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We would like to first acknowledge the Environmental Protection Agency (EPA) for providing grant funds to complete this important work for Thurston County and the South Puget Sound.

Watershed Characterization Technical Team

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List of Acronyms and abbreviations

303(d)	List of impaired water bodies specified in the Clean Water Act, Section 303(d)
Basin	1,000 to 10,000 acres
B-IBI	Benthic – Index of Biological Integrity
Catchment	32 to 320 acres
DAU	Drainage Analysis Unit (approximately 0.25 sq mile or 160 acres)
DBH	Diameter breast height
DEM	Digital Elevation Model
Ecological benefit	The ability of a DAU to maintain ecological processes
Ecology	Washington State Department of Ecology
EIA	Effective Impervious Area
Environmental benefit	The ability of a natural resource site to maintain function within a DAU
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ESB	Engrossed Senate Bill
FEMA	Federal Emergency Management Agency

FRAGSTATS	FRAGSTATS is a computer software program designed to compute a wide variety of landscape metrics
GeoData	Thurston County's GeoData Center
GIS	Geographical Information System
GLO	General Land Office
LiDAR	Light Detecting and Ranging
LWD	Large Woody Debris
NEPA	National Environmental Policy Act
PHS	Priority Habitats and Species
SEPA	State Environmental Policy Act
SSHIAP	Salmon and Steelhead Habitat Inventory and Assessment Program
Sub-basin	100 to 1,000 acres
Sub-watershed	320 to 19,200 acres
TIA	Total Impervious Area
TMDL	Total Maximum Daily Load
TRPC	Thurston County Regional Planning
USDA	US Department of Agriculture
USGS	US Geological Survey
WAC	Washington Administrative Code
WADNR	Washington Department of Natural Resources
Watershed	19,200 to 320,000 acres
WDFW	Washington State Department of Fish and Wildlife
WRIA	Water Resource Inventory Area as defined in Chapter 173-500 WAC

Executive Summary

This project was initiated to address a top priority in the Puget Sound Partnership's *Puget Sound Conservation and Recovery Plan* to reduce the environmental damage from stormwater runoff. This includes preventing nutrient and pathogen pollution by assessing the feasibility of a watershed-based National Pollutant Discharge Elimination System (NPDES) permit. This report presents the results of a watershed characterization of landscape conditions in the Deschutes River watershed that identified restoration, mitigation, and enhancement sites at the watershed scale rather than smaller jurisdictional boundaries used in traditional permit approaches.

There are multiple jurisdictions in Thurston County that have applied for their National Pollutant Discharge Elimination System (NPDES) Phase II and Phase I permits. Thurston County, in addition to the cities of Olympia, Lacey, and Tumwater are designated Phase II permittees. The Washington State Department of Transportation (WSDOT) is a NPDES Phase I permittee in Thurston County.

Each jurisdiction has applied for their respective permit separately. Separate permits could lead to duplicative efforts in planning, assessment, and monitoring as each jurisdiction addresses the six core Clean Water Act (CWA) programs and other requirements under the Safe Drinking Water Act (SDWA). These permits are managed by the Washington State Department of Ecology (WDOE) individually.

Watershed based methods will be most effective when the approach is driven by broader landscape needs and conditions rather than individual site needs. The results of this study provide refined existing data in support of CWA, SDWA, Endangered Species Act (ESA), Shoreline Management Act (SMA), and Critical Area Ordinance updates. This method represents a transition from a site-driven to a more holistic *landscape-driven* approach towards assessing ecosystem function and current ecological processes within a watershed.

This report presents the results of steps One, Two and Three of a six step process detailed in EPA's Watershed-Based NPDES Permitting Implementation Guidance drafted in 2003, and updated in 2007 to assess the feasibility of developing a watershed-based permit based on a watershed scale for the Deschutes River watershed. These steps are as follows:

- <u>Step One:</u> Select a Watershed and Determine the Boundaries
- <u>Step Two:</u> Identify and facilitate multiple jurisdictions to participate in a watershed-based NPDES permit or permit compliance approach using the EPA's guidance;
- <u>Step Three:</u> Collect and analyze data through a watershed characterization for permit development or permit compliance;
- <u>Step Four:</u> Develop watershed-based permit or permit compliance conditions and documentation.
- <u>Step Five:</u> Issue Watershed-Based NPDES Permit
- <u>Step Six:</u> Measure and Report Progress

Steps four, five and six have not been initiated as proposed, but it is anticipated that work will be completed during the second NPDES Phase I permit period (20012 to 2017).

The Natural Resource Council has recently published *Urban Stormwater Management in the United States* (NRC, 2009). This document, specifically chapter six details how NPDES permit holders could implement EPA's Watershed-Based NPDES Permitting.

This document presents the work of the technical team using Gersib et al. (2004) methods. *It is recommended that the reader review the methods prior to reading the report to better understand the results.* In addition, it is a culmination of refinements made by our technical team and a 2010 peer review by Derek Booth and Rich Horner to meet the needs of Thurston County. The report provides a scientific approach to analyzing the ecological processes that maintain a healthy watershed. The central goal of the watershed characterization work is to identify natural resource areas that could serve as restoration and enhancement sites to mitigate past and future urban development in the Deschutes River watershed.

