². This trail density is above the 60th percentile for NCCN watersheds (Rawhouser et al. 2012). The Chelan Public Utility District operates a hydropower project in the lower portion of Company Creek. Common recreational activities in the Company Creek watershed include day hiking, backpacking, mountaineering, fishing, and hunting.

Biological Resources

Four fish species have been documented in the Company Creek sample reach (Zyskowski 2007), and based on regional distribution information and habitat requirements, three additional fish species are potentially present (Table 52) (Wydoski and Whitney 2003). Previous NPS inventories of Company Creek did not document the presence of any amphibians within the sample reach (Rawhouser et al. 2009), nor have any been documented in the watershed, but based on regional distribution and habitat requirements, five species potentially occur in the area (Table 53) (Leonard et al. 1993, Galvan et al. 2005, WNHP WDFD BLM 2005).

Table 52. Fish species documented and potentially present in the Company Creek sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Longnose dace	<i>Rhinichthys cataractae</i>		X	Yes
Westslope cutthroat trout	<i>Oncorhynchus clarkii lewisi</i>	X		Yes
Rainbow trout	<i>Oncorhynchus mykiss</i>	X		No
Kokanee salmon	<i>Oncorhynchus nerka</i>	X		No
Chinook salmon	<i>Oncorhynchus tshawytscha</i>	X		No
Mountain whitefish	<i>Prosopium williamsoni</i>		X	Yes
Brook trout	<i>Salvelinus fontinalis</i>		X	No

Table 53. Amphibian species potentially present in the Company Creek sample reach and watershed.

Common Name	Scientific Name	Potentially Present
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>	X
Tailed frog ²	<i>Ascaphus truei</i>	X
Western toad ¹	<i>Anaxyrus boreas</i>	X
Pacific giant salamander ²	<i>Dicamptodon tenebrosus</i>	X
Pacific (Chorus) tree frog ¹	<i>Pseudacris regilla</i>	X
Cascade frog ²	<i>Rana cascadae</i>	X
Columbia spotted frog ²	<i>Rana luteiventris</i>	X

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

The greatest threat to water quality in Company Creek is related to the hydropower project operation on Company Creek. This facility, consisting of a hydroelectric plant and three diesel generators, is the only source of electricity for the residents and NPS facilities in the Stehekin Valley. Installed in 1976, the hydroelectric plant has a gravity fed penstock that diverts flow from Company Creek 1,200 m upstream of the powerhouse. The diversion entrance is a grate spanning one third of the creek that funnels water into a two-foot diameter penstock. During high flows, the penstock can carry up to 17 ft³/s, and during low flows, it carries a reduced flow of 10 ft³/s (Kirchhoffer and Malte 2003). See comprehensive list below of stressors that may present a risk to water quality in the Company Creek watershed.

- Increased sediment deposition from mass failures.
- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased sinuosity.
- Increased incision.
- Increased rate of non-native plant and animal invasions.
- Increased nutrient delivery.
- Decreased maximum stream flow.
- Decreased incidence of maximum stream flow events.
- Decreased minimum stream flow.
- Increased duration of minimum stream flow.
- Increased water temperature.
- Decreased dissolved oxygen.
- Increased incision.
- Increased stream bed armoring
- Increased steam bed and bank erosion.

- Increased risk of accidental toxic spills.
- Barriers to aquatic organism passage.
- Increased introduction of pathogens from animal and human waste.
- Increased nutrient delivery.

Sample Reach Characterization

The Company Creek sample reach is 400 m long and starts at an elevation of 387 m above sea level. Constituting a 3rd order stream (Strahler 1952), the sample reach begins 1.5 km upstream from the confluence with the Stehekin River. It occupies an anastomosing channel that is constrained by human alteration and incision into an alluvial fan. Torrent evidence suggests that high flows have caused scouring and deposition of substrate above the bankfull level (Table 54).

Table 54. Physical habitat characteristics measured in 2012 for the sample reach in Company Creek.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	–
Easting	668415
Northing	5357750
Reach Length (m)	400
Average Wetted Width (m)	7.43
Minimum (m)	4.6
Maximum (m)	10.2
Average Bankfull Width (m)	13
Minimum (m)	10.5
Maximum (m)	15.4
Average Thalweg Depth (m)	0.60
Minimum (m)	0.42
Maximum (m)	1.33
Valley Width (m)	300 ¹
Channel Pattern	Anastomosing channel
Channel Constraint	Broad valley but constrained by incision
Constraining Feature	Hill slope
Percent of channel length in contact with constraining feature.	10
Torrent Evidence	• Gravel and cobble berms above bankfull level. • Riparian trees scarred well above channel bed. • Trees have fallen into channel due to scouring.

¹Valley width was estimated as total distance observer could see.

Though the Company Creek sample reach was determined to be in an optimal condition at the time of the field visit in 2012, it exhibited several characteristics that are cause for concern (Table 55,

Figure 26). Human modifications have confined and channelized the stream which has resulted in reduced habitat diversity, increased erosion, and reduced bank stability. Currently, the stream banks and riparian zone appear to be adequately protected by vegetation, but this condition could rapidly change during conditions of torrential flow.

Table 55. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Company Creek. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	15
Embeddedness	20
Velocity/Depth Regime	16
Sediment Deposition	20
Channel Flow Status	20
Channel Alteration	10
Frequency of Riffles (or bends)	17
Bank Stability	10
Vegetative Protection	16
Riparian Vegetated Zone Width	20



Figure 26. Looking down stream in the Company Creek sample reach. The outfall of the hydroelectric project can be seen on the left side of this photograph.

Goodell Creek

Watershed Description

Goodell Creek is a tributary to the Skagit River which drains to the Puget Sound. The watershed encompasses 100.5 km² and ranges in elevation from 147 to 2,528 m at the summit of Fury Peak. Average annual precipitation in the watershed is 275 cm/year. Goodell Creek is fed by several mountain lakes, ground water inflow, and surface runoff of snow pack and glacial melt. The watershed is composed of the North Cascades Lowland Forest, North Cascades Highland Forest, and North Cascades Subalpine/Alpine Level IV Ecoregions.

The entire Goodell Creek watershed lies within the boundary of NOCA, most of which is designated as federally protected Wilderness (Figure 27). Human activity within the watershed consists of two primitive drive-in campgrounds and a large gravel pit that receives road materials generated from maintenance of Washington State Route 20. The watershed has no developed trails and only contains 7.8 km of roads, giving it a road density of 0.08 km/km². Recreational activities are limited to camping, day hiking, mountaineering, fishing, and hunting.

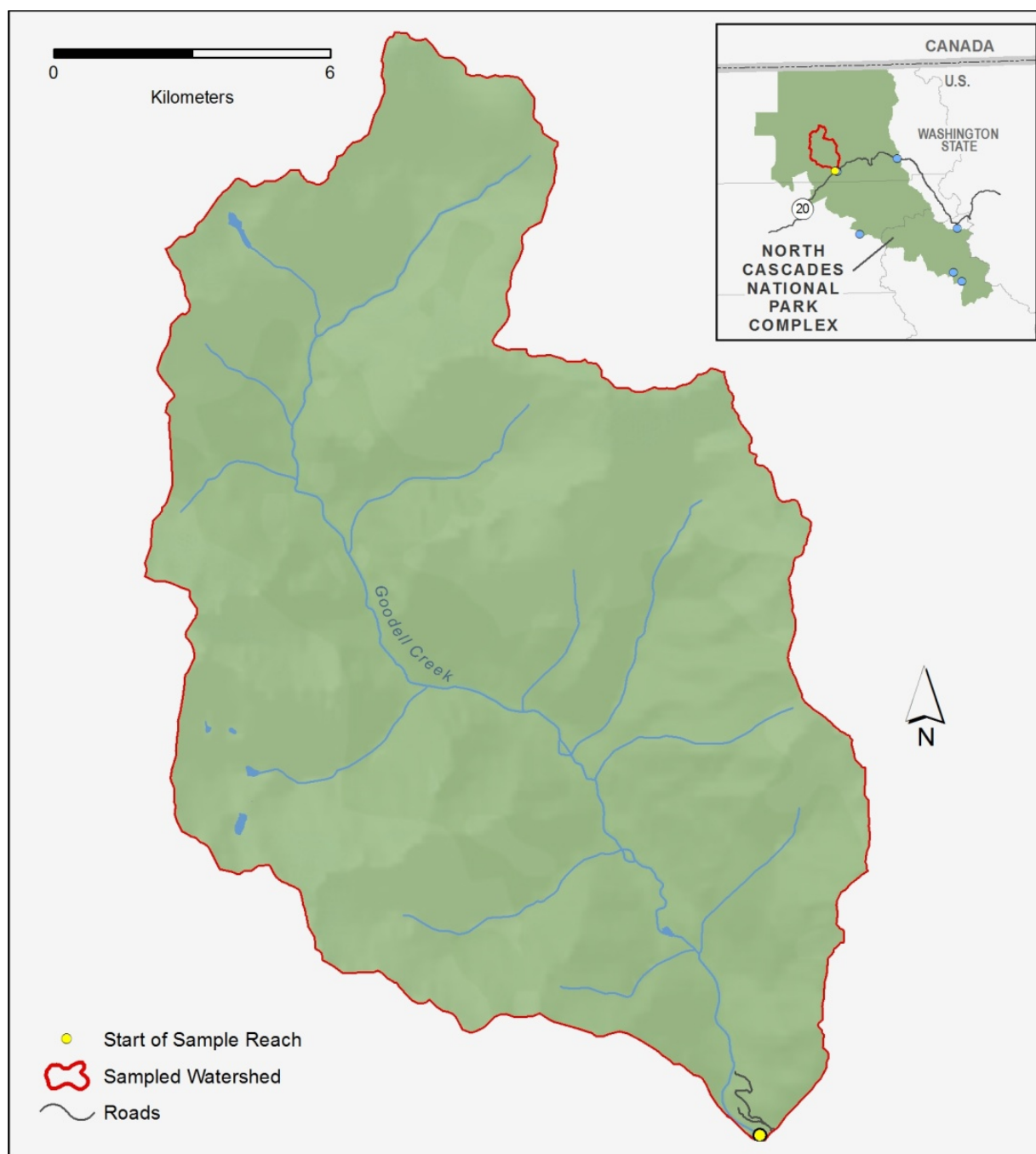


Figure 27. The Goodell Creek stream location and watershed.

Biological Resources

Fish have been documented in the Goodell Creek sample reach, but amphibians have not. Nine different species of fish have been documented in the Goodell Creek sample reach (Table 56) (Zyskowski 2007, WDFW 2014, Hugh Anthony, Aquatic Ecologist, North Cascades National park, personal communication, 2016), and an additional three species have the potential to be present but have not been documented (Wydoski and Whitney 2003, WDFW 2014). Though amphibian surveys

have been conducted in Goodell Creek, the sample reach has not been surveyed (Table 57) (Rawhouser et al. 2009). Two species of amphibians have been documented in the watershed, seven additional species may be found in the area (Table 57) (Leonard et al. 1993, WNHP WDFW BLM 2005, Rawhouser et al. 2009).

Table 56. Fish species documented and potentially present in the Goodell Creek sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Longnose dace	<i>Rhinichthys cataractae</i>		X	Yes
Coastal cutthroat trout	<i>Oncorhynchus clarkii clarkii</i>		X	Yes
Pink Salmon	<i>Oncorhynchus gorbuscha</i>	X		Yes
Chum salmon	<i>Oncorhynchus keta</i>	X		Yes
Coho salmon	<i>Oncorhynchus kisutch</i>	X		Yes
Rainbow trout/Steelhead	<i>Oncorhynchus mykiss</i>	X		Yes
Sockeye salmon	<i>Oncorhynchus nerka</i>	X		Yes
Chinook salmon	<i>Oncorhynchus tshawytscha</i>	X		Yes
Mountain whitefish	<i>Prosopium williamsoni</i>	X		Yes
Bull trout	<i>Salvelinus confluentus</i>	X		Yes
Brook trout	<i>Salvelinus fontinalis</i>		X	No
Dolly Varden	<i>Salvelinus malma</i>	X		Yes

Table 57. Amphibian species documented and potentially present in the Goodell Creek sample reach and watershed.

Common Name	Scientific Name	Documented in Watershed	Potentially Present
Northwestern Salamander ¹	<i>Ambystoma gracile</i>		X
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>		X
Tailed frog ²	<i>Ascaphus truei</i>	X	
Western toad ¹	<i>Anaxyrus boreas</i>		X
Pacific giant salamander ²	<i>Dicamptodon tenebrosus</i>	X	
Pacific (Chorus) tree frog ¹	<i>Pseudacris regilla</i>		X
Cascade frog ²	<i>Rana cascadae</i>		X
Columbia spotted frog ²	<i>Rana luteiventris</i>		X
Rough-skinned newt ¹	<i>Taricha granulosa</i>		X

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

Though water quality in Goodell Creek is potentially impacted by roads, campgrounds, and recreational use, the primary stressors of concern are related to an active gravel pit, several in-stream

channel modifications that have greatly altered the natural flow characteristics in Goodell Creek, and an existing levee constructed in the 1980's. Parts of this levee have been identified as an historic industrial dump site containing various materials including metals, glass, and asphalt chunks, associated with Washington Department of Transportation and Seattle City Light operations. The exact contents of this portion of the levee are unknown; however, it has been reported that this site is probably contaminated with arsenic and lead from sand blasting waste (NPS 2011). See comprehensive list below of stressors that may present a risk to water quality in the Goodell Creek watershed.

- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Increased rate of non-native plant and animal invasions.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).
- Increased nutrient delivery.
- Decreased pH.
- Increased levels of dissolved metals.
- Increased levels of petroleum products, oil, solvents, acids, and reagents.
- Decreased woody debris.
- Increased introduction of pathogens from animal and human waste.
- Introduction of chemicals from pharmaceutical waste.

Sample Reach Characterization

The Goodell Creek sample reach is 500 m long and begins at an elevation of 149 m above sea level. It starts immediately upstream of the State Route 20 Bridge that spans the creek. Flowing through an alluvial fan, this sample reach is a 4th order stream (Strahler 1952) occupying an anastomosing and braided channel that is constrained by bank armoring (Table 58, Figure 28).

Table 58. Physical habitat characteristics measured in 2012 for the sample reach in Goodell Creek.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	—
Easting	627701
Northing	5392724
Reach Length (m)	500
Average Wetted Width (m)	33.6
Minimum (m)	18.0
Maximum (m)	77.0
Average Bankfull Width (m)	50.9
Minimum (m)	34.6
Maximum (m)	80.0
Average Thalweg Depth (m)	0.94
Minimum (m)	0.40
Maximum (m)	3.0
Valley Width (m)	>150 ¹
Channel Pattern	Anastomosing channel
Channel Constraint	Broad valley but constrained by incision
Constraining Feature	Human alteration (dikes)
Contact with constraining feature	100%
Torrent Evidence	• Substrate not imbricated and/or angular. • Downstream contains large amounts of debris, logs and/or sediment. • Trees have fallen into channel due to scouring. • Massive deposits of debris, logs and/or sediment w/in reach. • Stream eroding newly laid matrix supported deposits.

¹Valley width was estimated as total distance observer could see.



Figure 28. Braided habitat and exposed gravel bars in the Goodell Creek sample reach.

The Rapid Habitat Assessment conducted for Goodell Creek in 2012 indicated that the sample reach was in sub-optimal condition chiefly due to the high occurrence of stream bank modifications and sediment deposition in the reach from flooding events (Table 59).

Table 59. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Goodell Creek. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	12
Embeddedness	17
Velocity/Depth Regime	16
Sediment Deposition	7
Channel Flow Status	8
Channel Alteration	3
Frequency of Riffles (or bends)	16
Bank Stability	14
Vegetative Protection	20
Riparian Vegetated Zone Width	12

Newhalem Creek

Watershed Description

Newhalem Creek is a tributary to the main stem of the Skagit River. The watershed is 72.6 km² in area and ranges in elevation from 146 to 2,482 m at the summit of Snowfield Peak. Average annual precipitation in the watershed is 253 cm/year. Newhalem Creek is fed by several mountain lakes, ground water inflow, and the runoff of snow pack and glacier melt. The watershed is composed of the North Cascades Lowland Forest, North Cascades Highland Forest, and North Cascades Subalpine/Alpine ecoregions Level IV Ecoregions.

The entire Newhalem Creek watershed lies within the boundary of NOCA, most of which is designated as federally protected Wilderness (Figure 29). From 1965 to 1967, 2.55 km² were clear-cut and 13.5 km of road were constructed in the watershed by the USFS (NPS 2011). Since NOCA's creation in 1968, the forest has regenerated into mixed stands dominated by red alder (*Alnus rubra*) and immature conifers. Unused, the road system was left in place with many of the culverts and much of the road prism still intact, possibly negatively affecting water quality. The watershed still has 9.6 km of actively maintained roads with a road density of 0.13 km/km², which is above the 50th percentile for NCCN watersheds (Rawhouser et al. 2012). The watershed also has 1.3 km of trails with a trail density of 0.02 km/km². Additionally, Seattle City Light operates a small-scale hydroelectric project in Newhalem Creek. Recreational activities within the watershed consist of day hiking, backpacking, mountaineering, fishing, and hunting.

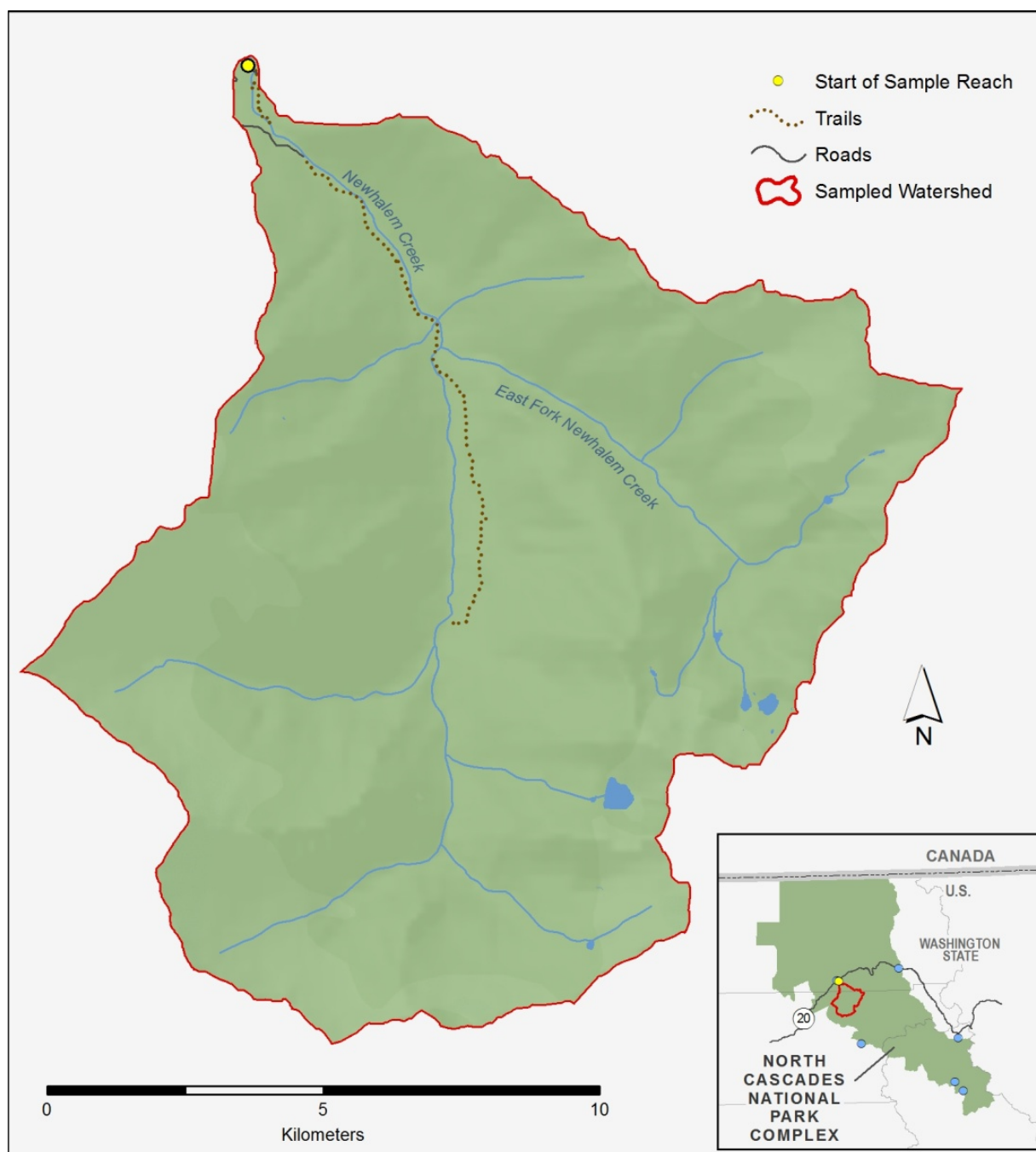


Figure 29. Nehalem Creek stream location and watershed.