At a landscape scale, the Deschutes Watershed study subdivided the study area into 275 drainage analysis units (DAU) and 12 sub-watersheds. Landscape attributes were used to characterize the condition of key ecological processes (movement of water, sediment, large wood debris, pollutants, and heat) and biological elements (aquatic integrity and upland habitat connectivity) that have been affected by the built out environment. This is accomplished by interpreting existing land cover and natural resource data and by developing databases that identify the location and condition of wetland, riparian, and floodplain resources. The goal is to identify targeted landscape areas having the potential to optimize environmental benefits if restored.

The methods identify possible candidate wetland, riparian, and floodplain restoration sites through photo and Geographical Information System (GIS) interpretation of the study area.

Previous watershed characterization work in Thurston County included identifying natural resource site areas appropriate for "stormwater retrofits". The retrofit list is a sub-set of data intended specifically for identifying potential wetland, riparian, and floodplain restoration sites that have the potential to mitigate water quality and quantity impacts of the built environment. The natural resource restoration priority list was intended to identify sites that maximize overall ecosystem function. However, the term "stormwater retrofit" has lead to confusion for the term usually refers to an engineered approach e.g., stormwater pond. Therefore, that step and reference have been discontinued.

In the study area, it was determined that the Percival Creek Sub-watershed was mostly altered by development with total impervious area (TIA) at 37% of the total watershed. These areas include the City of Olympia, Tumwater, as well as unincorporated Thurston County. The Moxlie Creek Sub-watershed had the second highest value for TIA at 35%.

Upper Deschutes Sub-watershed is least impacted by the built environment with only 1% TIA.

To identify and evaluate potential restoration opportunities, the methods used watershed characterization to identify the ecological and biological elements of each DAU. The methods also identified altered wetland, floodplain, and riparian resources. Each potential restoration site was put in the context of the existing landscape. The sites were then evaluated and prioritized for restoration and/or enhancement. In the study area, 2817 wetland areas, 486 riparian areas, and 47 floodplain areas for a total of 3350 potential sites.

Of these sites, 2119 potential wetland, floodplain and riparian restoration sites met the minimum criteria for restoration and/or enhancement potential. Those sites were prioritized for optimizing overall ecosystem function within the DAU and sub-watersheds. The remaining sites are either of high avoidance and/or preservation value, or would provide little to no environmental benefit if restored.

Background

This report summarizes a scientific framework for watershed characterization and describes a set of methods developed at the watershed scale to assist in better land use decisions. As a conceptual framework, this document serves as the key deliverable to Thurston County summarizing watershed characterization methods and developing key recommendations that other County departments, local jurisdictions, and other entities can use to help meet current and future environmental assessment and planning needs.

Watershed based methods will be most effective when the approach is driven by landscape need and condition rather than an individual site needs. The results will help to refine and provide new data to meet the needs of the Clean Water Act (CWA), Safe Drinking Water Act (SDWA), Endangered Species Act (ESA), Shoreline Management Act (SMA), and Critical Area Ordinance updates. It represents a transition from a site-driven to landscape-driven approach to assessing current ecological processes of the watershed.

Despite dramatic increases in effort, legal mandates, and expenditures for environmental protection and restoration over the past 20 years, the overall condition of natural ecosystems continues to decline (Karr 1995, Montgomery et al. 1995). A growing body of work indicates that declines in ecosystem integrity are perpetuated by existing policies and traditional techniques that tend to treat local symptoms of resource degradation and fail to address the root biological and physical causes of ecosystem degradation and population decline. These policy and traditional techniques perpetuate a narrow “site” review and analysis that often results in restoration that treat symptoms of localized habitat/resource degradation rather than addressing the systemic causes of ecosystem degradation (Frissell 1996, Angermeier and Schlosser 1995, Montgomery et al. 1995, Reeves et al. 1995, Ebersole et al. 1997).

Thurston County was designated a National Pollutant Discharge Elimination (NPDES) Phase II jurisdiction in the 2000 census. Thurston County submitted a NPDES Phase II permit application to Ecology in March 2003. With the issuance of the NPDES Permit for Phase II communities in February 2007, Thurston County determined that a more holistic approach was needed to incorporate all the required regulations at the watershed level to promote efficiency in monitoring, analyzing, and reporting on the current condition of our natural resources. Current government efforts are segmented and have not proven to provide protection to Thurston County's streams and the Puget Sound.

This study provides substantial opportunity to blend developing watershed approaches with new modeling and assessment tools to develop outcome-based approaches that Thurston County Resource Stewardship, Strategic Planning, and Public Works, can use to make better land use decisions and management.

General Framework for Watershed Characterization

The following is a very brief summary of how watershed characterizations are conducted in Thurston County. The reader is encouraged to read the methods included in Appendix A to have a better understanding of the landscape indictors, the natural resource attributes, and rules and assumptions used to complete a landscape characterization.

Briefing, the general framework is as follows:

1. Define appropriate spatial scales to be used in watershed characterization;
2. Compile land use/land cover information for pre-development and current conditions and estimate the type and extent of future growth/development;
3. Develop an understanding of the ecological processes within drainages occurring in the area, identify key drivers for those processes, and begin to understand how past and present land use has altered processes and disturbance regimes;
4. Assess landscape sensitivity to process alteration and identify areas most sensitive and most resistant to development;
5. Characterize the general condition of ecological processes within the largest acceptable landscape scale;
6. Identify landscape areas having specific levels of degradation to targeted ecological processes under current conditions;
7. Assess the probability that processes within target landscape areas will be maintained over the long-term using the future build-out scenario; and
8. This framework employs and adapts the five-step strategy outlined by Beechie and Bolton (1999). A complete, detailed scientific framework for watershed characterization is presented in this document.

See Figure 1 which outlines the process of conducting a watershed characterization

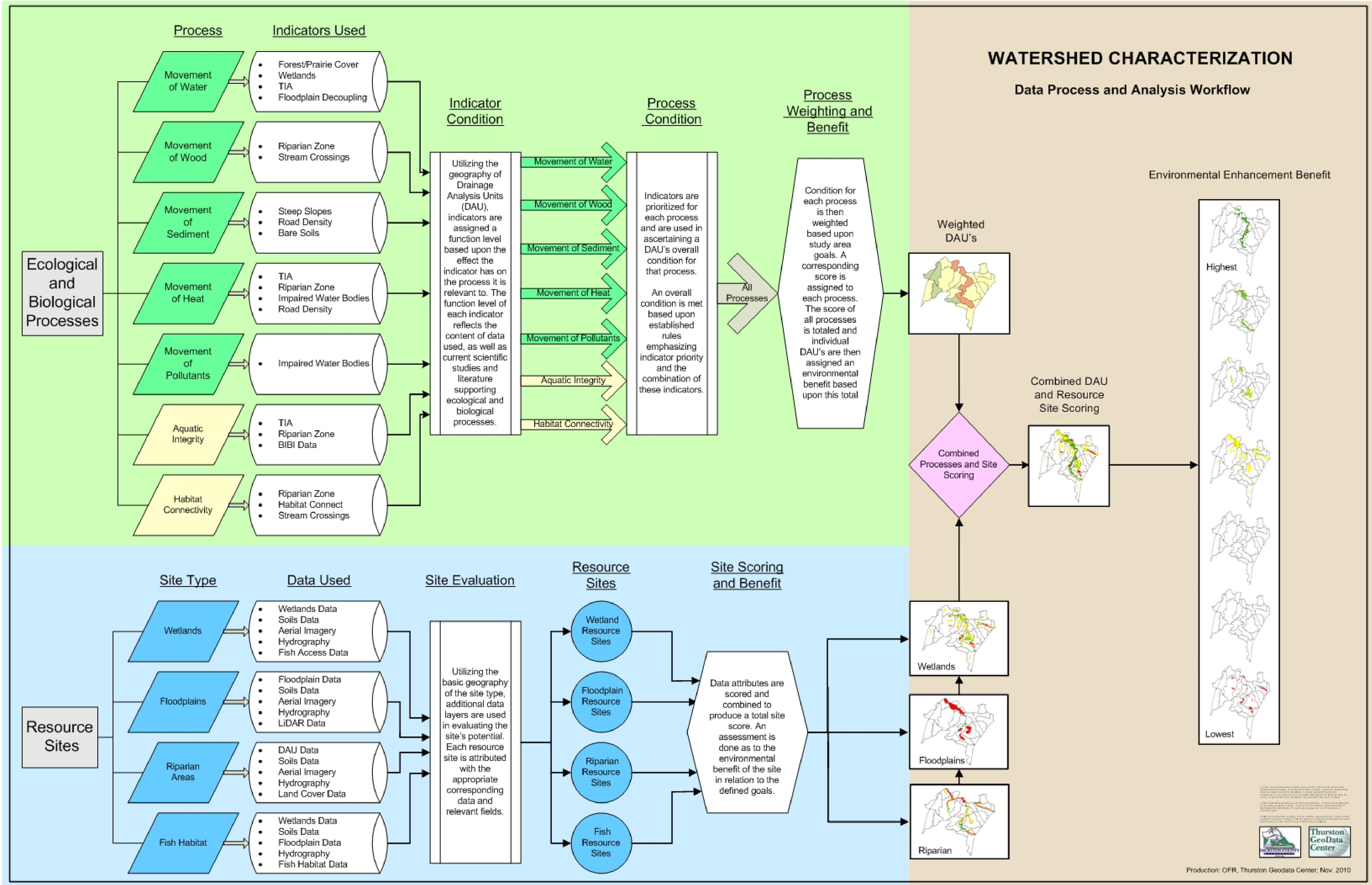

Figure 1.0 Process flowchart

What is in this document?

This document presents the work of the technical team using Gersib et al. (2004) landscape characterization methods and our refinements made by our technical team to meet the needs of Thurston County, a local government. The report provides a scientific approach to analyzing the ecological processes that maintain a healthy watershed. The goal of the watershed characterization work is to identify avoidance, mitigation,, restoration, and enhancement sites, because of current and past alterations to the landscape. In addition, preservation sites are identified to assist in improving watershed function in South Puget Sound watersheds. One of the goals in identifying priority preservation sites is to provide data to make sound decisions when using Conservation Futures funds to purchase natural resource parcels.