Biological Resources

Seven fish species have been documented in the sample reach in Newhalem Creek (Zyskowski 2007, WDFW 2014, Bob Wassem, Aquatic Ecologist, North Cascades National Park, unpublished data), and three additional species are potentially present according to regional distribution data and habitat requirements (Table 60) (Wydoski and Whitney 2003). Three species of amphibians have been documented in the watershed (Bury and Adams 2000, Galvan et al. 2005, Rawhouser et al. 2009),

and five additional species have the potential to be in the area, according to regional distribution data and habitat requirements (Table 61) (Leonard et al. 1993, WNHP WDFW BLM 2005). However, amphibian surveys have been conducted in the main stem of Newhalem Creek have not detected any amphibians (Table 76) (Rawhouser et al. 2009).

Table 60. Fish species documented and potentially present in the Newhalem Creek sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Longnose dace	<i>Rhinichthys cataractae</i>		X	Yes
Coastal cutthroat trout	<i>Oncorhynchus clarkii clarkii</i>		X	Yes
Coho salmon	<i>Oncorhynchus kisutch</i>	X		Yes
Rainbow trout/Steelhead	<i>Oncorhynchus mykiss</i>	X		Yes
Sockeye salmon	<i>Oncorhynchus nerka</i>	X		Yes
Chinook salmon	<i>Oncorhynchus tshawytscha</i>	X		Yes
Mountain whitefish	<i>Prosopium williamsoni</i>	X		Yes
Bull trout	<i>Salvelinus confluentus</i>	X		Yes
Brook trout	<i>Salvelinus fontinalis</i>		X	No
Dolly Varden	<i>Salvelinus malma</i>	X		Yes

Table 61. Amphibian species documented and potentially present in the Newhalem Creek sample reach and watershed.

Common Name	Scientific Name	Documented in Watershed	Potentially Present
Northwestern Salamander ¹	<i>Ambystoma gracile</i>		X
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>		X
Tailed frog ²	<i>Ascaphus truei</i>	X	
Western toad ¹	<i>Anaxyrus boreas</i>		X
Pacific giant salamander ²	<i>Dicamptodon tenebrosus</i>	X	
Pacific (Chorus) tree frog ¹	<i>Pseudacris regilla</i>		X
Red-legged frog ¹	<i>Rana aurora</i>	X	
Rough-skinned newt ¹	<i>Taricha granulosa</i>		X

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

Water quality is potentially impacted in Newhalem Creek from several sources including: roads, trails, forestry, a small hydropower project, and recreational use. The principal concerns for water quality in Newhalem Creek are the hydropower project and impacts related to the abandoned road system. Since 2004, under section 303(d) of the Clean Water Act, Washington State has listed Newhalem Creek as having impaired habitat due to insufficient in-stream flow (WDOE 2012). The

U.S. Geological Survey installed a real-time gauging station since this listing, and evidence of dewatering has not been documented. However, the NPS and the USGS still have concerns about the potential impacts to this system (USGS 2014b). See comprehensive list below of stressors that may present a risk to water quality in the Newhalem Creek watershed.

- Increased sediment deposition from mass failures.
- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased sinuosity.
- Increased incision.
- Increased rate of non-native plant and animal invasions.
- Increased nutrient delivery.
- Decreased maximum stream flow.
- Decreased incidence of maximum stream flow events.
- Decreased minimum stream flow.
- Increased duration of minimum stream flow.
- Increased water temperature.
- Decreased dissolved oxygen.
- Increased incision.
- Increased stream bed armoring
- Increased stream bed and bank erosion.
- Increased risk of accidental toxic spills.
- Barriers to aquatic organism passage.
- Increased introduction of pathogens from animal and human waste.
- Increased nutrient delivery.
- Introduction of chemicals from pharmaceutical waste.

Sample Reach Characterization

The Newhalem Creek sample reach is 500 m long and starts at an elevation of 149 m above sea level. The sample reach, which begins at the confluence with the Skagit River is a 4th order stream (Strahler 1952) occupying a single channel that is constrained by incision in to an alluvial fan (Table 62). The Rapid Habitat Assessment conducted for Newhalem Creek in 2012 indicated that the sample reach was in optimal condition, despite some evidence of channel alteration in the form of bridge abutments (Table 63, Figure 30).

Table 62. Physical habitat characteristics measured in 2012 for the sample reach in Newhalem Creek.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	—
Easting	5392370
Northing	628356
Reach Length (m)	500
Average Wetted Width (m)	14.4
Minimum (m)	9.90
Maximum (m)	27.0
Average Bankfull Width (m)	22.6
Minimum (m)	15.3
Maximum (m)	30.0
Average Thalweg Depth (m)	0.80
Minimum (m)	0.40
Maximum (m)	1.20
Valley Width (m)	>100 ¹
Channel Pattern	One channel
Channel Constraint	Broad valley but constrained by incision
Constraining Feature	Terrace/alluvial fan
Contact with constraining feature	100%
Torrent Evidence	No evidence of torrent scouring or torrent deposits.

¹Valley width was estimated as total distance observer could see.

Table 63. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Newhalem Creek. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	19
Embeddedness	20
Velocity/Depth Regime	20
Sediment Deposition	20
Channel Flow Status	20
Channel Alteration	12
Frequency of Riffles (or bends)	20
Bank Stability	20
Vegetative Protection	20
Riparian Vegetated Zone Width	20



Figure 30. Technician measuring water depth at the water temperature monitoring station in Newhalem Creek. Bridge used for vehicle access is seen in background of photograph.

North Fork Cascade River

Watershed Description

The North Fork of the Cascade River watershed is 53.5 km² in area and ranges in elevation from 576 to 2,711 m at the summit of Eldorado Peak. Average annual precipitation in the watershed is 224 cm/year. Newhalem Creek is fed by several mountain lakes, ground water inflow, snow pack and glacial melt. The watershed is composed of the North Cascades Lowland Forest, North Cascades Highland Forest, and North Cascades Subalpine/Alpine Level IV Ecoregions.

The entire North Fork Cascade River watershed lies within the boundary of NOCA, most of which is designated as federally protected Wilderness (Figure 31). This watershed contains some of the most popular trails in NOCA with almost 11,000 vehicles entering the area to access these trails in 2010 (NPS 2014). The watershed also has a total of 8.1 km of actively maintained roads with a road density of 0.15 km/km². It has 4.8 km of trails with a trail density of 0.09 km/km². Both road and trail densities are above the 50th percentile for NCCN watersheds (Rawhouser et al. 2012). Additionally, 43 abandoned mines have been documented in this watershed, a number equal to the much larger Stehekin River watershed.

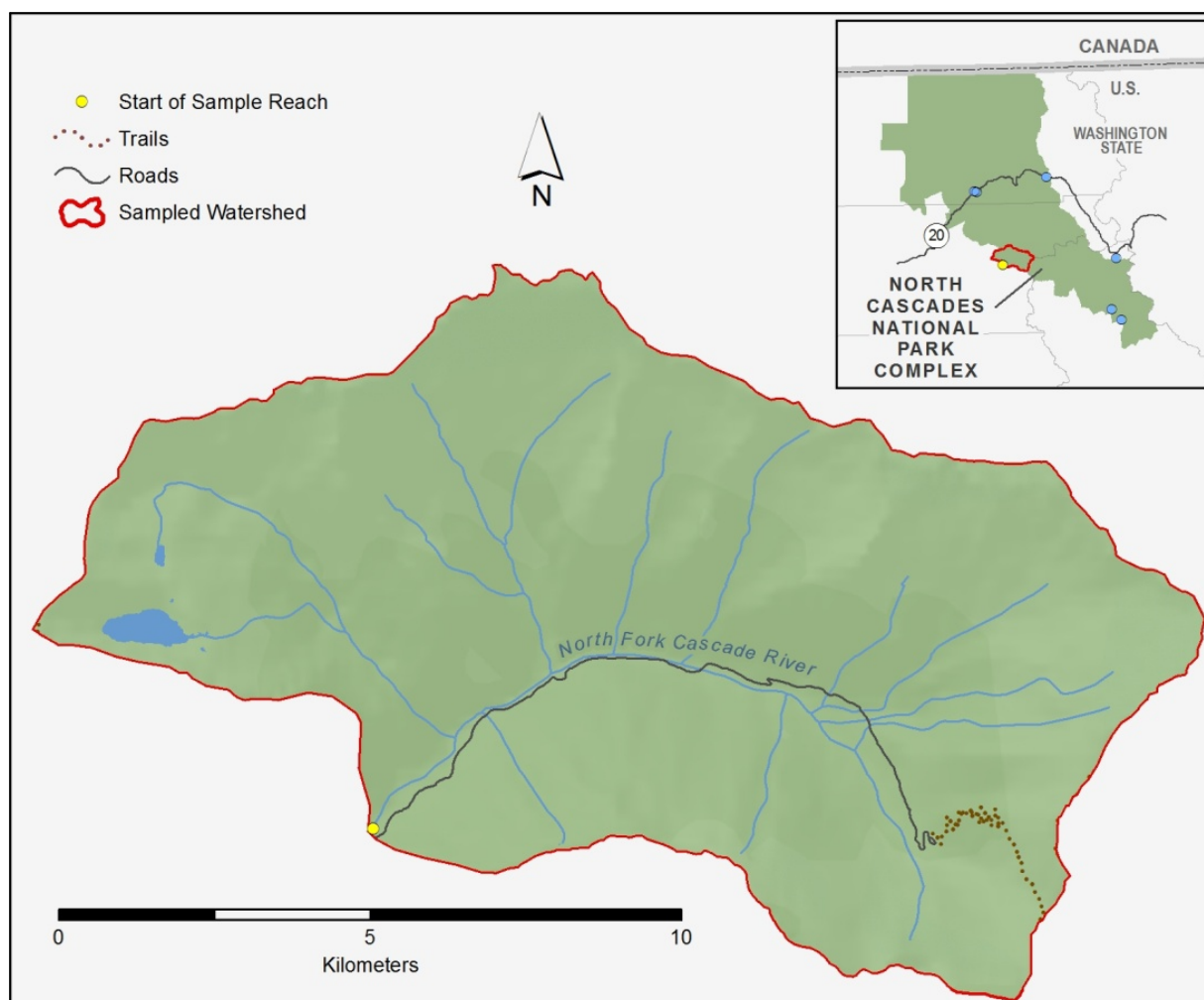


Figure 31. North Fork Cascade River stream location and watershed.

Biological Resources

One species of fish has been documented within the North Fork Cascade River sample reach (Table 64) (Zyskowski 2007), with two additional species possibly present (Wydoski and Whitney 2003). No amphibians have been documented in the sample reach or watershed; however no systematic surveys have been conducted within this area. Based on regional distributions and habitat requirements, there may be up to six species of amphibians present (Table 65) (Leonard et al 1993, Bury and Adams 2000, Galvan et al. 2005, WNHP WDFW BLM 2005).

Table 64. Fish species documented and potentially present in the North Fork Cascade River sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Rainbow trout	<i>Oncorhynchus mykiss</i>	X		Yes
Mountain whitefish	<i>Prosopium williamsoni</i>		X	Yes
Dolly Varden	<i>Salvelinus malma</i>		X	Yes

Table 65. Amphibian species potentially present in the North Fork Cascade River sample reach and watershed.

Common Name	Scientific Name	Potentially Present
Northwestern Salamander ¹	<i>Ambystoma gracile</i>	X
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>	X
Tailed frog ²	<i>Ascaphus truei</i>	X
Western toad ¹	<i>Anaxyrus boreas</i>	X
Pacific giant salamander ²	<i>Dicamptodon tenebrosus</i>	X
Pacific (Chorus) tree frog ¹	<i>Pseudacris regilla</i>	X

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

Water quality in the North Fork Cascade River is potentially impacted by roads, trails, mine drainage, and recreational use. The North Fork Cascade River Road parallels the river in the riparian zone for much of its length, and the high volume of vehicle traffic that uses it is of notable concern. See comprehensive list below of stressors that may present a risk to water quality in the North Fork Cascade River watershed.

- Increased sediment deposition from mass failures.
- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Increased rate of non-native plant and animal invasions.
- Increased water temperature.
- Decreased dissolved oxygen.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).
- Increased nutrient delivery.
- Decreased pH.
- Increased levels of dissolved metals.
- Increased levels of cyanide, petroleum products, oil, solvents, acids, and reagents.
- Increased introduction of pathogens from animal and human waste.
- Introduction of chemicals from pharmaceutical waste.

Sample Reach Characteristics

The North Fork Cascade River sample reach is 500 m long and starts at 588 m above sea level. The sample reach is a 4th order stream (Strahler 1952) and is located in the bottom of a U-shaped glacial valley and occupies a braided channel that is minimally constrained within the flood plain by debris cones and aprons (Table 66). Torrent evidence suggests the sample reach experiences periodic high flows that cause increased rates of erosion and scour (Table 66, Figure 32). The Rapid Habitat Assessment conducted for the North Fork Cascade River in 2012 indicated that the sample reach was in optimal condition (Table 67).

Table 66. Physical habitat characteristics measured in 2012 for the sample reach in the North Fork of the Cascade River.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	–
Easting	5371242
Northing	636467
Reach Length (m)	500
Average Wetted Width (m)	14.7
Minimum (m)	8.4
Maximum (m)	19.4
Average Bankfull Width (m)	38.5
Minimum (m)	20.1
Maximum (m)	52.7
Average Thalweg Depth (m)	0.74
Minimum (m)	0.31
Maximum (m)	2.20
Valley Width (m)	800 ¹
Channel Pattern	Braided channel
Channel Constraint	Narrow valley but not very constrained
Constraining Feature	Terrace/alluvial fan
Contact with constraining feature	30%
Torrent Evidence	• Substrate not imbricated and/or angular. • Trees have fallen into channel due to scouring. • Stream eroding newly laid matrix supported deposits.

¹Valley width was estimated as total distance observer could see.



Figure 32. Sample reach reference point, North Fork Cascade River.

Table 67. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the North Fork Cascade River. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	16
Embeddedness	17
Velocity/Depth Regime	16
Sediment Deposition	16
Channel Flow Status	12
Channel Alteration	20
Frequency of Riffles (or bends)	19
Bank Stability	20
Vegetative Protection	20
Riparian Vegetated Zone Width	20

Ruby Creek

Watershed Description

The Ruby Creek watershed encompasses 444.1 km² and ranges in elevation from 508 to 2,763 m at the summit of Mount Ballard. Average annual precipitation in the watershed is 145 cm/year. Groundwater inflow and surface runoff of rain and snow pack melt primarily feed Ruby Creek, which flows into the Skagit River at Ross Lake Reservoir. The watershed is composed of North Cascades Highland Forest and North Cascades Subalpine/Alpine Level IV Ecoregions.

Less than 2% of the Ruby Creek watershed is managed by the NPS (Figure 33). The majority of the watershed is managed by the Mount Baker and Wenatchee National Forests, and the Washington State Department of Transportation manages the State Route 20 corridor (Figure 33). This is a heavily used area, containing numerous popular trailheads and a large network of trails. The Ruby Creek watershed has 59.4 km of roads with a road density of 0.13 km/km², which is above the 50th percentile for NCCN watersheds. It also has 142.3 km of trails and a trail density of 0.32 km/km², which is above the 70th percentile for NCCN watersheds (Rawhouser et al. 2012). The watershed also has a total of 153 active and historic mines, which is more than any other watershed monitored within the NCCN. Common recreational activities in the Ruby Creek watershed include day hiking, backpacking, stock use, mountaineering, rock climbing, backcountry skiing, snowmobiling, helicopter assisted skiing, fishing, and hunting.

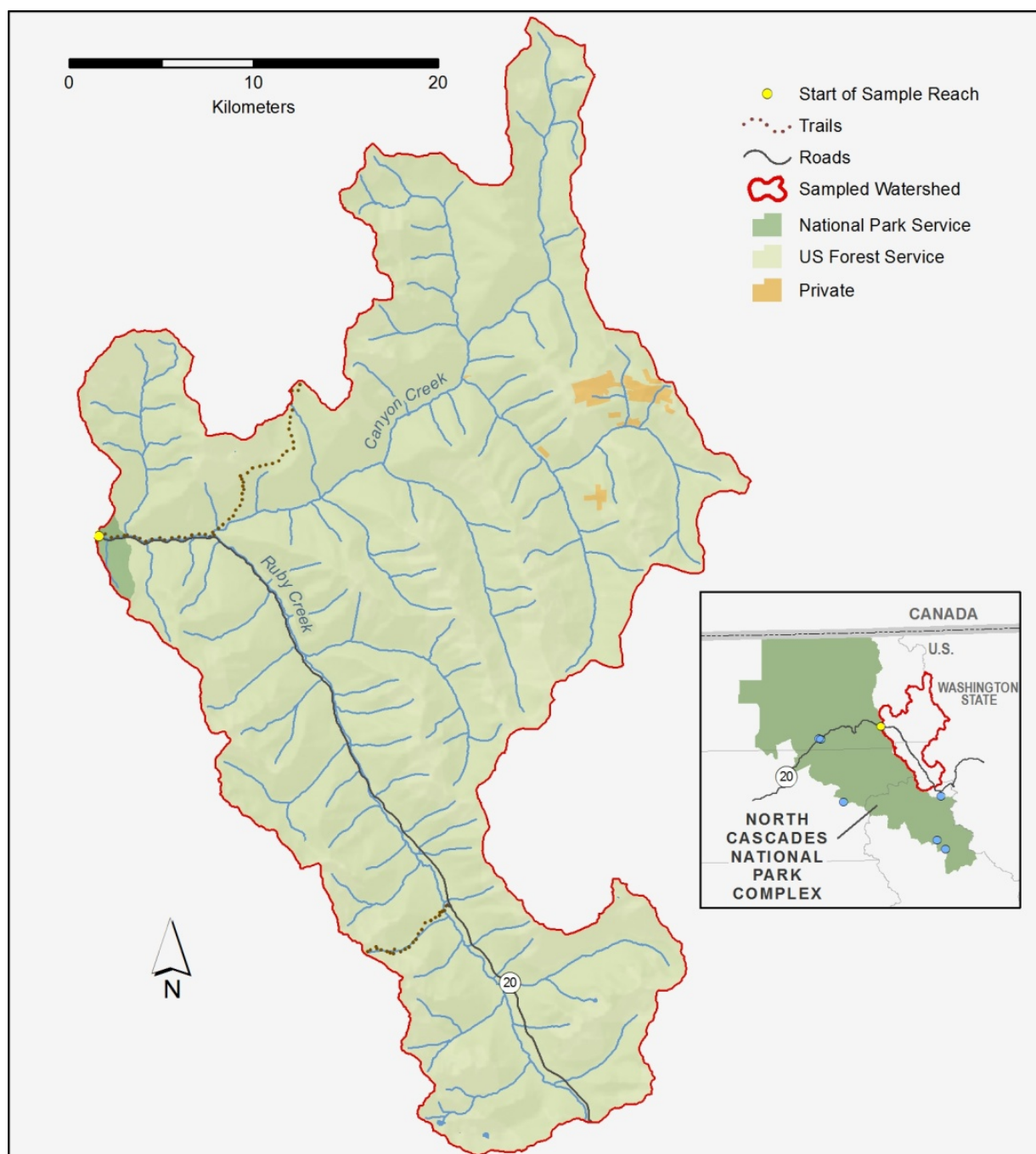


Figure 33. The Ruby Creek stream location and watershed.