The methods characterize the condition of key ecological processes (movement of water, sediment, large wood, pollutants, and heat) and biological elements (aquatic integrity and upland habitat connectivity) that have been affected by past urban development. This is accomplished by interpreting existing land cover and natural resource data and by developing databases that identify the location and condition of wetland, riparian, and floodplain resources. Following a description of baseline conditions, areas are then identified that target landscape areas having the potential to optimize environmental benefits if restored.

At the site scale, all possible candidate wetland, riparian, and floodplain restoration sites are identified through photo and Geographical Information System (GIS) interpretation of the study area.

The priority site list is intended specifically for identifying potential wetland, riparian, and floodplain restoration sites that have potential to mitigate water quality and quantity impacts of the built environment. The natural resource restoration priority list is intended to identify sites that maximize overall ecosystem function.

What are the general findings of this study?

At the landscape scale, it was determined that the entire study area had a total impervious area (TIA) value of 11%, a coniferous forest value of 30%, a mixed forest value of 11%, and a grasses value of 12%. It should be noted that the TIA values include other landscape attributes (e.g., shadowing) where it couldn't be distinguished from impervious cover. Only the predominant land cover values are listed in the table. It should also be noted that effective impervious area (EIA) is a much stronger indicator for the delivery and routing of water. However, the data required, including stormwater infrastructure is difficult to acquire on a large scale. Thus, by default we use TIA to determine the delivery and routing of water.

Table 1.0 contains the values of major land cover categories of the sub-watersheds. It should be noted that the total land cover values do not add up to 100%. Impervious area is a total of asphalt/pavement/bare earth. Coniferous forest is the total of predominately coniferous and homogenous forest. Mixed forest is mixed forest. And grasses are a total of turf/grasses and short grasses. Wetlands, deciduous forest, shrubs, scrub shrubs, and water are not listed in the table, but can be found in the Figure 1.2 Percent Land Cover figures for the Deschutes study area

Table 1.0 Land Cover Values in the Study Areas

Sub-Watershed	Impervious Area (%)	Coniferous Forest (%)	Mixed Forest (%)	Grasses (%)
Study Area	11	30	11	12
Upper Deschutes	1	49	14	5
Lawrence Lake	4	27	12	16
Vail	3	32	20	8
Rainier	6	24	4	29
Offut Lake	3	32	18	12
Spurgeon Creek	6	32	18	11
Pattison Lake	25	5	3	16
Lower Deschutes	21	13	7	21
Percival Creek	37	24	2	4
Moxlie Creek	35	12	7	21
East Budd	11	35	10	6
West Budd	24	36	5	4

Introduction to Watershed Characterization

What is a watershed characterization?

Watershed characterization is a series of steps that identify, screen, and prioritize hundreds of potential wetland, riparian, and floodplain restoration sites. These steps focus on gathering ecological and biological watershed data needed to identify where landscapes are and are not functioning properly, where degraded natural resources exist, and where to target restoration to maximize environmental benefits. In the end, this analysis will allow Thurston County to choose restoration sites that will provide the greatest function, have a high probability of being successful, and ensure that we get the highest value for our investments.

Through watershed characterization, the technical team seeks to integrate the restoration of wetland, riparian, floodplain, and stormwater impacts by restoring the landscape's capacity to function. We do this by assessing the condition of ecological processes, such as the movement of water, sediment, pollutants, large wood, and heat and aquatic integrity and upland habitat connectivity. The target is the restoration of degraded natural wetlands, riparian areas, and floodplains that have the greatest potential to mitigate past development impacts and result in measurable environmental benefits.

How is a watershed characterization conducted?

Watershed characterization consists of three key steps:

Part I. Characterize Condition of Ecological Processes in Study Area

The condition of landscape-scale ecological processes and the extent of human alteration to these systems are analyzed. Key physical processes include the movement of water, sediment, pollutants, large wood, and heat through stream systems within the study area. Key biological elements include aquatic integrity and upland habitat connectivity.

At a landscape scale, the Deschutes River watershed study area was subdivided into 275 drainage analysis units (DAU) catchments within 12 sub-watersheds. Multiple landscape attributes were used to characterize how land use change has altered the natural movement of water, sediment, pollutants, and large wood, along with aquatic integrity and upland habitat connectivity. This information was used to target restoration efforts within landscapes that have the greatest potential to restore and maintain environmental benefits over the long-term.

The Matrix of Pathways and Indicators (MPI) was used to determine the function of each ecological process and biological element at the DAU scale. Following assessment of each individual process and biological element, Rules and Assumptions were used to provide a final ranking of Properly Functioning (PF), At Risk (AR), or Not Properly Functioning (NPF) for each DAU. For complete details of the Rules and Assumptions, please consult Tables 8 through 14 in the Methods document. Appendix A of this document contains the Methods document. Figure 1.3 details all the landscape indicators used.

The following details which landscape indicators were used for each process assessed.

Human alteration to the movement of water

- Percent TIA
- Percent forest land
- Percent wetlands cover

Human alteration to the natural movement of sediment

- Percent bare soils
- Road density
- Percent unstable slopes.

Human alteration to the natural movement of large wood

- Percent forested riparian
- Number of stream crossings per kilometer of stream

Human alteration to the natural movement of pollutants

- Extent of 303(d) listed water bodies for nutrients, toxicants, bacteria, and temperature
- Condition and extent of wetlands

Human alteration to the natural movement of heat

- Extent of 303(d) listed water bodies for nutrients, toxicants, bacteria, and temperature
- Percent 67 meter riparian zone with mature canopy
- Road density
- Percent TIA

Aquatic integrity

- Percent riparian forest
- Percent TIA
- B-IBI scores

Habitat Connectivity

FRAGSTATS was utilized to determine habitat connectivity for forest and prairie landscapes. FRAGSTATS is a computer software program designed to compute a wide variety of landscape metrics for categorical map patterns. The original software (version 2) was released in the public domain during 1995 in association with the publication of a USDA Forest Service General Technical Report (McGarigal and Marks 1995). For more information, go to http://www.umass.edu/landeco/research/fragstats/fragstats.html

Determine the Ecological Benefit of the DAU

The final ranking of each DAU yields a baseline condition of ecological health for each DAU and sub-watershed after the assessment of individual ecological process and biological element using the indicators above and the application of the rules and assumptions in the Methods documents All DAUs within the study area with ecological processes considered "At Risk (AR)" under current land use conditions are identified for further consideration. DAUs in the AR category for multiple key ecological processes are assumed to provide the greatest potential to maximize environmental benefits when natural resource sites are restored.

Using the function condition assigned to the DAU in which a potential mitigation site occurs, identify which ecological processes and biological elements are considered “At Risk”. Identify a single ecological process or biological element that is the local recovery priority.

In the Deschutes River watershed, riparian and large woody debris were identified as a priority for the watershed (Anchor, 2009).

All DAUs are assigned an ecological benefit score. This score is then used to develop an ecological benefit rank using technical team best professional judgment. The movement of water is scored the highest based on the importance of that ecological process in a built landscape. The ecological processes and biological elements are ranked based on the criteria in Table 1.1:

Table 1.1 Weight criteria to rank DAUs.

Ecological Process/Biological Indicator in "At Risk" Condition	Score Weight	Total Score
Movement of Water	1 X 3	3
Local Theme – Movement of Large Wood	1 X 2	2
Movement of Pollutants	1 X 1	1
Movement of Heat	1 X 1	1
Movement of Sediment	1 X 1	1
Aquatic Integrity	1 X 1	1
Upland Habitat Connectivity	1 X 1	1
Maximum score for a DAU when all processes are "At Risk"		**10**

Once the DAU ecological processes and biological element function levels are ascertained, the function levels are translated to a ranking scheme. Ecological processes and biological elements which have been identified as "At Risk" are scored higher based upon the potential for enhancement from restored/rehabilitated marginal function levels. The ecological process scores are then ranked according to the weight criteria, and converted to a High, Moderate, or Low process rank, as detailed in Table 1.2.

Table 1.2 Convert Ecological Process Score to Ecological Process Rank

Ecological Process Score	Ecological Process Rank
7, 8, 9, 10 points	High
3, 4, 5, or 6 points	Moderate
0, 1, or 2 points	Low

Part II. Natural Resource Restoration Sites in Study Area

Natural resource sites (wetlands, riparian, and floodplain) were identified that have the potential to mitigate past development if restored.

Site datasets for wetlands, riparian areas, and floodplains were created which were then used to identify potential restoration sites. Existing data and extensive photo interpretation were used to develop wetland, riparian, and floodplain datasets.
These datasets differ significantly from existing natural resource data, such as local and state agencies might develop, in that they identify potential restoration sites rather than inventorying existing wetlands, riparian areas, and floodplains.

These potential restoration sites include intact existing wetlands and degraded or destroyed wetlands that have potential, if restored, to meet restoration and/or enhancement needs of local governments. The technical team established both site and landscape criteria to evaluate and rank potential floodplain, wetland, and riparian restoration sites.

The natural resource sites are evaluated based on the attributes assigned during site assessment. Some specific attributes include scores on vegetation alterations, hydrologic alterations, and adjacency to public lands. For specific details, please refer to Tables 22 to 24 in the Methods document.

Once all the attributes have been scored, the following ranking criteria are used to rank the sites High, Moderate, and Low, as detailed in Tables 1.3 to 1.5.

NOTE: The three point classes were developed using natural breaks in the data range points specific for the Deschutes Watershed.