Biological Resources

Rainbow trout and Bull trout (*Salvelinus confluentus*) are the only fish that have been documented in the Ruby Creek sample reach (USFW 2004, Meridian 2014). However, according to information on regional fish distributions, habitat requirements, and documentation of fish species present in other nearby locations, an additional three species may also be present (Table 68) (Wydoski and Whitney 2003). Surveys have been conducted, but no amphibians have been documented in the sample reach

as well, although two species have been documented within the watershed, including the Columbia spotted frog (*Rana luteiventris*), a Washington state candidate species (Rawhouser et al. 2009, WDFW 2015). An additional five species are potentially present (Table 69) (Leonard et al. 1993, WNHP WDFW BLM 2005).

Table 68. Fish species documented and potentially present in the Ruby Creek sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Westslope cutthroat trout	<i>Oncorhynchus clarkii lewisi</i>		X	No
Rainbow trout	<i>Oncorhynchus mykiss</i>	X		Yes
Bull trout	<i>Salvelinus confluentus</i>	X		Yes
Brook trout	<i>Salvelinus fontinalis</i>		X	No
Dolly Varden	<i>Salvelinus malma</i>		X ¹	Yes

¹Likely present due to documented presence in the immediately adjacent Panther Creek.

Table 69. Amphibian species documented and potentially present in the Ruby Creek sample reach and watershed.

Common Name	Scientific Name	Documented in Watershed	Potentially Present
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>		X
Tailed frog ²	<i>Ascaphus truei</i>	X	
Western toad ¹	<i>Anaxyrus boreas</i>		X
Pacific giant salamander ²	<i>Dicamptodon tenebrosus</i>		X
Pacific (Chorus) tree frog ¹	<i>Pseudacris regilla</i>		X
Columbia spotted frog ²	<i>Rana luteiventris</i>	X	

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

Water quality in Ruby Creek is potentially impacted by numerous sources that include trails, roads, active mining, mine drainage, and recreational use. The greatest threats to water quality in Ruby Creek are road maintenance associated with State Route 20, active mining activities, and recent illegal agricultural activities. State Route 20 runs parallel to the creek and in the riparian zone for much of its length. The highway supports a high volume of vehicle traffic seven months of the year and routinely suffers flooding and landslide damage that requires extensive rebuilding. In 2008, an illegal marijuana growing operation was discovered within the watershed. Roughly 0.02 km² of land was cleared, fertilizers, pesticides and herbicides were applied, and creeks were impounded to facilitate the crop growth (Mignonne Bivin, Plant Ecologist, North Cascades National Park, email

communication, 11-16-2013). See comprehensive list below of stressors that may present a risk to water quality in the Ruby Creek watershed.

- Increased sediment deposition from mass failures.
- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Increased rate of non-native plant and animal invasions.
- Increased water temperature.
- Decreased dissolved oxygen.
- Runoff of applied road chemicals and deicing compounds.
- Runoff of applied herbicides and pesticides.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).
- Increased nutrient delivery.
- Increased introduction of pathogens from animal and human waste.
- Decreased pH.
- Increased levels of dissolved metals.
- Increased levels of cyanide, petroleum products, oil, solvents, acids, and reagents.
- Introduction of chemicals from pharmaceutical waste.

Sample Reach Characterization

The Ruby Creek sample reach starts at 512 m above sea level and is 500 m long. Located at the bottom of a V-shaped valley in a river canyon, the Ruby Creek sample reach is a 4th order stream (Strahler 1952) that occupies one channel and is highly constrained by boulder, bedrock, and steep valley walls (Table 70). The Rapid Habitat Assessment conducted in 2012 on the Ruby Creek sample reach indicated optimal habitat quality (Table 71, Figure 34).

Table 70. Physical habitat characteristics measured in 2012 for the sample reach in Ruby Creek.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	—
Easting	649023
Northing	5396941
Reach Length (m)	500
Average Wetted Width (m)	18.3
Minimum (m)	11.0
Maximum (m)	32.6
Average Bankfull Width (m)	32.4
Minimum (m)	35.0
Maximum (m)	29.0
Average Thalweg Depth (m)	1.0
Minimum (m)	0.45
Maximum (m)	3.0
Valley Width (m)	98
Channel Pattern	One channel
Channel Constraint	Very constrained in V-shaped valley
Constraining Feature	Bedrock, hill-slope and terrace/alluvial fan
Percent of channel length in contact with constraining feature.	100
Torrent Evidence	No evidence of torrent scouring or torrent deposits.

Table 71. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Ruby Creek. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	10
Embeddedness	20
Velocity/Depth Regime	18
Sediment Deposition	20
Channel Flow Status	20
Channel Alteration	15
Frequency of Riffles (or bends)	20
Bank Stability	20
Vegetative Protection	20
Riparian Vegetated Zone Width	20



Figure 34. Looking upstream into the Ruby Creek sample reach.

Olympic National Park

Seven stream reaches are monitored in OLYM as part of the NCCN Water Quality monitoring protocol. Three of these stream locations are located along the Pacific strip and four are located in the inland portion of OLYM (Figure 35). All of the stream locations eventually drain into the Pacific Ocean except for one location that drains into the Strait of Juan de Fuca via Lake Crescent and the Lyre River.

The watersheds delineated for the stream locations within OLYM are composed of five Level IV Ecoregions consisting of the Coastal Lowlands, Coastal Uplands, Low Olympics, High Olympics, and Volcanics Ecoregions. The Coastal Lowlands and Upland Ecoregions are located exclusively along the Pacific strip. The Coastal Lowland Ecoregion is characterized by a marine influenced climate and contains beach habitat with low gradient, meandering, tannic streams and forests dominated by Sitka spruce, western hemlock, and Douglas-fir. Wetter lower areas support red alder (*Alnus rubra*), big leaf maple (*Acer macrophyllum*) and western red cedar. The Coastal Upland Ecoregion is characterized similarly to the Coastal Lowland Ecoregion; however it is described as having medium to high gradient tannic streams.

Higher in elevation and generally away from the influence of the Pacific strip, the Low Olympics, High Olympics, and Volcanics Ecoregions are found in the inland portion of OLYM. The Low Olympics Ecoregion is characterized as having streams with steep gradients and watersheds that receive high levels of precipitation yielding rainforest-like conditions with extremely high biomass. Dominant vegetation includes several varieties of epiphytes, western hemlock, western red cedar, Douglas-fir, and at higher elevations Pacific silver fir. Located at even higher elevations, the High Olympics Ecoregion transitions from a Pacific silver fir and mountain hemlock dominated forest to alpine meadows with lakes and wetlands present, with areas of bare rock at the highest elevations. The Volcanics Ecoregion has similar precipitation levels and plant communities as the Olympics Ecoregions; it is differentiated by a basaltic rock foundation (Omernik 2010).

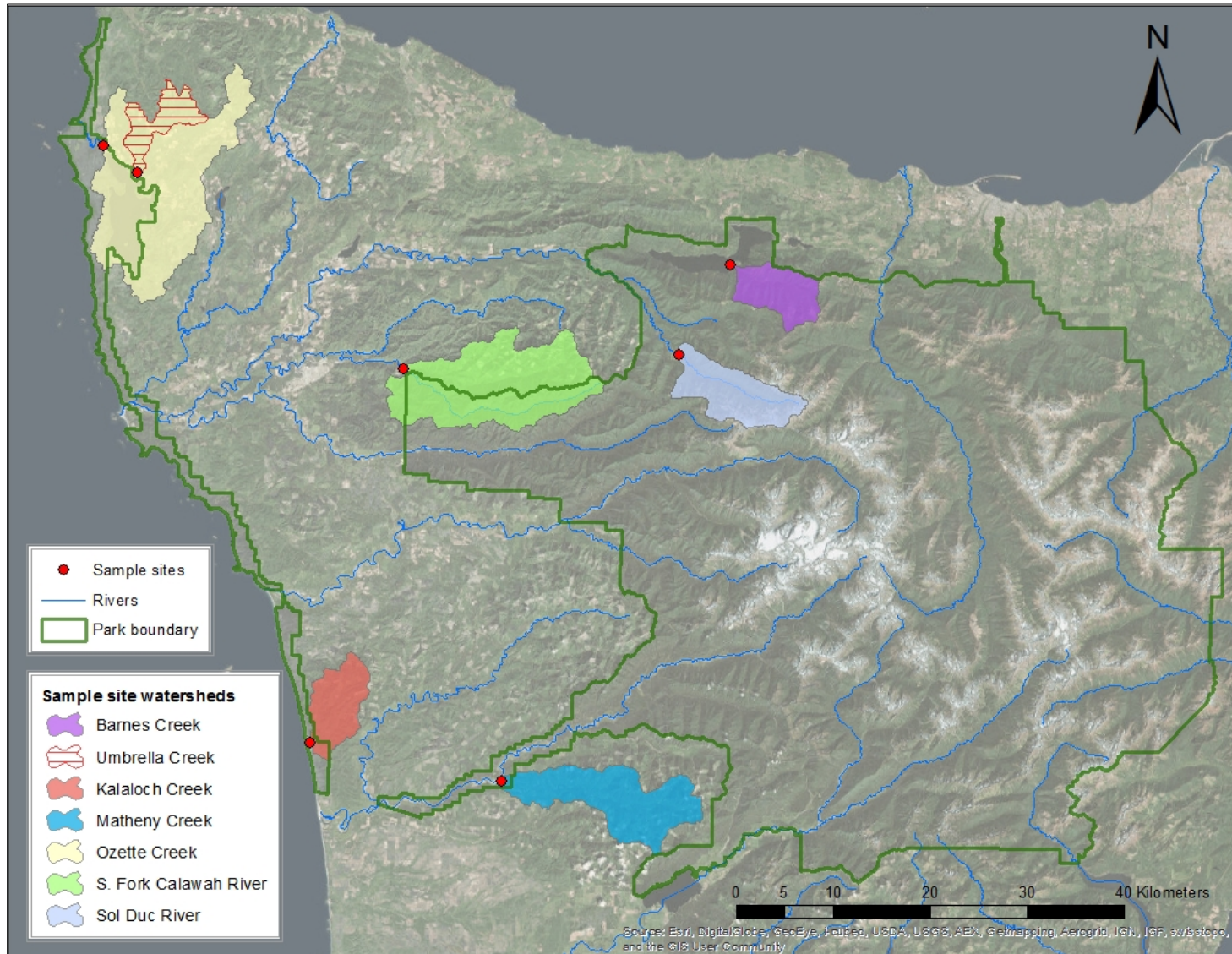


Figure 35. Map of the stream locations and associated watersheds for Olympic National Park.

Barnes Creek

Watershed Description

The Barnes Creek watershed is positioned along the northern border of OLYM and is completely contained within the park boundary (Figure 36). The Barnes Creek watershed drains directly into Lake Crescent, which was isolated from its historic outlet system (the Elwah River) within the last 10,000 years. The Barnes Creek watershed encompasses 40.7 km² and ranges in elevation from 177 m at Lake Crescent to 1,694 m along Happy Lake Ridge. Average annual precipitation in the watershed is 224 cm/year. Three mountain lakes, ground water inflow, and surface runoff of rain and snow pack melt primarily feed Barnes Creek. The watershed is composed of the Low Olympics and Volcanics Level IV Ecoregions.

Visitation and recreational use in the Barnes Creek area is high due to easy access to Lake Crescent, numerous day hiking opportunities, and the close proximity of the Olympic National Park environmental science learning center, Nature Bridge, and the Lake Crescent Lodge. The Barnes Creek watershed has 0.9 km of roads and a road density of 0.02 km/km². While the road density is below the 50th percentile for NCCN watersheds (Rawhouser et al. 2012), roads are still of concern since State Highway 101 and a service road traverse the lower watershed. In total, the Barnes Creek watershed contains 20.2 km of trails and has a trail density of 0.5 km/km² placing it above the 90th percentile for NCCN watersheds (Rawhouser et al. 2012). In 2013, the highway carried 516,475 westbound vehicles (NPS 2014). Nine abandoned mines are also present within the Barnes Creek watershed.

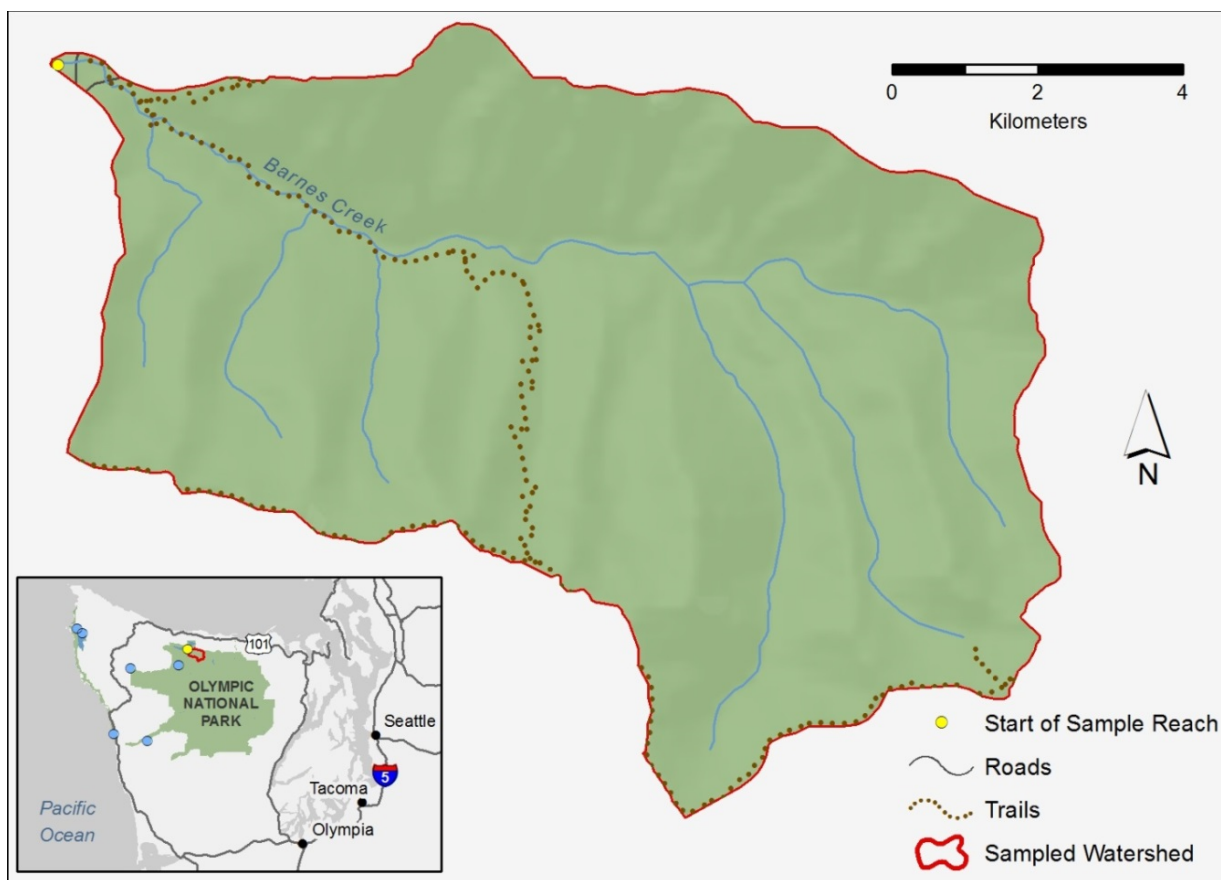


Figure 36. Barnes Creek stream location and watershed.

Biological Resources

The isolation of the Lake Crescent basin has created a unique fish community within the lake itself and its tributaries. Two distinct populations of cutthroat trout (*Oncorhynchus clarkii clarkii*), locally referred to as the Crescenti cutthroat trout, have been identified. The two populations are identified as either spring spawning or fall spawning. One endemic population of rainbow trout (*Oncorhynchus mykiss*), locally referred to as the Beardslee rainbow trout, has been identified. Kokanee (*Oncorhynchus nerka*) and the pygmy whitefish (*Prosopium coulteri*) are also present in the lake. Only one of the cutthroat trout populations, the spring spawning Crescenti, has been documented in the Barnes Creek sample reach (Table 72).

As recently as the early 1990's, the spawning abundance of the Crescenti cutthroat trout has diminished to less than 100 individuals per year.¹ The Crescenti cutthroat trout have developed a number of unique life history traits. The spring spawning population takes advantage of multiple tributaries to Lake Crescent, including Barnes Creek, and shoreline habitat on the lake. The fall

¹ Additionally, the Beardslee rainbow trout are at risk of extinction, as they are known to spawn solely in a 4000 m² section of gravel at the outlet of Lake Crescent. Their spawning numbers have also diminished to less than 100 individuals per year.

spawning population spawns solely in the lake outlet (the Lyre River) with the young migrating back to the lake to rear.

The Kokanee are known to be a crucial food-web element of the Lake Crescent ecosystem. Spawning habitat for this species is limited. They are suspected to be a shoreline spawning population, utilizing gravels located near the mouths of the tributaries to the lake, like Barnes Creek (Patrick Crain, Fisheries Biologist, Olympic National Park, email communication, 01-30-2014). Kokanee have historically been observed in Barnes Creek, but to date this has not been confirmed (Table 72) (Patrick Crain, Fisheries Biologist, Olympic National Park, email communication, 04-04-2017).

Typically in this region, several sculpin species would be expected to be present, but due to the unique geologic history of Lake Crescent, it is likely that only the Prickly Sculpin (*Cottus asper*) occurs in Barnes Creek (Table 72) (Wydoski and Whitney 2003, Patrick Crain, Fisheries Biologist, Olympic National Park, email communication, 01-30-2014).

Table 72. Fish species documented and potentially present in the Barnes Creek sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Coastal Cutthroat trout ¹	<i>Oncorhynchus clarkii clarkii</i>	X		Yes
Kokanee Salmon	<i>Oncorhynchus nerka</i>		X	Yes
Prickly sculpin	<i>Cottus asper</i>		X	Yes

¹ Spring spawning Crescent cutthroat trout.

Two amphibian species have been documented in the Barnes Creek sample reach (Galvan et al. 2005), and an additional nine species are potentially present, some of which have been documented in the larger Lake Crescent watershed (Table 73) (Leonard et al. 1993, Galvan et al. 2005, WNHP WDFW BLM 2005).

Table 73. Amphibian species documented and potentially present within the Barnes Creek sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present
Northwest salamander ¹	<i>Ambystoma gracile</i>		X
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>		X
Tailed frog ²	<i>Ascaphus truei</i>	X	
Western toad ¹	<i>Anaxyrus boreas</i>		X
Cope's giant salamander ²	<i>Dicamptodon copei</i>		X
Van Dyke's salamander ²	<i>Plethodon vandykei</i>		X
Pacific (chorus) tree frog ¹	<i>Pseudacris regilla</i>		X

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

³Documented in the larger Lake Crescent watershed.