Table 1.3 Convert Wetland Environmental Process Score to Process Rank

Environmental Process Score	Environmental Process Rank
7 to 12 points	High
4 to 6 points	Moderate
0 to 3 points	Low

Table 1.4 Convert Riparian Environmental Process Score to Process Rank

Environmental Process Score	Environmental Process Rank
6 to 10 points	High
3 to 5 points	Moderate
0 to 2 points	Low

Table 1.5 Convert Floodplain Environmental Process Score to Process Rank

Environmental Process Score	Environmental Process Rank
9 to 10 points	High
7 to 8 points	Moderate
6 points	Low

Part III. Assess Potential Sites within the DAU

This section presents the results of a ranking process for all potential natural resource restoration sites within the DAU. This ranking of a natural resource restoration site is based on a combination of each site individual site's rank and combined with the ranking of the DAU within which the restoration site is located. The result of this combination is a final score from 0 to 6, with a score of 6 representing those sites with the greatest potential for environmental benefit if restored. Table 1.6 is used to score the natural resource sites in the context of the DAU.

Thus, the Ecological Benefit (DAU) and the Environmental Benefit (Resource Sites) are ranked to provide a final score from 0 to 6.

Table 1.6 Combined DAU and Site Score Ranking

Ecological Processes	Resource Sites	Total Score
High	High	6
High	Moderate	5
Moderate	High	4
Moderate	Moderate	3
Low	High	2
Low	Moderate	1
N/A	Low	0

For complete details on methods used in watershed characterizations, please refer to Appendix A of this report.

Updates and Modifications to the Methods

As the Gersib et al., 2004 methods were applied, it was determined that the methodology needed to be updated and refined. In applying the Gersib et al methods, the following modifications and/ or clarifications have been made:

- The indicator "percent change in drainage network" in the matrix was not used in some areas. This was necessary because we did not have sufficient stormwater infrastructure data.
- Further defined "mature forest" to mean "hydrologically mature forest" (Douglas fir 25 years old (DNR, 2009).
- A "prairie landscape" was added to the matrix. Some studies indicate that the addition of impervious surface over outwash soils has a larger hydrological effect than covering till soils (Brascher, 2006).
- There is the need to develop better indicators for the "movement of sediment". The original use of the matrix was for forestry activities. In an urban environment, with required stormwater best management practices (BMP), cleared earth is typically paved

within a limited amount of time, thus no bare soils in the DAU. The exception would be agricultural activities, but they are also temporarily exposed prior to replanting.

- There was a lack of data for the condition process "movement of pollutants" thus only areas that had data were analyzed.
- 67 meter buffers were applied throughout the analysis vs. 33 meter, as stated in the matrix for the movement of heat. The 67 meter buffer reflects the standard aquatic buffer that Thurston County currently has in effect, and the 67 meter also accounts for stream layers that are inaccurate.
- The rules and assumptions were updated and developed based on best available science.
- Attributes for initial natural resource site identification and condition descriptions were standardized (e.g., a value given for adjacency to public lands).

Further work is required to improve the Gersib, et al 2004 methods for future watershed characterizations:

- Thurston County's FEMA maps are outdated and incomplete. Future goals include updating the Federal Insurance Rate Maps (FIRM) using LiDAR.
- Thurston County's stormwater infrastructure maps are incomplete. This data is essential to fully understand the delivery and routing of water. Thurston County has initiated an aggressive program of collecting stormwater infrastructure data to better analyze the movement of water.
- Aquatic integrity and habitat connectivity indicators could be further defined and improved. Based on this work, Thurston County added additional Benthic Indicator Biotic Indicators (BIBI) sites in our proposed study areas to assess aquatic integrity.
- Additionally, Thurston County is assessing the feasibility of conducting specie specific habitat connectivity.

In 2010, Thurston County contracted with Derek Booth, PhD. and Richard Horner, PhD. to complete a peer review of the Methods. Comments were received back in late summer, 2010. The intent is to update the Methods following the completion of the Nisqually River watershed, the last Puget Sound watershed characterization funded by EPA grant # XXXX. It is anticipated that the Nisqually watershed characterization will be completed December 2011.

How was local information and expertise acquired and used?

An important part of the watershed characterization effort is coordination with local and regional governmental entities and watershed groups. The reasons for doing this are:

- To ensure that local natural resources managers and interest groups are aware of what studies are being conducted within their area, what a watershed characterization is, and how it works.
- To gain insight into local permitting criteria and policies.

- To ensure that information developed through watershed characterization is compatible with existing planning efforts by local, tribal, or regional governments, whenever possible.
- To acquire locally developed datasets of relevance to watershed characterization.
- To identify and acquire local watershed recovery plans, priorities, and locally identified restoration opportunities.

An integral part of watershed characterization is the identification and use of locally identified themes. These themes are included in Limiting Factors Analyses, watershed plans, salmon recovery plans, etc. The local themes are used, in part, to establish criteria for prioritizing potential restoration sites.

Draft and final reports containing watershed priorities for habitat restoration, salmonid recovery, water quantity and base flow improvements, and water quality improvements were reviewed for incorporation into the ranking of potential restoration sites.

Each of these documents contains locally defined projects or targeted stream reaches for water quality enhancement, runoff control, ecosystem recovery, salmon recovery, sediment control, flood amelioration, or similar benefits. The locally identified recovery sites/areas are incorporated into the watershed characterization analysis prioritize our candidate restoration sites.

What are the project deliverables?