Table 73 (continued). Amphibian species documented and potentially present within the Barnes Creek sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present
Red-legged frog ¹	<i>Rana aurora</i>		X
Cascades frog ²	<i>Rana cascadae</i>		X
Olympic torrent salamander ²	<i>Rhyacotriton olympicus</i>	X	
Rough skinned newt ¹	<i>Taricha granulosa</i>		X ³

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

³Documented in the larger Lake Crescent watershed.

Stressors of Water Quality

The largest potential impact to water quality in Barnes Creek comes from infrastructure, roads, trails, and recreational use. In operation from May to January, the Lake Crescent Lodge includes over 15 buildings and a network of paved access roads and parking lots. Some of these developments are within 10 m of the wetted channel (Figure 37). Three bridges (State Highway 101, a service road, and a trail) cross Barnes Creek within 1 km of its confluence with Lake Crescent. These structures confine Barnes Creek into a single channel, leading to channel incision and isolating the creek from its historic alluvial floodplain. This fundamentally changes the hydrologic structure and function of the creek and alters the process of gravel build up at the mouth of the creek. This gravel could be a critical element to Kokanee spawning success. Trails within this watershed are some of the most heavily used trails in OLYM, with the Barnes Creek trail being one of the only trails being accessible by wheelchair in OLYM. See comprehensive list below of stressors that may present a risk to water quality in the Barnes Creek watershed.

- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased wood.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Increased rate of non-native plant and animal invasions.
- Increased water temperature.
- Decreased dissolved oxygen.
- Runoff of applied road chemicals and deicing compounds.
- Runoff of herbicides and pesticides
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).

- Increased nutrient delivery.
- Increased introduction of pathogens from animal and human waste.
- Increased nutrient delivery.
- Introduction of chemicals from pharmaceutical waste.
- Increased amounts of organic matter.
- Decreased pH.
- Increased levels of dissolved metals.
- Increased levels of cyanide, petroleum products, oil, solvents, acids, and reagents.

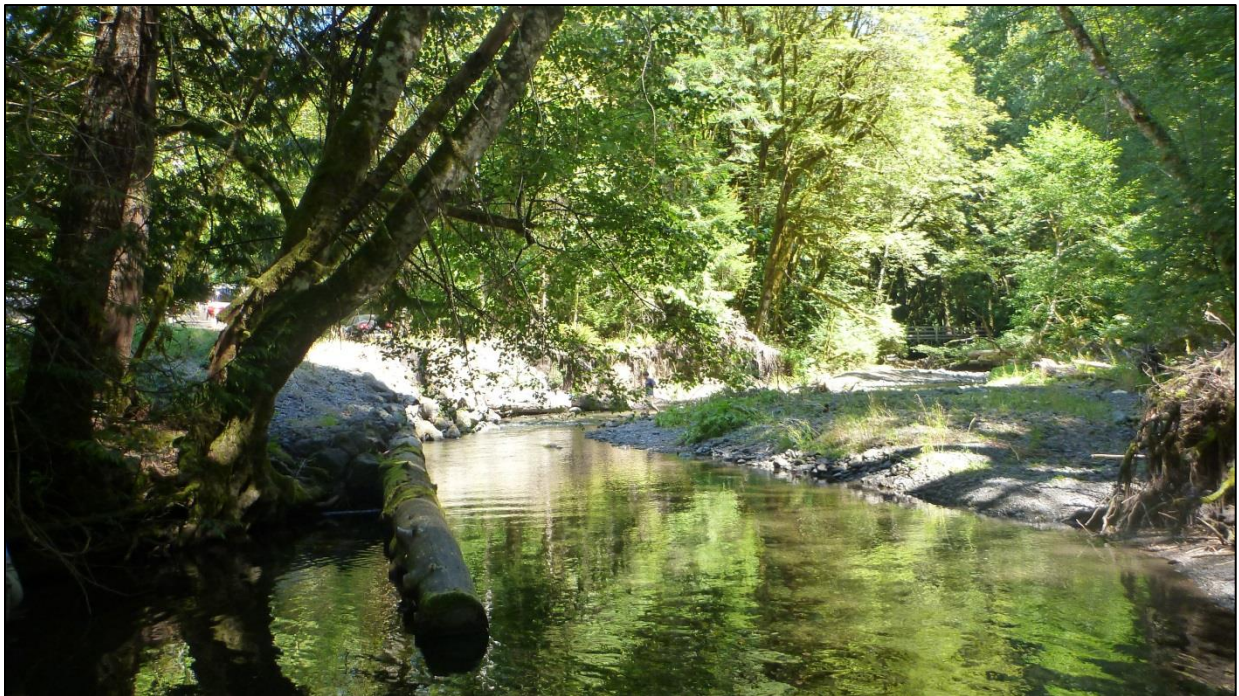


Figure 37. Photograph showing typical habitat and stressors within Barnes Creek. Bank erosion and parked cars can be seen in upper left corner.

Sample Reach Characteristics

The sample reach in Barnes Creek starts approximately 100 m upstream from its confluence with Lake Crescent, at an elevation of 180 m above sea level (Table 74). The sample reach is 400 m long and is a 3rd order stream (Strahler 1952). The sample reach runs through a broad alluvial fan and occupies a single channel, which is constrained by incision and human activities (Table 74, Figure 36).

Table 74. Physical habitat characteristics measured in 2012 for the sample reach in Barnes Creek.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	—
Easting	440,360
Northing	5,322,895
Reach Length (m)	400
Average Wetted Width (m)	9.45
Minimum (m)	4.0
Maximum (m)	19.2
Average Bankfull Width (m)	15.2
Minimum (m)	12.9
Maximum (m)	17.4
Average Thalweg Depth (m)	0.41
Minimum (m)	0.16
Maximum (m)	0.94
Valley Width (m)	61 ¹
Channel Pattern	One channel
Channel Constraint	Broad valley but constrained by incision
Constraining Feature	Human alteration
Contact with constraining feature	30%
Torrent Evidence	- Downstream contains large amounts of debris, logs and or sediment. - Trees have fallen in to channel due to scouring.

¹Valley width was estimated as total distance observer could see.

The Rapid Habitat Assessment conducted for Barnes Creek in 2012 indicated the sample reach is at the low end of optimal habitat conditions (Table 75). Even though the sample reach contained a diverse and stable habitat structure, human alteration was evident and had compromised bank stability (Figure 37).

Table 75. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Barnes Creek. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	15
Embeddedness	17
Velocity/Depth Regime	20
Sediment Deposition	13
Channel Flow Status	14
Channel Alteration	12

Table 75 (continued). Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Barnes Creek. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Frequency of Riffles (or bends)	18
Bank Stability	16
Vegetative Protection	16
Riparian Vegetated Zone Width	10

Umbrella Creek

Watershed Description

A tributary to Lake Ozette, the Umbrella Creek watershed is nested within the boundaries of the larger Ozette River watershed (Figure 38). The watershed encompasses 29.3 km² and has a range in elevation from 14 m at Lake Ozette up to 358 m. Average annual precipitation in the watershed is 269 cm/year. Ground water inflow and surface runoff of rain primarily feed Umbrella Creek. The watershed is composed of the Coastal Upland and Low Olympics Level IV Ecoregions.

The Umbrella Creek watershed is almost entirely privately held and managed as commercial forest, with a small area managed by the state of Washington (Figure 38). Human activity within the watershed consists primarily of roads, logging, and recreational activities associated with Lake Ozette. The Umbrella Creek watershed contains 120.2 km of roads and a road density of 4.11 km/km², which is the 3rd highest for all of the NCCN (Rawhouser et al. 2012). It also has 0.1 km of trails with a trail density of 0.002 km/km².

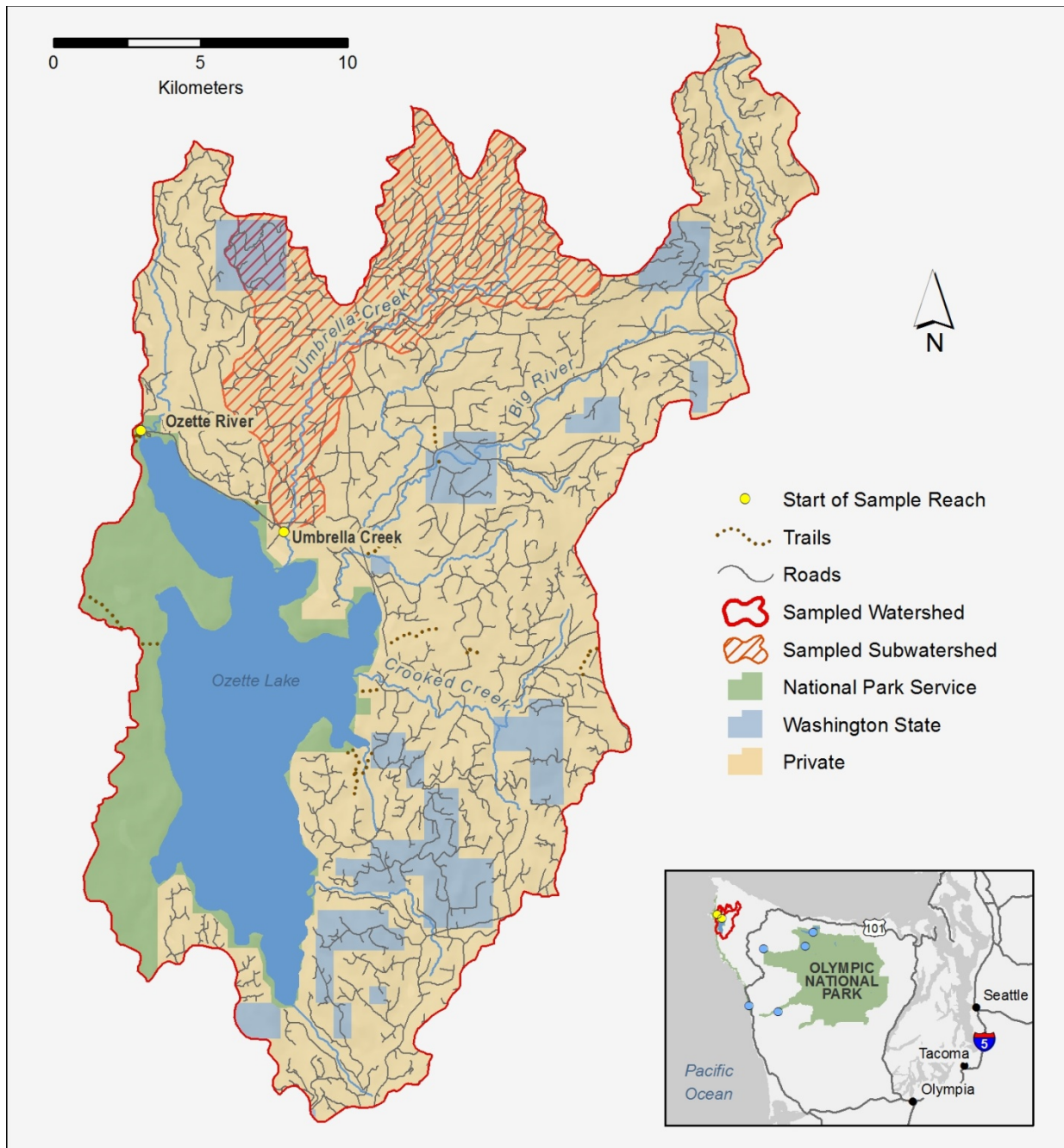


Figure 38. The Ozette River and Umbrella Creek stream locations and watersheds.

Biological Resources

Seven species of fish have been documented in the Umbrella Creek sample reach, and several other species are potentially present (Table 76) (Wydoski and Whitney 2003, Patrick Crain, Fisheries Biologist, Olympic National Park, email communication, 01-30-2014). Surveys for amphibians have not been conducted in Umbrella Creek or the surrounding watershed; but several species are likely to be found in the sample reach (Table 77) (Leonard et al. 1993, Galvan et al. 2005, WNHP WDFW BLM 2005).

Table 76. Fish species documented and potentially present in the Umbrella Creek sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
American shad	<i>Alosa sapidissima</i>		X	No
Coastrange sculpin	<i>Cottus sp.</i>		X	Yes
Prickly sculpin	<i>Cottus asper</i>		X	Yes
Slimy sculpin	<i>Cottus cognatus</i>		X	Yes
Riffle sculpin	<i>Cottus gulosus</i>		X	Yes
Reticulate sculpin	<i>Cottus perplexus</i>		X	Yes
Torrent sculpin	<i>Cottus rhotheus</i>		X	Yes
Peamouth	<i>Mylocheilus caurinus</i>	X		Yes
Olympic mudminnow	<i>Novumbra hubbsi</i>		X	Yes
Northern pikeminnow	<i>Ptychocheilus oregonensis</i>		X	Yes
Speckled dace	<i>Rhinichthys osculus</i>		X	Yes
Redside shiner	<i>Richardsonius balteatus</i>	X		Yes
Threespine stickleback	<i>Gasterosteus aculeatus</i>		X	Yes
Pacific lamprey	<i>Lampetra tridentata</i>		X	Yes
Coastal Cutthroat trout	<i>Oncorhynchus clarkii clarkii</i>	X		Yes
Chum salmon	<i>Oncorhynchus keta</i>	X		Yes
Coho salmon	<i>Oncorhynchus kisutch</i>	X		Yes
Rainbow trout/Steelhead	<i>Oncorhynchus mykiss</i>	X		Yes
Sockeye salmon	<i>Oncorhynchus nerka</i>	X		Yes

Table 77. Amphibian species potentially present within the Umbrella Creek sample reach and watershed.

Common Name	Scientific Name	Potentially Present
Northwest salamander ¹	<i>Ambystoma gracile</i>	X
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>	X
Tailed frog ²	<i>Ascaphus truei</i>	X
Western toad ¹	<i>Anaxyrus boreas</i>	X
Cope's giant salamander ²	<i>Dicamptodon copei</i>	X
Pacific (chorus) tree frog ¹	<i>Pseudacris regilla</i>	X
Red-legged frog ¹	<i>Rana aurora</i>	X
Olympic torrent salamander ²	<i>Rhyacotriton olympicus</i>	X
Rough skinned newt ¹	<i>Taricha granulosa</i>	X

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

As a tributary to Ozette Lake and a significant contributor to available sockeye salmon (*Oncorhynchus nerka*) spawning habitat, Umbrella Creek has in-depth historic information and data that addresses environmental stressors, habitat conditions, and water quality. The Lake Ozette Sockeye Limiting Factors Analysis, completed in May of 2009 for the Makah Indian Tribe and NOAA Fisheries, provides a summary of some of that information for both Umbrella Creek and the Ozette River and can be used in future evaluation of habitat conditions in these two systems (Haggerty et al. 2009).

The Washington Department of Ecology lists Umbrella Creek as impaired under section 303(d) of the Clean Water Act for water temperature exceedances and concerns about dissolved oxygen levels (WDOE 2012). These conditions are likely the result of road construction and a legacy effect from past logging practices which are the primary human activities within the watershed with the largest potential to impact water quality. See comprehensive list below of stressors that may present a risk to water quality in the Umbrella Creek watershed.

- Increased sediment deposition from mass failures.
- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Habitat fragmentation.
- Barriers to aquatic organism passage.
- Increased rate of non-native plant invasions.
- Increased water temperature.
- Decreased dissolved oxygen.
- Runoff of applied road chemicals.
- Runoff of applied herbicides and pesticides.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).
- Increased nutrient delivery.
- Increased runoff of toxic compounds from illegal dumping.
- Increased introduction of pathogens from animal and human waste.

Sample Reach Characteristics

The sample reach in Umbrella Creek starts approximately 1 km upstream from its confluence with Lake Ozette at an elevation of 20 m above sea level. The upstream extent ends just below the bridge on the Hoko Ozette Road. The sample reach length is 240 m and is a braided, 3rd order stream (Strahler 1952) that migrates across its floodplain. Torrent evidence suggests that this section of Umbrella Creek is located in a depositional zone (Table 78, Figure 39). The Rapid Habitat Assessment scores for Umbrella Creek in 2012 indicated poor habitat quality due to high rates of sediment deposition, low pool variability, low channel flow, lack of sinuosity, and limited habitat diversity (Table 79).

Table 78. Physical habitat characteristics measured in 2012 for the sample reach in Umbrella Creek.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	–
Easting	379129
Northing	5332499
Reach Length (m)	240
Average Wetted Width (m)	7.54
Minimum (m)	2.6
Maximum (m)	16.0
Average Bankfull Width (m)	16.1
Minimum (m)	10.6
Maximum (m)	20.7
Average Thalweg Depth (m)	0.39
Minimum (m)	0.13
Maximum (m)	0.82
Valley Width (m)	50 ¹
Channel Pattern	Braided channel
Channel Constraint	Broad valley but constrained by incision
Constraining Feature	Terrace/alluvial fan
Contact with constraining feature	100%
Torrent Evidence	• Gravel and cobble berms above bankfull level. • Trees have fallen into channel due to scouring. • Massive deposits of debris, logs and or sediment within reach. • Stream eroding newly laid matrix supported deposits.

¹Valley width was estimated as total distance observer could see.



Figure 39. Photograph showing typical habitat and gravel deposition within the Umbrella Creek sample reach.

Table 79. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Umbrella Creek. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	12
Pool Substrate Characterization	15
Pool Variability	11
Sediment Deposition	7
Channel Flow Status	9
Channel Alteration	15
Channel Sinuosity	6
Bank Stability	12
Vegetative Protection	16
Riparian Vegetated Zone Width	20

Ozette River

Watershed Description

The Ozette River is the outlet for Lake Ozette and flows directly into the Pacific Ocean (Figure 38). The Ozette River watershed encompasses 220.3 km² and ranges in elevation from 2 to 593 m above sea level. Annual precipitation in the watershed is 260 cm/year. The river is fed by Ozette Lake,

which is primarily fed by ground water inflow and surface runoff of rain. The watershed is composed of the Coastal Lowlands, Coastal Uplands and the Low Olympics Level IV Ecoregions.

The Ozette River watershed primarily consists of privately held commercial forest, with smaller sections managed by the state of Washington (Figure 38). The Lake Ozette shoreline is owned and managed by the NPS. The Ozette district of OLYM is a popular destination, with 60,412 recreational visitors in 2012 (NPS 2014) using the area for boating, fishing, camping, hiking, and staying at the Lost Resort located on Lake Ozette. The watershed has 585 km of roads with a road density of 2.66 km/km². This road density is above the 90th percentile for NCCN watersheds (Rawhouser et al. 2012). The watershed also has 10.5 km of trails and a trail density of 0.05 km/km².

Biological Resources

Eleven fish species have been documented in the Ozette River sample reach, and several others are potentially present (Table 80) (Wydoski and Whitney 2003, Patrick Crain, Fisheries Biologist, Olympic National Park, email communication, 01-30-2014). Surveys within the Ozette River watershed have documented four different species of amphibians (Galvan et al. 2005), though none have been documented in the sample reach (Table 81). Five additional species may also be present in the sample reach (Table 81) (Leonard et al. 1993, Galvan et al. 2005, WNHP WDFW BLM 2005).

Table 80. Fish species documented and potentially present in the Ozette River sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Largemouth bass	<i>Micropterus salmoides</i>		X	No
American shad	<i>Alosa sapidissima</i>	X		No
Coastrange sculpin	<i>Cottus aleuticus</i>		X	Yes
Prickly sculpin	<i>Cottus asper</i>		X	Yes
Slimy sculpin	<i>Cottus cognatus</i>		X	Yes
Reticulate sculpin	<i>Cottus perplexus</i>		X	Yes
Torrent sculpin	<i>Cottus rhotheus</i>		X	Yes
Peamouth	<i>Mylocheilus caurinus</i>	X		Yes
Olympic mudminnow	<i>Novumbra hubbsi</i>		X	Yes
Northern pikeminnow	<i>Ptychocheilus oregonensis</i>	X		Yes
Redside shiner	<i>Richardsonius balteatus</i>	X		Yes
Threespine stickleback	<i>Gasterosteus aculeatus</i>		X	Yes
Yellow bullhead	<i>Ictalurus natalis</i>		X	No
Yellow perch	<i>Perca flavescens</i>		X	No
Pacific lamprey	<i>Lampetra tridentata</i>	X		Yes
Coastal Cutthroat trout	<i>Oncorhynchus clarkii clarkii</i>	X		Yes
Chum salmon	<i>Oncorhynchus keta</i>	X		Yes
Coho salmon	<i>Oncorhynchus kisutch</i>	X		Yes
Rainbow trout/Steelhead	<i>Oncorhynchus mykiss</i>	X		Yes

Table 80 (continued). Fish species documented and potentially present in the Ozette River sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Sockeye salmon	<i>Oncorhynchus nerka</i>	X		Yes
Chinook salmon	<i>Oncorhynchus tshawytscha</i>	X		Yes

Table 81. Amphibian species documented and potentially present within the Ozette River sample reach and watershed.

Common Name	Scientific Name	Documented in Watershed	Potentially Present
Northwest salamander ¹	<i>Ambystoma gracile</i>	X	
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>		X
Tailed frog ²	<i>Ascaphus truei</i>		X
Western toad ¹	<i>Anaxyrus boreas</i>	X	
Cope's giant salamander ²	<i>Dicamptodon copei</i>		X
Pacific (chorus) tree frog ¹	<i>Pseudacris regilla</i>	X	
Red-legged frog ¹	<i>Rana aurora</i>	X	
Olympic torrent salamander ²	<i>Rhyacotriton olympicus</i>		X
Rough skinned newt ¹	<i>Taricha granulosa</i>		X

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

The Washington Department of Ecology lists the Ozette River as impaired under section 303(d) of the Clean Water Act for water temperature exceedances, and concerns about dissolved oxygen and pH levels (WDOE 2012). Lake Ozette is also listed for elevated levels of mercury (WDOE 2012). Potential impact to water quality in the Ozette River comes from roads, trails, forestry, NPS infrastructure, and visitor use, as well as legacy effects from past human activities. It is likely that habitat conditions within the lake have been significantly impacted over the years from the historic practice of large woody debris (LWD) removal in the 1800s and 1900s and as recently as 1985 (Kramer 1953, Haggerty et al. 2009). Absence of LWD, low pool frequency, and limited refuge cover are all consequences of the historic practice of wood removal. See comprehensive list below of stressors that may present a risk to water quality in the Ozette River watershed.

- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.

- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Increased rate of non-native plant invasions.
- Increased water temperature.
- Decreased dissolved oxygen.
- Runoff of applied road chemicals and deicing compounds.
- Runoff of applied herbicides and pesticides.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).
- Increased nutrient delivery.
- Increased runoff of toxic compounds from illegal dumping.

Sample Reach Characteristics

The sample reach begins at an elevation of 20 m above sea level, at the confluence with Lake Ozette, and is 500 m in length. The sample reach is a 3rd order river (Strahler 1952) that occupies a single channel and is constrained by incision into an alluvial terrace (Table 82).

Table 82. Physical habitat characteristics measured in 2012 for the sample reach in the Ozette River.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	
Easting	375816
Northing	5334717
Reach Length (m)	500
Average Wetted Width (m)	16.9
Minimum (m)	12.1
Maximum (m)	23.5
Average Bankfull Width (m)	26.6
Minimum (m)	25.7
Maximum (m)	26.6
Average Thalweg Depth (m)	0.85
Minimum (m)	0.50
Maximum (m)	1.25
Valley Width (m)	>500 ¹
Channel Pattern	One channel
Channel Constraint	Broad valley but constrained by incision
Constraining Feature	Terrace/alluvial fan
Contact with constraining feature	100%

Table 82 (continued). Physical habitat characteristics measured in 2012 for the sample reach in the Ozette River.

Physical Habitat Characterization Parameters	Values
Torrent Evidence	• Channel has little evidence of pool riffle structure. • Massive deposits of debris, logs and/or sediment w/in reach. • Stream eroding newly laid matrix supported deposits.

¹Valley width was estimated as total distance observer could see.

The Rapid Habitat Assessment conducted for the Ozette River in 2012 indicated that the sample reach was in marginal condition due to low pool variability, low channel sinuosity, uniform habitat conditions, and poor vegetative protection within the riparian zone. Although some of these traits may be natural conditions representative of low gradient rivers in the Coastal Lowlands Ecoregion, some may be attributed to human activity. For example, the lack of LWD originating from large diameter (>2 m) coniferous trees is one reason this reach has low habitat diversity and is likely caused by historic logging, development, and the systematic removal of wood from the channel in the early 1950s (Kramer 1953, Haggerty et al. 2009). The prevalence of reed canary grass, a non-native invasive species, in this reach also impacts habitat quality (Table 83, Figure 40). Reed canary grass excludes native vegetation from growing, provides poor cover and shading within the riparian zone, and islands of reed canary grass within the channel may be affecting sediment transport.

Table 83. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Ozette River. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	15
Pool Substrate Characterization	13
Pool Variability	7
Sediment Deposition	8
Channel Flow Status	16
Channel Alteration	15
Channel Sinuosity	7
Bank Stability	14
Vegetative Protection	10
Riparian Vegetated Zone Width	20



Figure 40. Uniform habitat conditions in the Ozette River sample reach. Example of reed canary grass island can be seen in the lower left corner of the image.

Kalaloch Creek

Watershed Description

Kalaloch Creek drains directly into the Pacific Ocean. The watershed encompasses 44.5 km² and ranges in elevation from 2 to 445 m. Average annual precipitation in the watershed is 297 cm/year. Ground water inflow and surface runoff of rain primarily feed Kalaloch Creek. The watershed is composed of the Coastal Lowlands, the Coastal Uplands and the Low Olympics Level IV Ecoregions.

The Kalaloch Creek watershed is primarily composed of state and privately held forestland with a small portion managed by the NPS (Figure 41). Human activity within the watershed consists of roads and NPS infrastructure; infrastructure includes seasonal housing, maintenance facilities, and a water treatment plant that withdrew water from the creek up until the summer of 2014. Water withdrawal from the creek has been replaced by a well water system. The watershed contains 117.2 km of roads and has a road density of 2.63 km/km², which is above the 90th percentile for NCCN watersheds (Rawhouser et al. 2012). Though not in the watershed delineated for the stream location, State Highway 101 does cross Kalaloch Creek downstream from the sample reach. The watershed

also contains 0.8 km of trails and has a trail density of 0.02 km/km². Proximity to a major state highway, access to the Pacific Ocean, the Kalaloch Lodge, as well as a small NPS visitor center and facilities make this a popular recreation destination for park visitors.

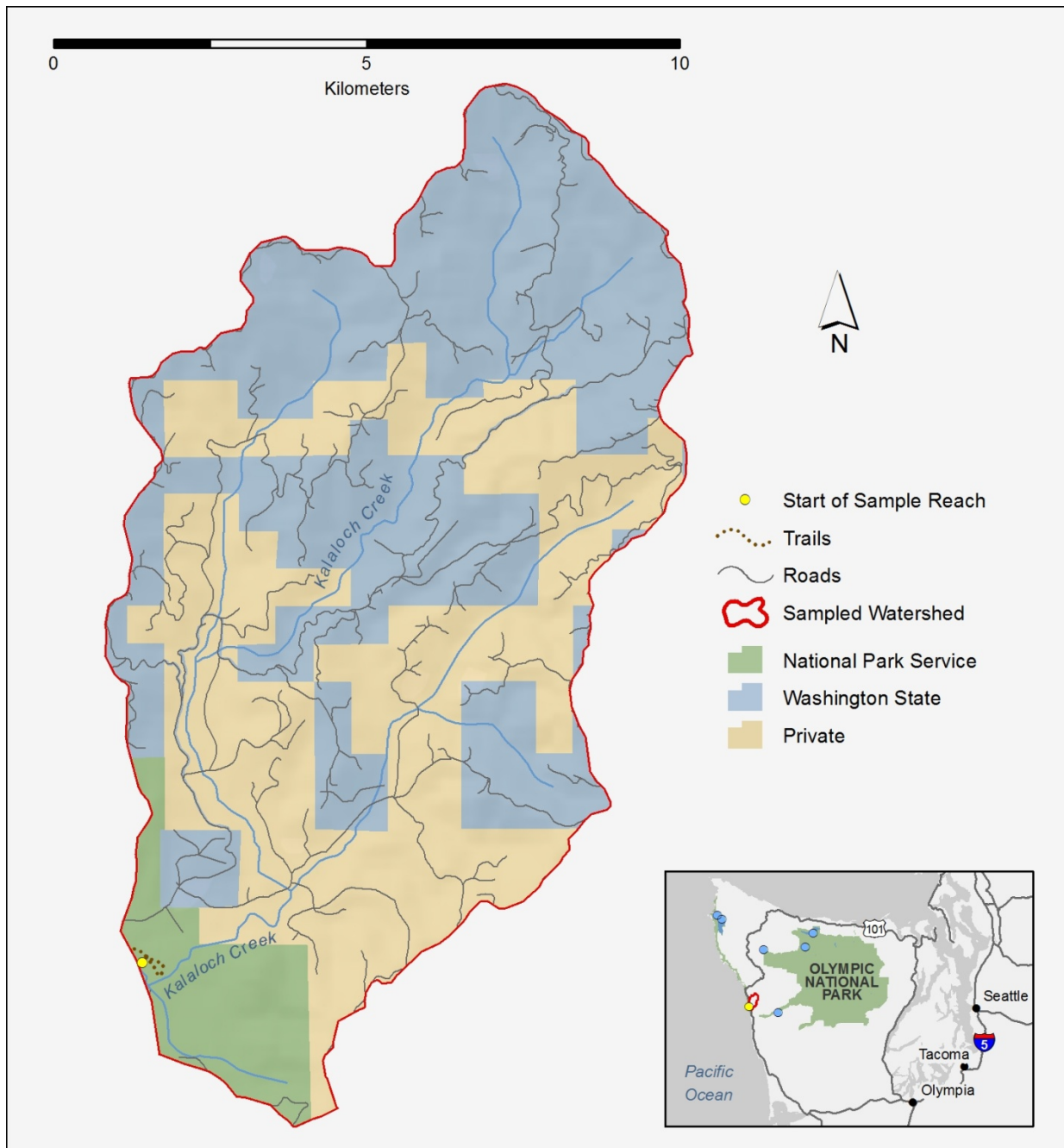


Figure 41. Kalaloch Creek stream location and watershed.

Biological Resources

Many fish have been documented in Kalaloch Creek, but little is known about the presence of amphibian species. Six species of fish have been documented in the reach, including the Federally

Threatened bull trout, and several others are potentially present (Table 84) (Wydoski and Whitney 2003, Patrick Crain, Fisheries Biologist, Olympic National Park, email communication, 01-30-2014). Due to the lack of public land, amphibian surveys have been limited, and only the red-legged frog has been documented in the sample reach (Table 85) (Galvan et al. 2005). Information on regional distributions and habitat requirements indicate that seven additional amphibian species have the potential to be present in this area (Table 106) (Leonard et al. 1993, Galvan et al. 2005, WNHP WDFW BLM 2005).

Table 84. Fish species documented and potentially present in the Kalaloch Creek sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Coastrange sculpin	<i>Cottus aleuticus</i>		X	Yes
Prickly sculpin	<i>Cottus asper</i>		X	Yes
Slimy sculpin	<i>Cottus cognatus</i>		X	Yes
Reticulate sculpin	<i>Cottus perplexus</i>		X	Yes
Torrent sculpin	<i>Cottus rhotheus</i>		X	Yes
Pacific lamprey	<i>Lampetra tridentata</i>	X		Yes
Coastal Cutthroat trout	<i>Oncorhynchus clarkii clarkii</i>	X		Yes
Coho salmon	<i>Oncorhynchus kisutch</i>	X		Yes
Rainbow trout/Steelhead	<i>Oncorhynchus mykiss</i>	X		Yes
Bull trout	<i>Salvelinus confluentus</i>	X		Yes

Table 85. Amphibian species documented and potentially present within the Kalaloch Creek sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present
Northwest salamander ¹	<i>Ambystoma gracile</i>		X
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>		X
Tailed frog ²	<i>Ascaphus truei</i>		X
Western toad ¹	<i>Anaxyrus boreas</i>		X
Pacific (chorus) tree frog ¹	<i>Pseudacris regilla</i>		X
Red-legged frog ¹	<i>Rana aurora</i>	X	
Olympic torrent salamander ²	<i>Rhyacotriton olympicus</i>		X
Rough skinned newt ¹	<i>Taricha granulosa</i>		X

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

The Washington Department of Ecology lists Kalaloch Creek as impaired under section 303(d) of the Clean Water Act for water temperature exceedances (WDOE 2012). The largest potential impact to

water quality in Kalaloch Creek comes from road development and forestry practices in the watershed, and to a lesser extent, from NPS infrastructure and recreational use. See comprehensive list below of stressors that may present a risk to water quality in the Kalaloch Creek watershed.

- Increased sediment deposition from mass failures.
- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Habitat fragmentation.
- Barriers to aquatic organism passage.
- Increased rate of non-native plant and animal invasions.
- Increased water temperature.
- Decreased dissolved oxygen.
- Runoff of applied road chemicals and deicing compounds.
- Runoff of applied herbicides and pesticides.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).
- Increased nutrient delivery.
- Increased introduction of pathogens from animal and human waste.
- Introduction of chemicals from pharmaceutical waste.
- Increased runoff of toxic compounds from illegal dumping.

Sample Reach Characteristics

The sample reach in Kalaloch Creek starts approximately 1 km upstream from the creek mouth at the Pacific Ocean and is at 6 m above sea level, which is beyond the influence of saltwater. The sample reach is 400 m long and is a 3rd order stream (Strahler 1952) occupying a single channel, which is incised into a broad terrace (Table 86, Figure 41). The Rapid Habitat Assessment conducted for Kalaloch Creek in 2012 indicated optimal to sub-optimal conditions within the sample reach (Table 87, Figure 42).

Table 86. Physical habitat characteristics measured in 2012 for the sample reach in Kalaloch Creek.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	—
Easting	397142
Northing	5,273,439
Reach Length (m)	400
Average Wetted Width (m)	12.2
Minimum (m)	8.8
Maximum (m)	19.1
Average Bankfull Width (m)	18.3
Minimum (m)	15.5
Maximum (m)	22.0
Average Thalweg Depth (m)	0.74
Minimum (m)	0.30
Maximum (m)	1.40
Valley Width (m)	>500 ¹
Channel Pattern	One channel
Channel Constraint	Broad valley but constrained by incision
Constraining Feature	Hill slope and Terrace/alluvial fan
Contact with constraining feature	75%
Torrent Evidence	• Trees have fallen into channel due to scouring. • Massive deposits of debris, logs and or sediment within reach.

¹Valley width was estimated as total distance observer could see.



Figure 42. Kalaloch Creek, looking downstream into the sample reach.

Table 87. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Kalaloch Creek. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	18
Pool Substrate Characterization	14
Pool Variability	17
Sediment Deposition	14
Channel Flow Status	14
Channel Alteration	19
Channel Sinuosity	7
Bank Stability	18
Vegetative Protection	18
Riparian Vegetated Zone Width	16

Matheny Creek

Watershed Description

The Matheny Creek watershed ranges in elevation from 51 to 991 m and encompasses 95.2 km². Average annual precipitation in the watershed is 379 cm/year. Ground water inflow and surface runoff of rain primarily feed Matheny Creek, a tributary to the Queets River. The watershed is composed of the Coastal Uplands and Low Olympics Level IV Ecoregions.

The majority of the Matheny Creek watershed is managed by the USFS and the Washington State Department of Natural Resources (Figure 43). Human activity within the watershed consists primarily of roads and logging. The Matheny Creek watershed contains 178.1 km of roads and has a road density of 1.87 km/km², which is above the 80th percentile for NCCN watersheds (Rawhouser et al. 2012).

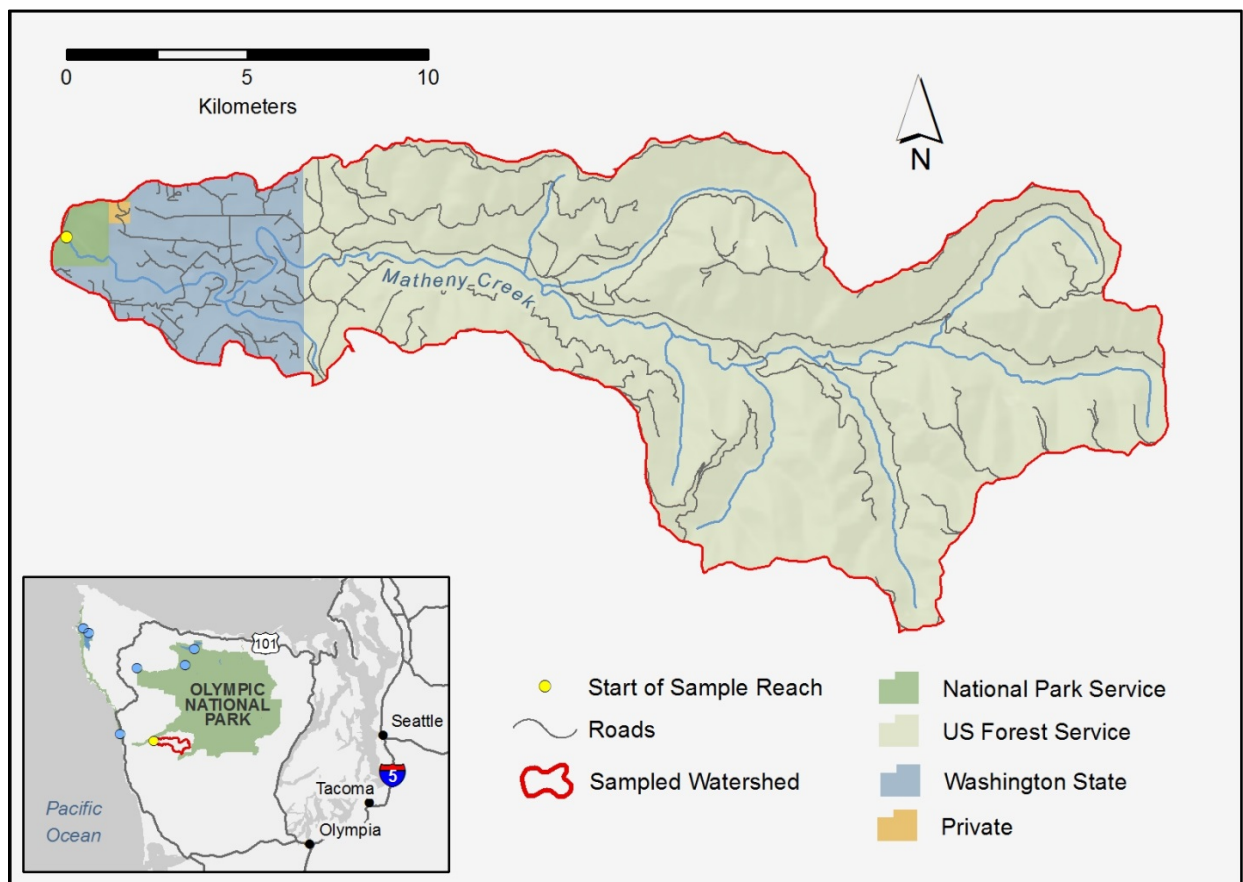


Figure 43. The Matheny Creek stream location and watershed.