Watershed characterization deliverables for the Deschutes River watershed Study are:

- Extensive documentation of technical methods, assumptions, and results of watershed characterization in a manner that is comprehensive and understandable.
- Extensive information on the landscape condition of key ecological processes.
- Potential wetland, floodplain, riparian habitat data layers with all site-specific data.
- A prioritized list of potential natural resource restoration sites for overall ecosystem function in the study area.
- A prioritized list of potential natural resource preservation sites.

The goal is to make this report clear and understandable to the average person, while still providing all of the technical documentation necessary to support science-based decision-making. To do this, there is a multi-level presentation:

- In the main report body, the format seeks to "tell the story" of the study area and of the results
- Detailed step-by-step results are provided in the appendices
- The technical methods in a separate methods document (Appendix A)

- The GIS data, modeling assumptions, and other technical details are available electronically upon request or on the website

It is hopeful that this format will be more understandable for the non-technical reader and yet ensure that all methods, data, assumptions, and results are readily accessible to technical and regulatory reviewers.

What are the limitations?

The most significant limitation of the results is the data used in the analysis. While the study utilized relatively recent satellite data (SPOT imagery 2009 and LiDAR 2001), other coverages used include 2009 aerials and other state data. Thus, all sites should be verified as still available (e.g., not developed). In addition, this methodology identifies sites at a GIS scale. Further work is required to assess sites for actual restoration, mitigation, and/or preservation opportunities.

Another caveat is the Department of Natural Resources (DNR) stream hydro layer used in the analysis. When the DNR hydro layer was compared to LiDAR data, it was obvious that the stream layer is not accurate in some reaches. To compensate for the errors we applied a 67 meter buffer vs. a 33 meter buffer as detailed in the original methods.

The Study Area

What is the study area and how was it defined and subdivided for analysis?

The Deschutes River Study Area is shown in *Figure1.1 Deschutes River Study Area*. The study area was delineated using LiDAR data. Multiple scales were established including approximately 0.25 sq mile DAUs, 12 sub-watersheds, and the entire Deschutes River study area. These scales were based on the Center for Watershed Protection definitions (Zielinski, 2002). The analysis used the 0.25 sq mile DAUs (stormwater management and site design scale), sub-watersheds (stream classification and management scale), and the watershed (watershed-based zoning scale) (Figure 1.2 Study Area Sub-watersheds and Figure 1.3 Study area Drainage Analysis Units).