Biological Resources

Eight species of fish have been documented in the Matheny Creek sample reach and several others are potentially present (Table 88) (Wydoski and Whitney 2003, Patrick Crain, Fisheries Biologist, Olympic National Park, unpublished data on file at OLYM, email communication, 01-30-2014). Four species of amphibians have been documented in the Matheny Creek sample reach (Table 89) (Galvan

et al. 2005), and six additional species are potentially present (Table 89) (Leonard et al. 1993, Galvan et al. 2005, WNHP WDFW BLM 2005).

Table 88. Fish species documented and potentially present in the Matheny Creek sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Largescale sucker	<i>Catostomus macrocheilus</i>		X	Yes
Coastrange sculpin	<i>Cottus aleuticus</i>		X	Yes
Prickly sculpin	<i>Cottus asper</i>		X	Yes
Slimy sculpin	<i>Cottus cognatus</i>		X	Yes
Reticulate sculpin	<i>Cottus perplexus</i>		X	Yes
Torrent sculpin	<i>Cottus rhotheus</i>		X	Yes
Longnose dace	<i>Rhinichthys cataractae</i>		X	Yes
Speckled dace	<i>Rhinichthys osculus</i>	X		Yes
Western brook lamprey	<i>Lampetra richardsoni</i>		X	Yes
Pacific lamprey	<i>Lampetra tridentata</i>		X	Yes
Coastal Cutthroat trout	<i>Oncorhynchus clarkii clarkii</i>	X		Yes
Chum salmon	<i>Oncorhynchus keta</i>	X		Yes
Coho salmon	<i>Oncorhynchus kisutch</i>	X		Yes
Rainbow trout/Steelhead	<i>Oncorhynchus mykiss</i>	X		Yes
Chinook salmon	<i>Oncorhynchus tshawytscha</i>	X		Yes
Mountain whitefish	<i>Prosopium williamsoni</i>	X		Yes
Bull trout	<i>Salvelinus confluentus</i>	X		Yes

Table 89. Amphibian species documented and potentially present within the Matheny Creek sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present
Northwest salamander ¹	<i>Ambystoma gracile</i>		X
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>		X
Tailed frog ²	<i>Ascaphus truei</i>		X
Western toad ¹	<i>Anaxyrus boreas</i>	X	
Cope's giant salamander ²	<i>Dicamptodon copei</i>		X
Pacific (chorus) tree frog ¹	<i>Pseudacris regilla</i>	X	
Red-legged frog ¹	<i>Rana aurora</i>	X	
Cascades frog ²	<i>Rana cascadae</i>		X
Olympic torrent salamander ²	<i>Rhyacotriton olympicus</i>	X	
Rough skinned newt ¹	<i>Taricha granulosa</i>		X

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

The Washington Department of Ecology lists Matheny Creek as impaired under section 303(d) of the Clean Water Act for water temperature exceedances (WDOE 2012). Legacy effects from historic forest practices and road development are considered the primary stressors within the Matheny Creek watershed with the largest potential to impact water quality and are likely the cause of the 303(d) violations. See comprehensive list below of stressors that may present a risk to water quality in the Matheny Creek watershed.

- Increased sediment deposition from mass failures.
- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Habitat fragmentation.
- Barriers to aquatic organism passage.
- Increased rate of non-native plant invasions.
- Increased water temperature.
- Decreased dissolved oxygen.
- Runoff of applied road chemicals and deicing compounds.
- Runoff of applied herbicides and pesticides
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).
- Increased nutrient delivery.
- Increased runoff of toxic compounds from illegal dumping.

Sample Reach Characteristics

The Matheny Creek sample reach starts at 55 m above sea level approximately 50 m upstream from the confluence with the Queets River. The sample reach is 500 m long and is a 3rd order stream (Strahler 1952) that occupies an anastomosing channel, flowing largely unconstrained through a broad floodplain (Table 90).

Table 90. Physical habitat characteristics measured in 2012 for the sample reach in Matheny Creek.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	–
Easting	416951
Northing	5269731
Reach Length (m)	500
Average Wetted Width (m)	16.0
Minimum (m)	12.5
Maximum (m)	18.7
Average Bankfull Width (m)	42
Minimum (m)	35
Maximum (m)	49.7
Average Thalweg Depth (m)	0.61
Minimum (m)	0.34
Maximum (m)	1.25
Valley Width (m)	600 ¹
Channel Pattern	Anastomosing channel
Channel Constraint	Broad valley and unconstrained
Constraining Feature	None
Contact with constraining feature.	n/a
Torrent Evidence	No evidence of torrent scouring or torrent deposits

¹Valley width was estimated as total distance observer could see.

The Rapid Habitat Assessment conducted for Matheny Creek in 2012 indicated optimal to sub-optimal habitat conditions within the sample reach (Table 91). Stable and diverse habitat was created by a high diversity of velocity and depth regimes as well as a high frequency of riffle habitat. However, bank stability was compromised by lack of vegetative protection, and channel flow status was low, resulting in expansive areas of exposed gravel bars (Figure 44).

Table 91. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Matheny Creek. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	20
Embeddedness	19
Velocity/Depth Regime	18
Sediment Deposition	13
Channel Flow Status	7
Channel Alteration	18
Frequency of Riffles (or bends)	16

Table 91 (continued). Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for Matheny Creek. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Bank Stability	12
Vegetative Protection	11
Riparian Vegetated Zone Width	20



Figure 44. Habitat representative of the sample reach within Matheny Creek.

South Fork Calawah River

Watershed Description

The South Fork Calawah River is a tributary to the Quillayute River. The watershed encompasses 155.2 km² and has a range in elevation from 122 to 1,149 m. Average annual precipitation in the watershed is 351 cm/year. Ground water inflow and surface runoff of rain primarily feed the South Fork Calawah River. The watershed is composed entirely of the Low Olympics Level IV Ecoregion.

The watershed is composed entirely of federal lands managed by the Olympic National Forest and the NPS (Figure 45). Human activity within the watershed consists primarily of roads and trails. The watershed has 122.7 km of roads with a road density of 0.79 km/km². The road density is above the 70th for NCCN watersheds (Rawhouser et al. 2012). It also has 8.8 km of trails with a trail density of 0.06 km/km².

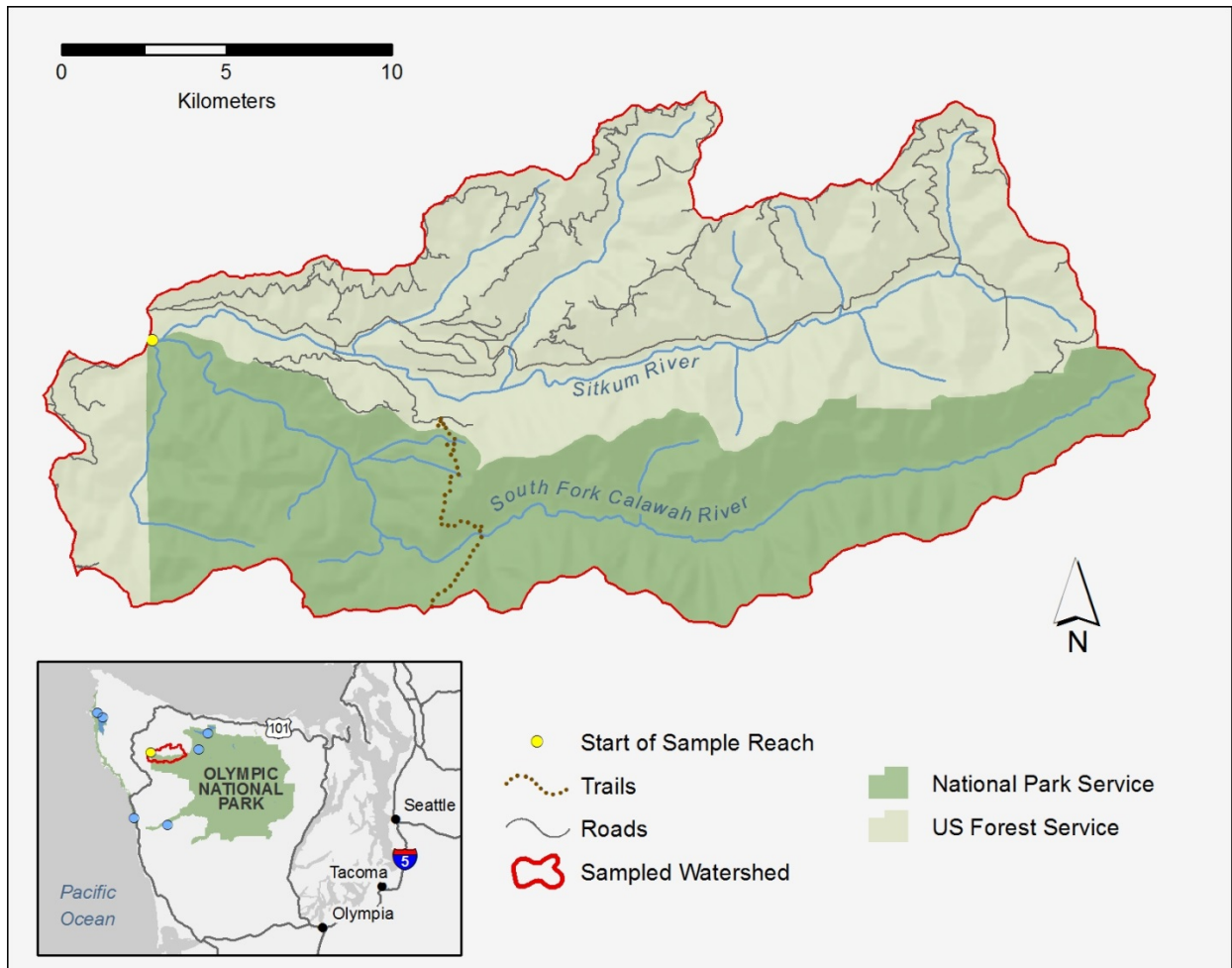


Figure 45. The South Fork Calawah River stream location and watershed.

Biological Resources

Seven species of fish have been documented in the sample reach, and several others are potentially present (Table 92) (Wydoski and Whitney 2003, Patrick Crain, Fisheries Biologist, Olympic National Park, unpublished data on file at OLYM, email communication, 01-30-2014). Only one species of amphibian has been documented in the South Fork Calawah River watershed (Table 93) (Galvan et al. 2005); however, regional distribution data and habitat requirements indicate that ten additional species are potentially present in the area (Table 93) (Leonard et al. 1993, Galvan et al. 2005, WNHP WDFW BLM 2005).

Table 92. Fish species documented and potentially present in the South Fork Calawah River sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Coastrange sculpin	<i>Cottus aleuticus</i>		X	Yes
Prickly sculpin	<i>Cottus asper</i>		X	Yes
Slimy sculpin	<i>Cottus cognatus</i>		X	Yes
Riffle sculpin	<i>Cottus gulosus</i>		X	Yes
Longnose dace	<i>Rhinichthys cataractae</i>	X		Yes
Pacific lamprey	<i>Lampetra tridentata</i>		X	Yes
Coastal Cutthroat trout	<i>Oncorhynchus clarkii clarkii</i>	X		Yes
Coho salmon	<i>Oncorhynchus kisutch</i>	X		Yes
Summer and Winter Steelhead	<i>Oncorhynchus mykiss</i>	X		Yes
Sockeye salmon	<i>Oncorhynchus nerka</i>	X		Yes
Chinook salmon	<i>Oncorhynchus tshawytscha</i>	X		Yes
Mountain whitefish	<i>Prosopium williamsoni</i>	X		Yes

Table 93. Amphibian species documented and potentially present within the South Fork Calawah River sample reach and watershed.

Common Name	Scientific Name	Documented in Watershed	Potentially Present
Northwest salamander ¹	<i>Ambystoma gracile</i>		X
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>		X
Tailed frog ²	<i>Ascaphus truei</i>		X
Western toad ¹	<i>Anaxyrus boreas</i>		X
Cope's giant salamander ²	<i>Dicamptodon copei</i>		X
Van Dyke's salamander ²	<i>Plethodon vandykei</i>		X
Pacific (chorus) tree frog ¹	<i>Pseudacris regilla</i>		X
Red-legged frog ¹	<i>Rana aurora</i>		X
Cascades frog ²	<i>Rana cascadae</i>		X
Olympic torrent salamander ²	<i>Rhyacotriton olympicus</i>	X	
Rough skinned newt ¹	<i>Taricha granulosa</i>		X

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Site Stressors

The greatest threats to water quality in the South Fork Calawah River arise from commercial forestry and road development (Figure 45). The Washington Department of Ecology lists South Fork Calawah River as impaired under section 303(d) of the Clean Water Act for water temperature exceedances (WDOE 2012). See comprehensive list below of stressors that may present a risk to water quality in the South Fork Calawah River watershed.

- Increased sediment deposition from mass failures.
- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Habitat fragmentation.
- Barriers to aquatic organism passage.
- Increased rate of non-native plant invasions.
- Increased water temperature.
- Decreased dissolved oxygen.
- Runoff of applied road chemicals and deicing compounds.
- Runoff of applied herbicides.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).
- Increased nutrient delivery.
- Increased runoff of toxic compounds from illegal dumping.

Sample Reach Characteristics

The South Fork Calawah River sample reach starts at an elevation 122 m above sea level and is 500 m long. Located in the bottom of a V-shaped valley, the reach is a 4th order stream (Strahler 1952) that occupies a single channel and is constrained by bedrock and boulders (Table 94 and Figure 46). The sample reach also shows evidence of scour and erosion that likely reduces the extent of pool-riffle habitat (Table 94).

Table 94. Physical habitat characteristics measured in 2012 for the sample reach in the South Fork Calawah River.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	
Easting	406679
Northing	5312032
Reach Length (m)	500

Table 94 (continued). Physical habitat characteristics measured in 2012 for the sample reach in the South Fork Calawah River.

Physical Habitat Characterization Parameters	Values
Average Wetted Width (m)	21.6
Minimum (m)	10.0
Maximum (m)	31.6
Average Bankfull Width (m)	26.2
Minimum (m)	22.0
Maximum (m)	29.9
Average Thalweg Depth (m)	0.85
Minimum (m)	0.25
Maximum (m)	1.7
Valley Width (m)	47.7
Channel Pattern	One channel
Channel Constraint	Very constrained in a V-shaped valley
Constraining Feature	Bedrock an and hill slope
Contact with constraining feature	90%
Torrent Evidence	• Channel has little evidence of pool-riffle structure. • Channel scoured to bedrock. • Gravel and cobble berms above bankfull level.



Figure 46. South Fork Calawah River habitat, showing bedrock constraints on right side of photograph.

The Rapid Habitat Assessment conducted for the South Fork Calawah River in 2012 indicated overall sub-optimal habitat conditions (Table 95). Pool variability and sinuosity were scored low, indicating a lack of diversity in available habitat. Additionally, low channel flow status led to a relatively small wetted width for the channel size, creating expansive gravel bars (Figure 46).

Table 95. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the South Fork Calawah River. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	11
Pool Substrate Characterization	16
Pool Variability	14
Sediment Deposition	11
Channel Flow Status	9
Channel Alteration	18

Table 95 (continued). Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the South Fork Calawah River. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Channel Sinuosity	10
Bank Stability	20
Vegetative Protection	20
Riparian Vegetated Zone Width	20

Sol Duc River

Watershed Description

The Sol Duc River watershed encompasses 61.1 km² and ranges in elevation from 469 to 1,863 m at Happy Lake Ridge. Average annual precipitation in the watershed is 380 cm/year. Ground water inflow, over a dozen mountain lakes, and surface runoff from rainfall and snow pack melt primarily feed the Sol Duc River. The watershed is composed of the Low Olympics and High Olympics Level IV Ecoregions.

The Sol Duc River watershed above the sample reach is entirely managed by the NPS (Figure 47). Human activity within the watershed consists of trails, roads, park infrastructure, and recreational use. The Sol Duc Hot Springs Resort, several popular day hikes within the watershed, and other backpacking access points make this a popular recreation destination for visitors. The watershed contains 6.1 km of roads with a road density of 0.10 km/km², which is above the 50th percentile for NCCN watersheds (Rawhouser et al. 2012). In total, the Sol Duc River watershed contains 32.7 km of trails and has a trail density of 0.54 km/km², which is above the 90th percentile for NCCN watersheds (Rawhouser et al. 2012). One abandoned mine is also located in the watershed.

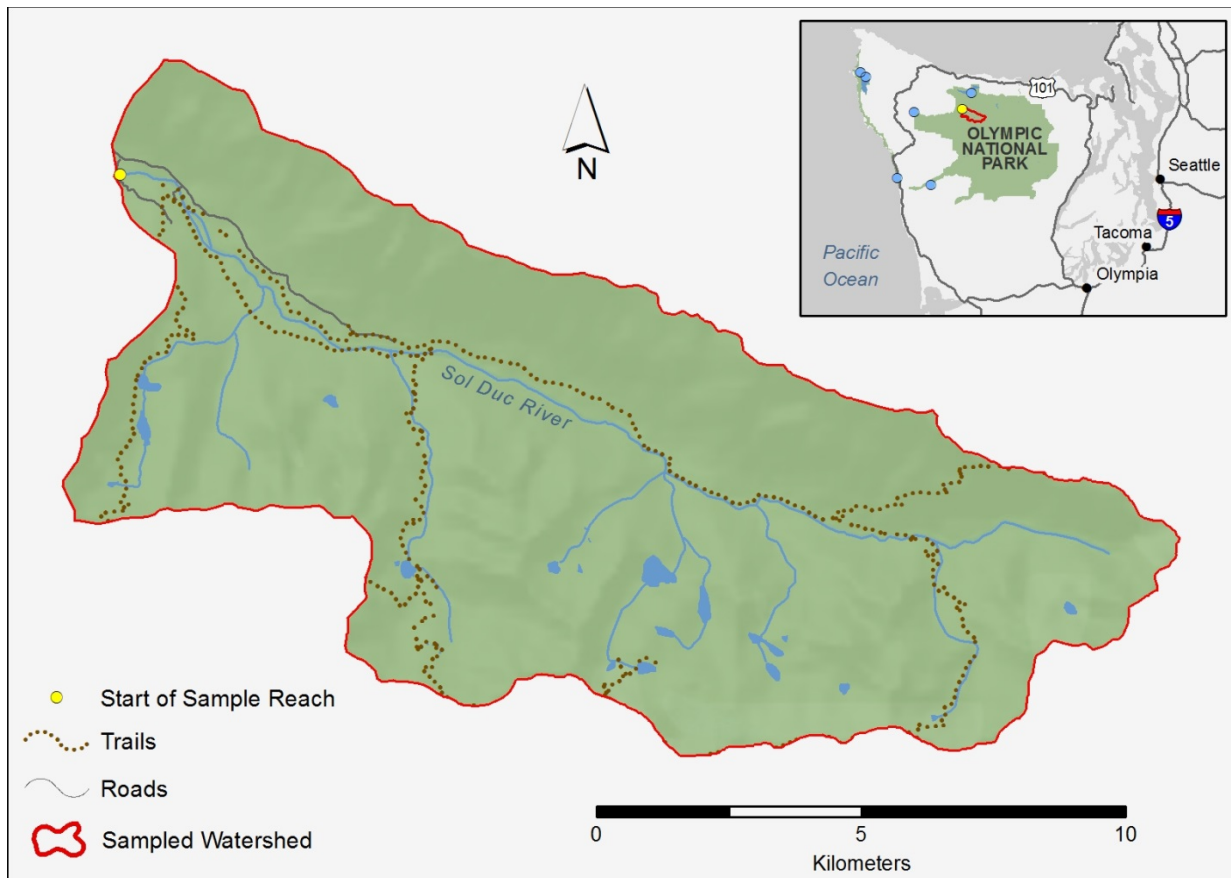


Figure 47. The Sol Duc River stream location and watershed.

Biological Resources

Four species of fish have been documented in this sample reach, and several additional species are potentially present (Table 96) (Wydoski and Whitney 2003, Patrick Crain, Fisheries Biologist, Olympic National Park, unpublished data on file at OLYM, email communication, 01-30-2014). Two amphibian species have been documented in the Sol Duc River sample reach, and nine additional species have been documented in the watershed (Table 97) (Leonard et al. 1993, Galvan et al. 2005, WNHP WDFW BLM 2005).

Table 96. Fish species potentially present and documented in the Sol Duc River sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Potentially Present	Native
Prickly sculpin	<i>Cottus asper</i>		X	Yes
Slimy sculpin	<i>Cottus cognatus</i>		X	Yes
Shorthead sculpin	<i>Cottus confusus</i>		X	Yes
Coastal Cutthroat trout	<i>Oncorhynchus clarkii clarkii</i>	X		Yes
Coho salmon	<i>Oncorhynchus kisutch</i>	X		Yes
Rainbow trout/Steelhead	<i>Oncorhynchus mykiss</i>	X		Yes
Chinook salmon	<i>Oncorhynchus tshawytscha</i>	X		Yes

Table 97. Amphibian species documented and potentially present within the Sol Duc River sample reach and watershed.

Common Name	Scientific Name	Documented in Sample Reach	Documented in Watershed
Northwest salamander ¹	<i>Ambystoma gracile</i>		X
Long-toed salamander ¹	<i>Ambystoma macrodactylum</i>		X
Tailed frog ²	<i>Ascaphus truei</i>	X	
Western toad ¹	<i>Anaxyrus boreas</i>		X
Cope's giant salamander ²	<i>Dicamptodon copei</i>		X
Van Dyke's salamander ²	<i>Plethodon vandykei</i>		X
Pacific (chorus) tree frog ¹	<i>Pseudacris regilla</i>		X
Red-legged frog ¹	<i>Rana aurora</i>	X	
Cascades frog ²	<i>Rana cascadae</i>		X
Olympic torrent salamander ²	<i>Rhyacotriton olympicus</i>		X
Rough skinned newt ¹	<i>Taricha granulosa</i>		X

¹Facultative stream dwelling species.

²Obligate stream dwelling species.

Stressors of Water Quality

The NCCN stream location in the Sol Duc River was chosen to coincide with the same location as the Washington Department of Ecology's listing of pH exceedances, under section 303(d) of the Clean Water Act (WDOE 2012). The Department notes that these conditions may be natural, and it is uncertain whether the high pH readings are a result of human activity or geothermal activity (WDOE 2012). Also under section 303(d) of the Clean Water Act, for this reach, dissolved oxygen and temperature are of concern (WDOE 2012). These issues, at least in part, may also be natural conditions arising from geothermal activity. Additional sources likely contributing to these violations include trails, roads, NPS infrastructure, the Sol Duc Hot Springs Resort, and recreational use. See comprehensive list below of stressors that may present a risk to water quality in the Sol Duc River watershed.

- Increased sediment deposition from mass failures.
- Increased fine sediment deposition from surface runoff.
- Increased turbidity from sedimentation and surface runoff.
- Decreased spatial diversity of flow and depth regimes.
- Decreased sinuosity.
- Increased incision.
- Decreased woody debris.
- Increased maximum stream flow.
- Increased incidence of maximum stream flow events.
- Decreased minimum flow.
- Increased duration of minimum flow periods.
- Habitat fragmentation.
- Barriers to aquatic organism passage.
- Increased rate of non-native plant and animal invasions.
- Increased water temperature.
- Decreased dissolved oxygen.
- Runoff of applied herbicides and pesticides.
- Accidental toxic spills.
- Runoff of petroleum based toxic compounds from automobile use.
- Runoff of metal based toxic compounds from automobile use (brake pads and exhaust).
- Increased nutrient delivery.
- Increased introduction of pathogens from animal and human waste.
- Increased nutrient delivery.
- Introduction of chemicals from pharmaceutical waste.

Sample Reach Characteristics

The Sol Duc River sample reach starts at an elevation of 478 m above sea level. The sample reach was extended to 680 m long, exceeding the maximum length defined in the protocol (Rawhouser et al. 2013), to start below a significant side channel and end above the Sol Duc Resort. The sample reach is a 4th order stream (Strahler 1952) that occupies an anastomosing channel and runs unconstrained within a broad terrace (Table 98).

Table 98. Physical habitat characteristics measured in 2012 for the sample reach in the Sol Duc River.

Physical Habitat Characterization Parameters	Values
Reference Point Location (UTMs)	—
Easting	435080
Northing	5313554
Reach Length (m)	680

Table 98 (continued). Physical habitat characteristics measured in 2012 for the sample reach in the Sol Duc River.

Physical Habitat Characterization Parameters	Values
Average Wetted Width (m)	21.8
Minimum (m)	14.5
Maximum (m)	33.1
Average Bankfull Width (m)	25.0
Minimum (m)	21.3
Maximum (m)	35.2
Average Thalweg Depth (m)	0.91
Minimum (m)	0.45
Maximum (m)	2.10
Valley Width (m)	700 ¹
Channel Pattern	Anastomosing channel
Channel Constraint	Broad valley and unconstrained
Constraining Feature	Hill slope, Terrace/alluvial fan, Human alteration
Contact with Constraining feature	40%
Torrent Evidence	- Channel has little evidence of pool-riffle structure. - Trees have fallen into channel due to scouring.

¹Valley width was estimated from topographic map program TOPO.

The Rapid Habitat Assessment conducted for the Sol Duc River in 2012 indicated overall sub-optimal habitat conditions (Table 99). Channelization, due to bank armoring, is contributing to low pool variety and reduced channel sinuosity and creating a lack of diversity in available habitat. The presence of the Sol Duc Hot Springs Resort, adjacent to the stream channel in parts of the reach, contributes to low riparian zone scores.

Table 99. Results from the qualitative assessment of the riparian and in-stream habitat within the sample reach in 2012 for the Sol Duc River. The scoring ranges from 20, which represents very high quality riparian and in-stream habitat conditions, to 0, which represents poor riparian and in-stream habitat conditions.

Habitat Parameter	Score
Epifaunal Substrate/Available Cover	10
Pool Substrate Characterization	19
Pool Variability	16
Sediment Deposition	13
Channel Flow Status	15
Channel Alteration	12
Channel Sinuosity	11
Bank Stability	17
Vegetative Protection	18
Riparian Vegetated Zone Width	8

Summary of NCCN Watershed Characteristics

Watershed Area

Watershed size varied greatly across the parks and ranged from 1.4 to 883.7 km² (Figure 48). While the two largest watersheds occurred in NOCA and the two smallest watersheds occurred in LEWI, watershed size was fairly well distributed among the parks.

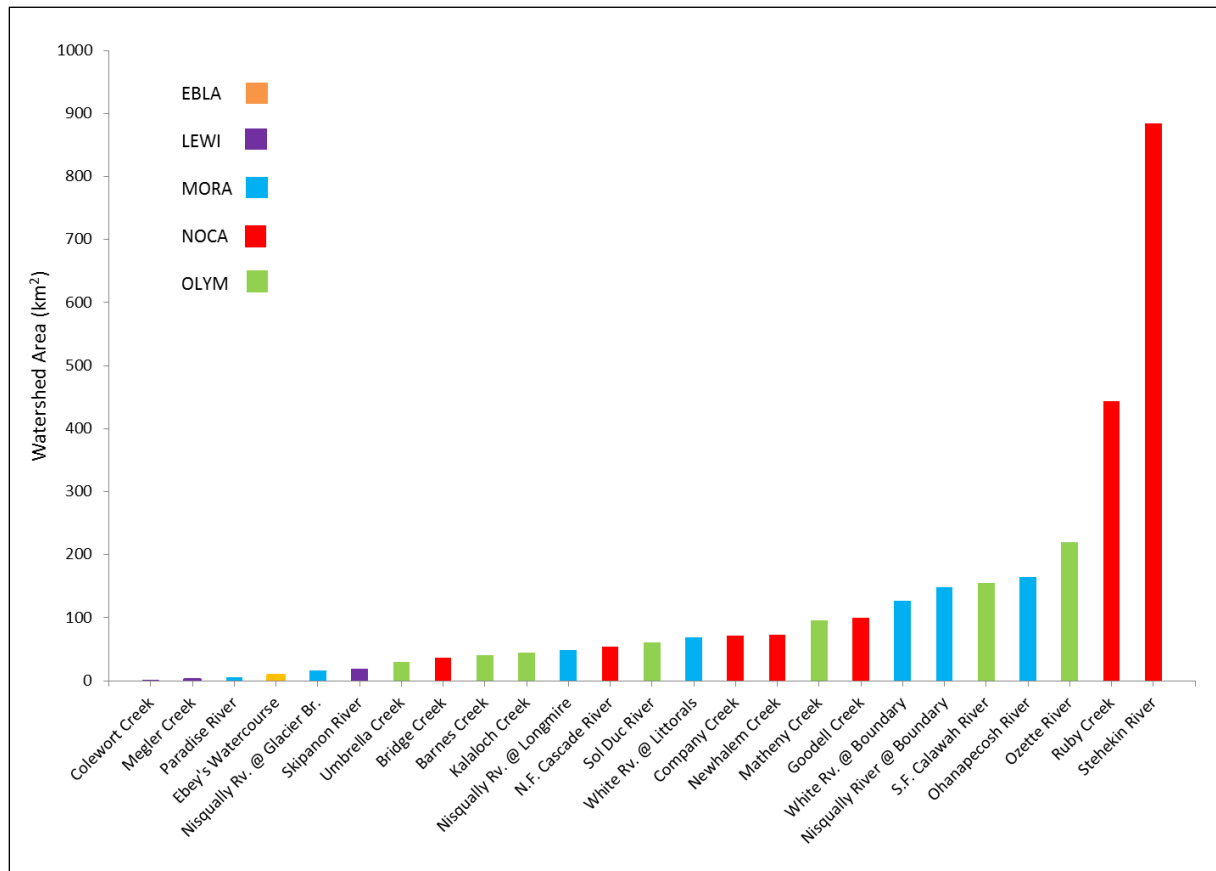


Figure 48. Distribution of North Coast and Cascade Network sample site watershed areas, rank ordered smallest to largest.

Elevation

Minimum and maximum elevations for stream locations ranged from 2 m in Kalaloch Creek and the Ozette River, both near the Pacific Ocean in OLYM, to 1,341 m in the Paradise River on the flanks of Mount Rainier. Mean watershed elevations were similar for MORA and NOCA. However, the maximum elevations for MORA's watersheds were generally higher, with larger ranges, suggesting higher gradient streams (Figure 49). Elevations were lower for the stream locations associated with the Puget Sound or Pacific Ocean at EBLA, LEWI and OLYM (Figure 49). Watersheds within OLYM also tended to have narrower elevation ranges than the other two large parks, which suggest lower gradient streams (Figure 49).

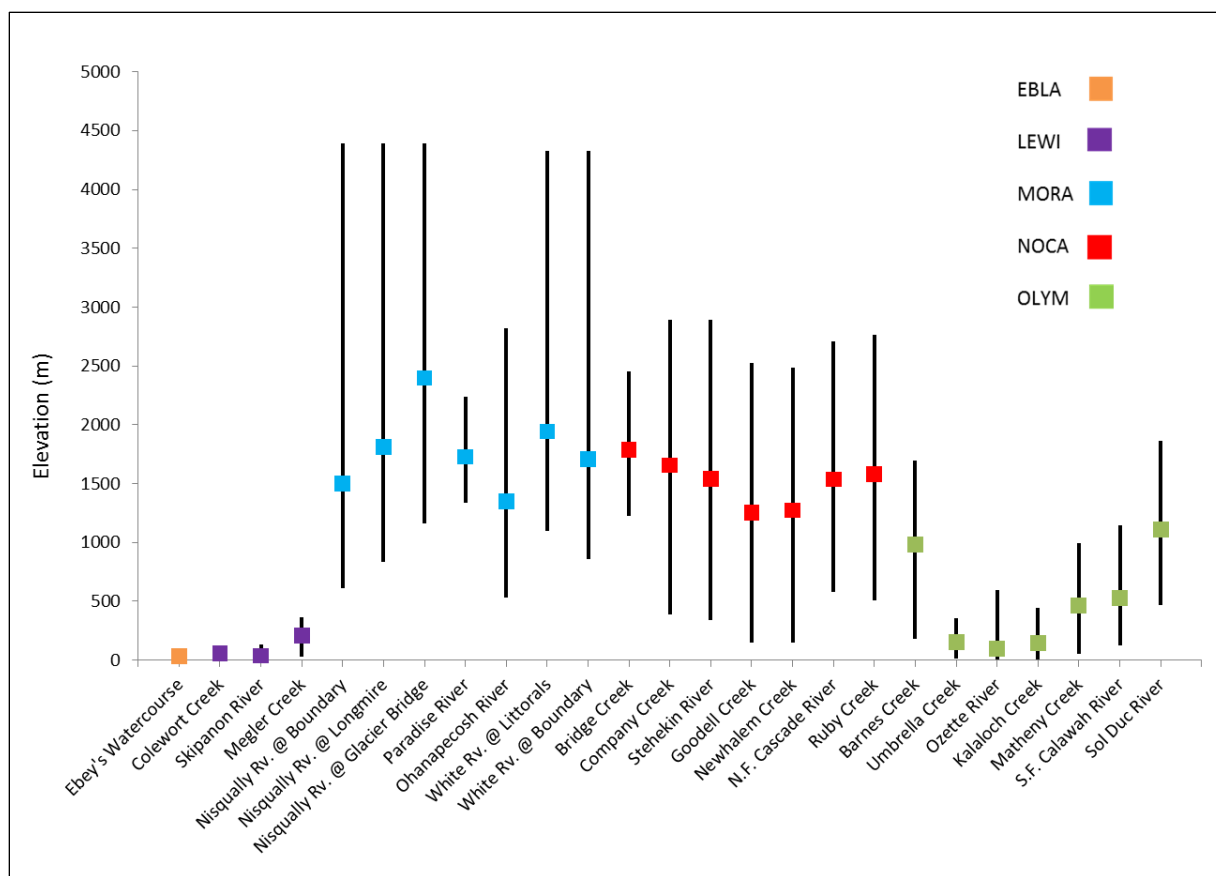


Figure 49. Mean elevation values in meters above sea level for each North Coast and Cascade Network watershed (colored squares). Maximum and minimum elevations within the watersheds are indicated by the top and bottom of the vertical lines. In general, the minimum elevations for each site represent the stream location.

Precipitation

Average annual precipitation ranged from 54 cm/year for Ebey's Watercourse at EBLA to 386 cm/year at the Sol Duc River in OLYM (Figure 50). The stream locations with the lowest precipitation were found in the rain shadow of the Cascade (NOCA) and Olympic Mountains (OLYM) and to a lesser degree the rain shadow of Mt. Rainier (MORA).

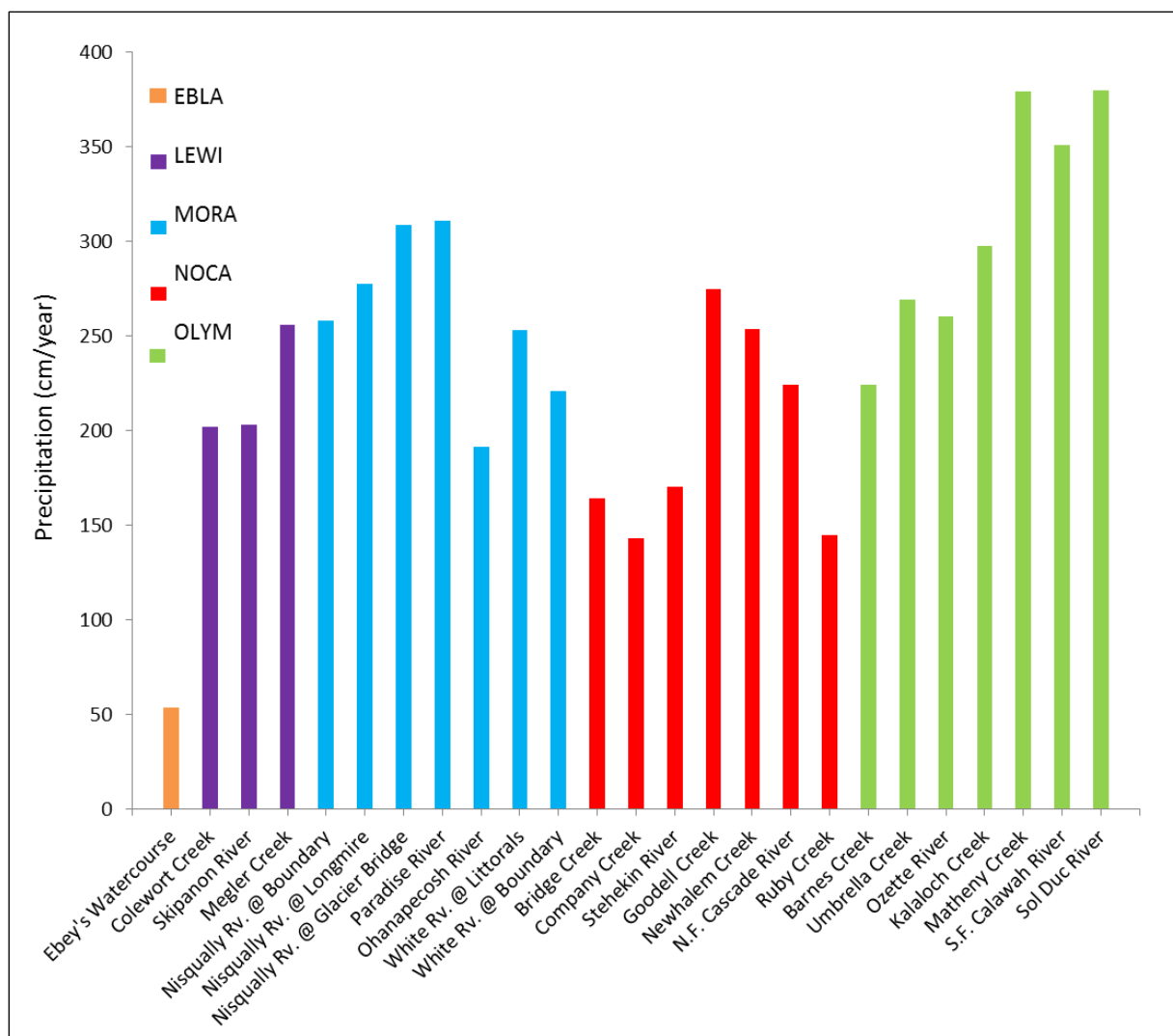


Figure 50. Average precipitation rates (cm/year) for each North Coast and Cascade Network watershed.

Literature Cited

- Anthony, H. D., and R. S. Glesne. 2013. Stehekin River kokanee expanded spawning surveys, 2000 and 2010. Natural Resource Data Series NPS/NOCA/NRDS—2013/506. National Park Service, Fort Collins, Colorado.
- Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish. Second edition. EPA/841-B-99-002. Environmental Protection Agency, Office of Water, Washington, D.C.
- Beason, S. R., L. C. Walkup, and P. M. Kennard. 2014. Aggradation of glacially-sourced braided rivers at Mount Rainier National Park, Washington: Summary report for 1997-2012. Natural Resource Technical Report NPS/MORA/NRTR—2014/910. National Park Service, Fort Collins, Colorado.
- Brenkman, S. J., S. C. Corbett, and P. R. Kennedy. 2008. Inventory of fish species in Lewis and Clark National Historical Park, Oregon (2007). Natural Resource Technical Report NPS/NCCN/NRTR—2008/142. National Park Service, Fort Collins, Colorado.
- Bury, B. R., and M. J. Adams. 2000. Inventory and monitoring of amphibians in North Cascades and Olympic National Parks, 1995-1998. Final report. U. S. Geological Survey, Forest & Rangeland Ecosystem Science Center, Corvallis, Oregon.
- Fancy, S. G., J. E. Gross, and S. L. Carter. 2009. Monitoring the condition of natural resources in U.S. National Parks. *Environmental Monitoring and Assessment* 151:161-174.
- Galvan, S. K., M. J. Adams, P. J. Happe, and S. M. Claeson. 2003. Olympic National park amphibian and reptile inventory, with emphasis upon terrestrial herpetofauna (1999-2001). U. S. Geological Survey, Forest & Rangeland Ecosystem Science Center, Corvallis, Oregon.
- Galvan, S. K., M. J. Adams, B. Samora, R. E. Holmes, S. Stonum, P. J. Happe, R. S. Glesne, and A. Rawhouser. 2005. North Coast and Cascades Network consolidated amphibian database and mapping project. Forest & Rangeland Ecosystem Science Center, Corvallis, Oregon.
- Haggerty, M. J., A. C. Ritchie, J. G. Shellberg, M. J. Crewson, and J. Jalonen. 2009. Lake Ozette sockeye limiting factors analysis. Prepared for the Makah Indian Tribe and NOAA Fisheries in Cooperation with the Lake Ozette Sockeye Steering Committee, Port Angeles, Washington. Available at: http://www.mhaggertyconsulting.com/Lake_Ozette_Sockeye.php (accessed 26 February 2015).
- Island County. 2004. Ground water recharge topic paper, Appendix. Island County Health Department Unpublished Report, Coupeville, Washington.
- Kirchhoffer, J. G., and P. C. Malte. 2003. Balancing energy option in Stehekin, Washington. Department of Mechanical Engineering, University of Washington, Seattle, Washington.

- Kondratieff, B. C., and R. A. Lechleitner. 2002. Stoneflies (plecoptera) of Mount Rainier National Park, Washington. *Western North American Naturalist* 62: 385-404.
- Kramer, R. 1953. Completion report by stream clearance unit on Ozette and Big Rivers. Washington Department of Fisheries, Stream Improvement Division Unpublished Report, Olympia, Washington.
- Larrabee, M. A. 2011. Hydrologic and geomorphic assessment of Ebey's Prairie, Central Whidbey Island, Washington. Thesis. Western Washington University, Bellingham, Washington.
- Leonard, W. P., H. A. Brown, L. L. C. Jones, K. R. McAllister, and R. M. Storm. 1993. Amphibians of Washington and Oregon. Seattle Audubon Society, Seattle, Washington.
- National Park Service (NPS), North Cascades National Park Service Complex, Pacific West Region (NOCA). 2011. Ross Lake National Recreation Area, final general management plan and environmental impact statement, volume 1. North Cascades National Park, Sedro-Woolley, Washington.
- National Park Service (NPS). National Park Service Visitor Use Statistics. Integrated Resource Management Applications portal. Available at: <https://irma.nps.gov/Stats/Reports/Park> (accessed 11 February 2014).
- National Park Service (NPS), North Cascades National Park Service Complex, Pacific West Region (NOCA). 2012. Lake Chelan National Recreation Area; Stehekin River corridor implementation plan and final environmental impact statement, volume 1. North Cascades National Park, Sedro-Woolley, Washington.
- Omernik, J. 2010. Level III and IV ecoregions of Washington. Available at ftp://ftp.epa.gov/wed/ecoregions/wa/wa_eco.pdf (accessed 11 February 2014).
- Oregon State University (OSU). Oregon Explorer web site. Available at: <http://oregonexplorer.info/> (accessed 20 February 2014).
- PRISM Climate Group (PRISM). 2012. Parameter-elevation Regressions on Independent Slopes Model: United States average monthly or annual precipitation, 1981 - 2010. Oregon State University, PRISM Group, Corvallis, Oregon. Available at: <http://www.prism.oregonstate.edu/> (accessed 11 February 2015).
- Rawhouser, A. K., R. E. Holmes, and R. S. Glesne. 2009. A survey of stream amphibian species composition and distribution in the North Cascades National Park Service Complex, Washington State (2005). Natural Resource Technical Report NPS/NCCN/NRTR—2009/169. National Park Service, Fort Collins, Colorado.
- Rawhouser, A. K., L. P. Grace, R. A. Lofgren, R. S. Glesne, J. R. Boetsch, C. A. Welch, B. A. Samora, P. Crain and R. E. Holmes. 2012. North Coast and Cascades Network water quality

- monitoring protocol. Natural Resource Report NPS/NCCN/NRR—2012/571. National Park Service, Fort Collins, Colorado.
- Samora, B. A., and A. Anderson. 2010. Nisqually to Paradise road rehabilitation project 2010 survey results and recommendations associated with amphibians and aquatic invertebrate species of concern. National Park Service Unpublished Report, Longmire, Washington.
- Samora, B., M. Layes, and R. Lofgren. 2013. Ebey's Landing National Historic Reserve amphibian inventory 2002-2003. Natural Resource Technical Report NPS/NCCN/NRTR—2013/684. National Park Service, Fort Collins, Colorado.
- Samora, B., M. Layes, and R. Lofgren. 2015. Lewis and Clark National Historical Park amphibian inventory 2002 and 2005. Non-sensitive version. Natural Resource Technical Report NPS/NCCN/NRR—2015/1028.N. National Park Service, Fort Collins, Colorado.
- Samora, B. A., R. Lofgren and M. Layes. 2013a. Mount Rainier National Park amphibian inventory 2001-2003: Non-sensitive version. Natural Resource Technical Report. NPS/NCCN/NRTR—2013/696.N. National Park Service. Fort Collins, Colorado.
- Samora B. A, R. Lofgren, and M. Layes. 2013b. An inventory of fish in streams in Mount Rainier National Park 2001-2003: Non-sensitive version. Natural Resource Technical Report. NPS/NCCN/NRTR—2013/717.N. National Park Service. Fort Collins, Colorado.
- Strahler, A. N. 1952. Dynamic basis of geomorphology. Geological Society of America Bulletin 63:923-938.
- Tyler, T. J., C. D. McIntire, B. Samora, R. L. Hoffman, and G. L. Larson. 2003. Inventory of aquatic breeding amphibians, Mount Rainier National Park, 1994-1999. U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, Corvallis, Oregon.
- U.S. Environmental Protection Agency (USEPA). 2004. Wadeable stream assessment: Field operations manual. EPA841-B-04-004. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, D.C.
- U.S. Environmental Protection Agency (USEPA). 2012a. Vector digital data. Level IV Ecoregions of Washington. U.S. Environmental Protection Agency, Corvallis, Oregon. Available from http://www.epa.gov/wed/pages/ecoregions/wa_eco.htm (accessed 5 February 2014).
- U.S. Environmental Protection Agency (USEPA). 2012b. Vector digital data. Level IV Ecoregions of Oregon. U.S. Environmental Protection Agency, Corvallis, Oregon. Available from http://www.epa.gov/wed/pages/ecoregions/or_eco.htm (accessed 5 February 2014).
- U.S. Fish and Wildlife Service (USFWS). 2004. Draft recovery plan for the Coastal-Puget Sound distinct population segment of bull trout (*Salvelinus confluentus*). Volume I (of II): Puget Sound Management Unit, Portland, Oregon.

- U. S. Geological Survey (USGS). 2014a. USGS Washington Water Science Center web site: Chelan Basin – Real-Time Sites. Available at:
<http://wa.water.usgs.gov/cgi/realtime.data.cgi?basin=chelan> (accessed 23 January 2014).
- U. S. Geological Survey (USGS). 2014b. USGS National Water Information System: Web Interface. USGS 12178100 Newhalem Creek near Newhalem, WA. Available at:
http://waterdata.usgs.gov/nwis/uv?site_no=12178100 (accessed 2-26-2014).
- Washington Department of Ecology (WDOE). 2012. Water Quality Assessment and 303(d) List. Available at: <http://www.ecy.wa.gov/programs/wq/303d/index.html> (accessed 12 November 2015).
- Washington Natural Heritage Program (WNHP), Washington Department of Fish and Wildlife (WDFW), and U.S. Department of Interior Bureau of Land Management (BLM). 2005. Washington Herp Atlas. Available from <http://www1.dnr.wa.gov/nhp/refdesk/herp/> (accessed 11 February 2014).
- Washington Natural Heritage Program (WNHP), and Washington Department of Fish and Wildlife (WDFW). 2014. Rare Animals. Available from
http://www1.dnr.wa.gov/nhp/refdesk/lists/animal_ranks.html (accessed 10 November 2015).
- Washington Department of Fish and Wildlife (WDFW). 2015. WDFS Species of Concern web site. Available at: <http://wdfw.wa.gov/conservation/endangered/> (accessed 24 February 2015).
- Washington Department of Fish and Wildlife (WDFW). 2014. WDFD Mapping SalmonScape web site. Available at: <http://fortress.wa.gov/dfw/gispublic/apps/salmonscape/default.htm> (accessed 12 February 2014).
- Wydoski, R. S., and R. R. Whitney. 2003. Inland fishes of Washington, 2nd edition, revised and expanded. American Fisheries Society, Bethesda, Maryland and University of Washington Press, Seattle, Washington.
- Zyskowski, S. E. 2007. Stream fish inventories 2001 to 2003, North Cascades National Park Service Complex and Mount Rainier National Park, Washington. North Cascades National Park Service Complex. Sedro-Woolley, Washington.

Appendix A: NCCN Watershed Elevation and Precipitation Analysis

Watershed Identification	Precipitation				Minimum Elevation (m)	Maximum Elevation (m)	Average Elevation (m)	Elevation Standard Deviation (m)
	Minimum Precipitation (cm/year)	Maximum Precipitation (cm/year)	Average Precipitation (cm/year)	Standard Deviation (cm/year)				
EBLA_str_EbeysWC_90a	54.0	54.7	54.4	0.2	4	67	35	10
LEWI_str_Colewort_30a	206.5	210.3	208.4	1.9	3	127	57	31
LEWI_str_Skipanon_30a	200.2	216.7	207.4	4.7	7	133	37	28
LEWI_str_Megler_100a	243.5	243.5	243.5	0	29	362	210	83
MORA_str_NisqNIBO_2000a	187.4	401.1	272.7	59.4	609	4392	1503	681
MORA_str_NisqNILO_2300a	216.1	391.3	307.9	49.3	837	4392	1812	707
MORA_str_NisqNIGB_3800a	243.2	391.3	336.5	43.8	1159	4392	2398	773
MORA_str_Paradise_4440a	294.8	356.1	328.3	21.7	1341	2241	1727	183
MORA_str_OhanaOHCA_1780a	161.7	369.2	195.9	29.4	533	2821	1351	347
MORA_str_White_3640a	181.4	405.6	249.2	65.4	1101	4330	1942	514
MORA_str_White_2830a	128.5	405.6	216.8	61.6	860	4330	1709	500
NOCA_str_Bridge_3990a	142.2	163.5	154.7	5.3	1226	2451	1786	244
NOCA_str_Company_1270a	101.7	274.7	130.6	36.5	386	2893	1657	400
NOCA_str_Stehekin1200a	87.7	284.0	170.9	37.2	340	2893	1539	453
NOCA_str_Goodell_490a	193.1	358.8	273.9	41.2	147	2528	1255	494
NOCA_str_Newhalem_490a	214.8	331.8	279.2	26.3	146	2482	1273	450
NOCA_str_NFCascade_1930a	215.4	337.8	257.3	31.9	576	2711	1536	449
NOCA_str_Ruby_1680a	134.3	231.8	155.3	21.6	508	2763	1583	351
OLYM_str_Barnes_590a	255.5	467.4	349.0	49.2	177	1694	982	335
OLYM_str_Umbrella_65a	247.3	296.2	277.8	12.5	14	358	154	70
OLYM_str_Ozette_20a	230.2	333.5	267.6	18.0	2	593	94	85
OLYM_str_Kalaloch_20a	282.1	326.1	308.5	12.7	2	445	141	88
OLYM_str_Matheny_180a	303.2	410.4	373.2	26.4	51	991	463	217
OLYM_str_SFCalawah_405a	317.2	390.4	345.9	19.6	122	1149	528	216
OLYM_str_SolDuc_1550a	297.0	468.1	386.3	41.9	469	1863	1107	291

Appendix B: NCCN Watershed Stressor Analysis

149

Watershed Identification	Watershed area (km2)	Trails (km)	Trail density (km/km2)	Trail crossings	Roads (km)	Road density (km/km2)	Road crossings	Mines
EBLA_str_EbeyesWC_90a	8.5	2.9	0.34	0	20.2	2.37	0	1
LEWI_str_Colewort_30a	1.4	0.3	0.22	1	2.3	1.61	0	0
LEWI_str_Skipanon_30a	19.1	3.2	0.17	1	43.8	2.29	12	0
LEWI_str_Megler_100a	1.8	0	0	0	2.8	1.54	0	0
MORA_str_NisqNIBO_2000a	148.1	93.4	0.63	37	105.3	0.71	37	6
MORA_str_NisqNILO_2300a	48.6	51.7	1.06	23	35.8	0.74	11	6
MORA_str_NisqNIGB_3800a	16.4	7.3	0.45	8	1.9	0.11	1	0
MORA_str_Paradise_4440a	5.2	15.9	3.05	9	9.7	1.87	5	0
MORA_str_OhanaOHCA_1780a	164.1	79.3	0.48	35	37.7	0.23	23	1
MORA_str_White_3640a	68.4	45.3	0.66	25	12.1	0.18	5	1
MORA_str_White_2830a	126.6	66.4	0.52	28	42.3	0.33	21	4
NOCA_str_Bridge_3990a	36.4	26.2	0.72	8	9.6	0.26	7	0
NOCA_str_Company_1270a	71.1	16.1	0.23	11	0	0	0	5
NOCA_str_Stehekin1200a	883.7	255.0	0.29	155	51.3	0.06	41	43
NOCA_str_Goodell_490a	100.5	0	0	0	7.8	0.08	9	1
NOCA_str_Newhalem_490a	72.6	1.3	0.02	0	9.6	0.13	10	0
NOCA_str_NFCascade_1930a	53.5	4.8	0.09	2	8.1	0.15	14	43
NOCA_str_Ruby_1680a	444.1	142.3	0.32	124	59.4	0.13	53	153
OLYM_str_Barnes_590a	40.7	20.2	0.50	14	0.9	0.02	2	9
OLYM_str_Umbrella_65a	29.3	0.1	0.002	0	120.2	4.11	29	0
OLYM_str_Ozette_20a	220.3	10.5	0.05	4	585.3	2.66	178	0
OLYM_str_Kalaloch_20a	44.5	0.8	0.02	2	117.2	2.63	20	0
OLYM_str_Matheny_180a	95.2	0	0	0	178.1	1.87	42	0
OLYM_str_SFCalawah_405a	155.2	8.8	0.06	4	122.7	0.79	41	0
OLYM_str_SolDuc_1550a	61.1	32.7	0.54	26	6.1	0.10	7	1

Appendix C: Comprehensive List of Stressors and Associated Sources

Source of Stressor	Stressor
Roads & Trails	Increased sediment deposition from mass failures. Increased fine sediment deposition from surface runoff. Increased turbidity from sedimentation and surface runoff. Decreased spatial diversity of flow and depth regimes. Decreased sinuosity. Increased incision. Decreased woody debris. Increased maximum stream flow. Increased incidence of maximum stream flow events. Decreased minimum flow. Increased duration of minimum flow periods. Habitat fragmentation. Barriers to aquatic organism passage. Increased rate of non-native plant invasions. Increased water temperature. Decreased dissolved oxygen. Runoff of applied road chemicals and deicing compounds. Runoff of applied herbicides. Accidental toxic spills. Runoff of petroleum based toxic compounds from automobile use. Runoff of metal based toxic compounds from automobile use (brake pads and exhaust). Increased nutrient delivery.
Urban & Recreational Infrastructure Development	Increased fine sediment deposition from surface runoff. Increased turbidity from surface runoff. Decreased spatial diversity of flow and depth regimes. Decreased sinuosity. Increased incision. Decreased woody debris. Increased maximum stream flow. Increased incidence of maximum stream flow events. Decreased minimum flow. Increased duration of minimum flow periods. Habitat fragmentation. Barriers to aquatic organism passage. Increased rate of non-native plant invasions. Increased rate of non-native animal invasions. Increased maximum water temperatures. Decreased minimum water temperatures.

Source of Stressor	Stressor
	Runoff of applied herbicides and pesticides. Accidental toxic spills. Increased introduction of pathogens from animal and human waste. Increased nutrient delivery. Introduction of chemicals from pharmaceutical waste. Increased amounts of organic matter.
Forestry & Logging	Increased sediment deposition from mass failures. Increased fine sediment deposition from surface runoff. Increased turbidity from sedimentation and surface runoff. Decreased spatial diversity of flow and depth regimes. Decreased sinuosity. Increased incision. Decreased woody debris. Increased maximum stream flow. Increased incidence of maximum stream flow events. Decreased minimum flow. Increased duration of minimum flow periods. Increased rate of non-native plant invasions. Increased water temperature. Decreased dissolved oxygen. Runoff of applied herbicides and pesticides. Increased risk of accidental toxic spills. Increased nutrient delivery.
Agriculture	Increased fine sediment deposition from surface runoff. Increased turbidity from sedimentation and surface runoff. Decreased spatial diversity of flow and depth regimes. Decreased sinuosity. Increased incision. Decreased woody debris. Increased maximum stream flow. Increased incidence of maximum stream flow events. Decreased minimum flow. Increased duration of minimum flow periods. Increased rate of non-native plant invasions. Increased water temperature. Decreased dissolved oxygen. Runoff of herbicides and pesticides. Accidental toxic spills. Increased nutrient delivery. Increased introduction of pathogens from animal and human waste. Increased nutrient delivery.

Source of Stressor	Stressor
Mining	Increased amounts of organic matter.
	Decreased pH.
	Increased levels of dissolved metals.
	Increased levels of cyanide, petroleum products, oil, solvents, acids, and reagents.
	Increased sediment deposition from mass failures.
	Increased fine sediment deposition from surface runoff.
	Increased turbidity from sedimentation and surface runoff.
	Decreased spatial diversity of flow and depth regimes.
	Decreased sinuosity.
	Increased incision.
	Decreased woody debris.
	Increased maximum stream flow.
	Increased incidence of maximum stream flow events.
	Decreased minimum stream flow.
	Increased duration of minimum flow periods.
	Barriers to aquatic organism passage.
	Increased rate of non-native plant invasions.
Small Hydropower Development	Increased water temperature.
	Increased risk of accidental toxic spills.
	Increased maximum stream flow.
	Increased incidence of maximum stream flow events.
	Decreased maximum stream flow.
	Decreased incidence of maximum stream flow events.
	Decreased minimum stream flow.
	Increased duration of minimum stream flow.
	Increased water temperature.
	Decreased dissolved oxygen.
	Decreased spatial diversity of flow and depth regimes.
	Decreased sinuosity.
Recreational Use	Increased incision.
	Increased stream bed armoring
	Increased steam bed and bank erosion.
	Increased risk of accidental toxic spills.
	Barriers to aquatic organism passage.
	Increased fine sediment deposition from surface runoff.
	Increased turbidity from surface runoff.
	Decreased woody debris.
	Habitat fragmentation.
	Increased rate of non-native plant invasions.
	Increased rate of non-native animal invasions.
	Accidental toxic spills.

Source of Stressor	Stressor
	Increased introduction of pathogens from animal and human waste. Increased nutrient delivery. Introduction of chemicals from pharmaceutical waste. Runoff of petroleum based compounds from motorized use.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 963/137727, April 2017

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA TM