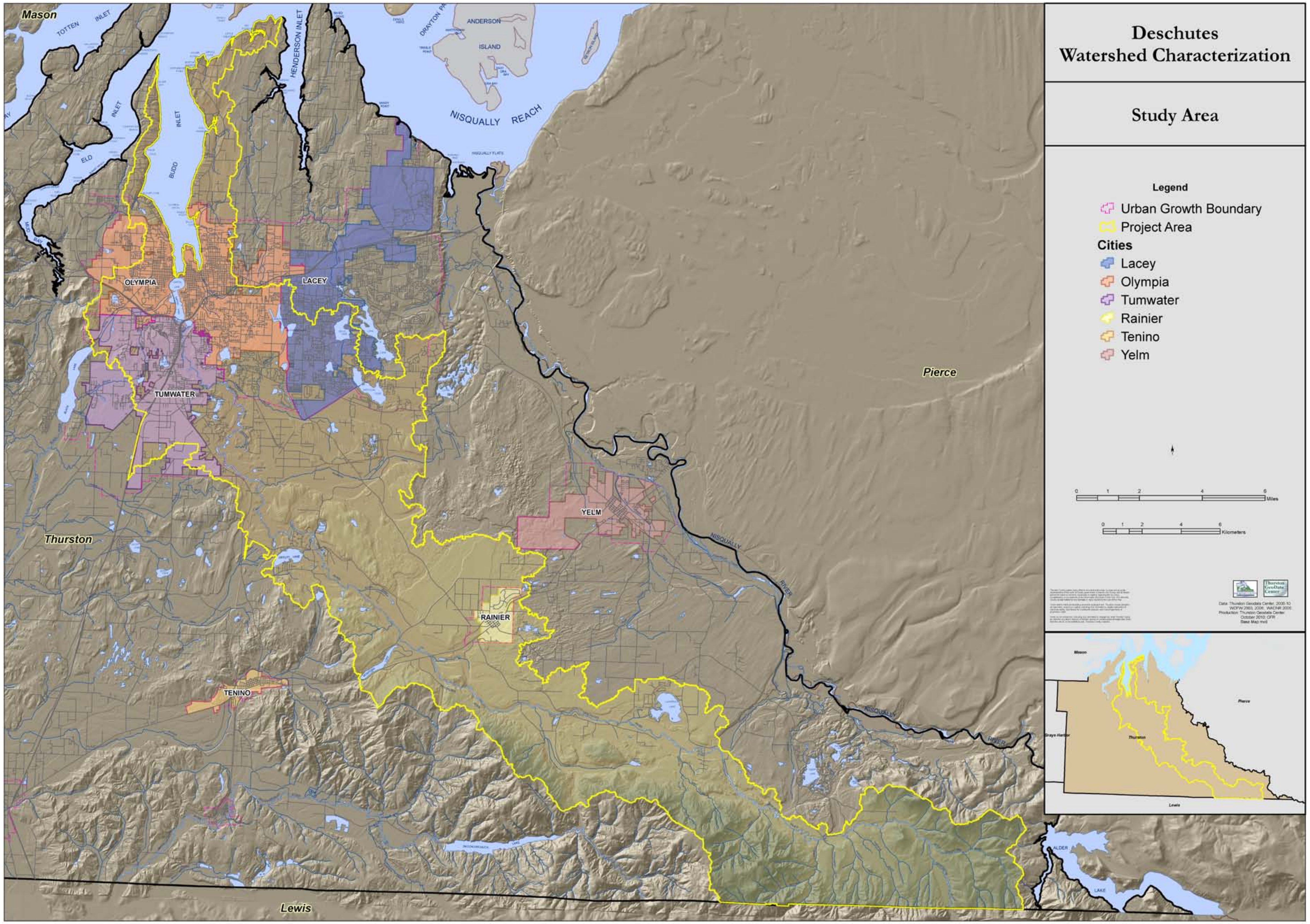

Figure 1.1 Deschutes River Watershed Study Area

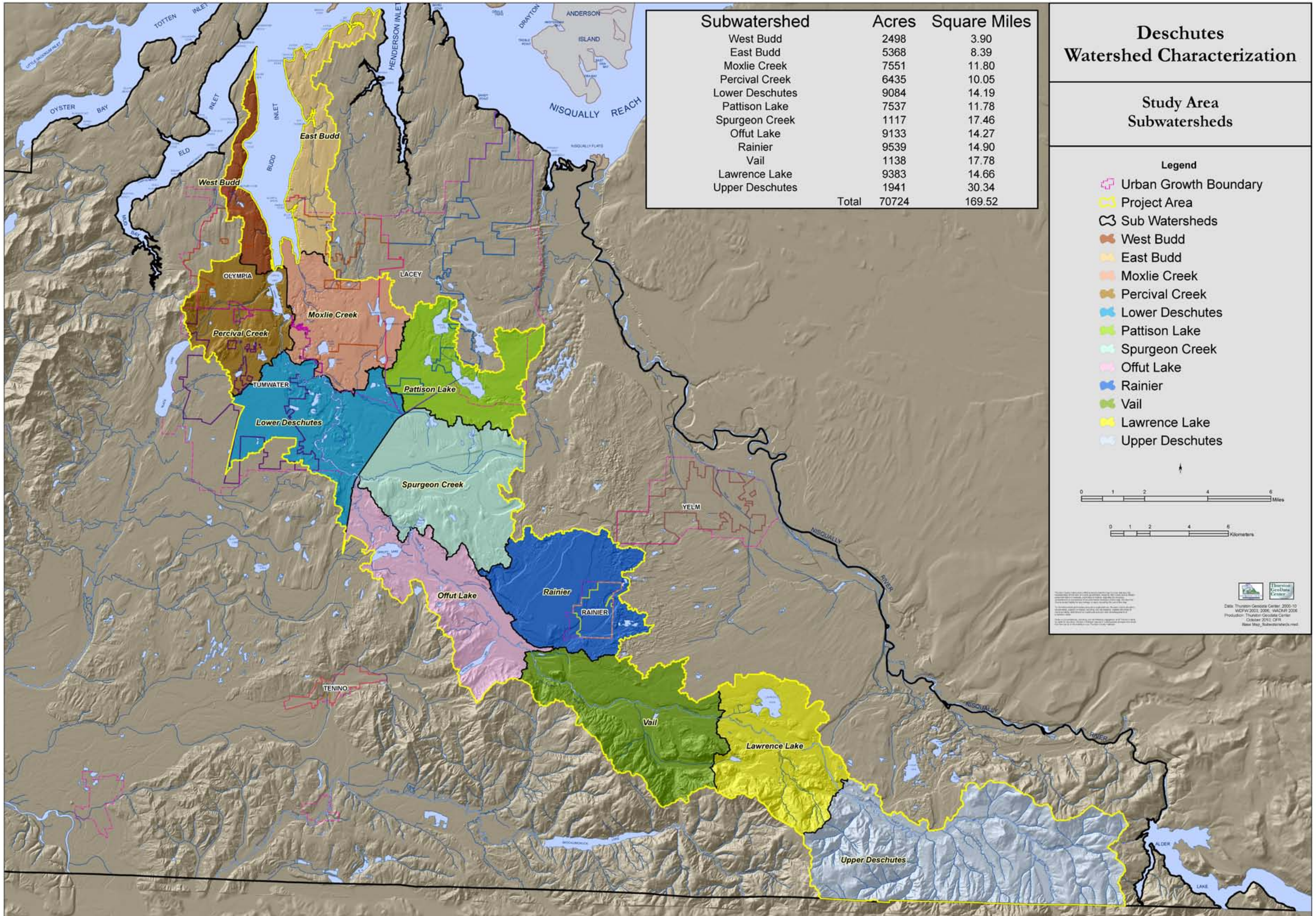

Figure 1.2 Deschutes River Watershed Study Area Subwatersheds

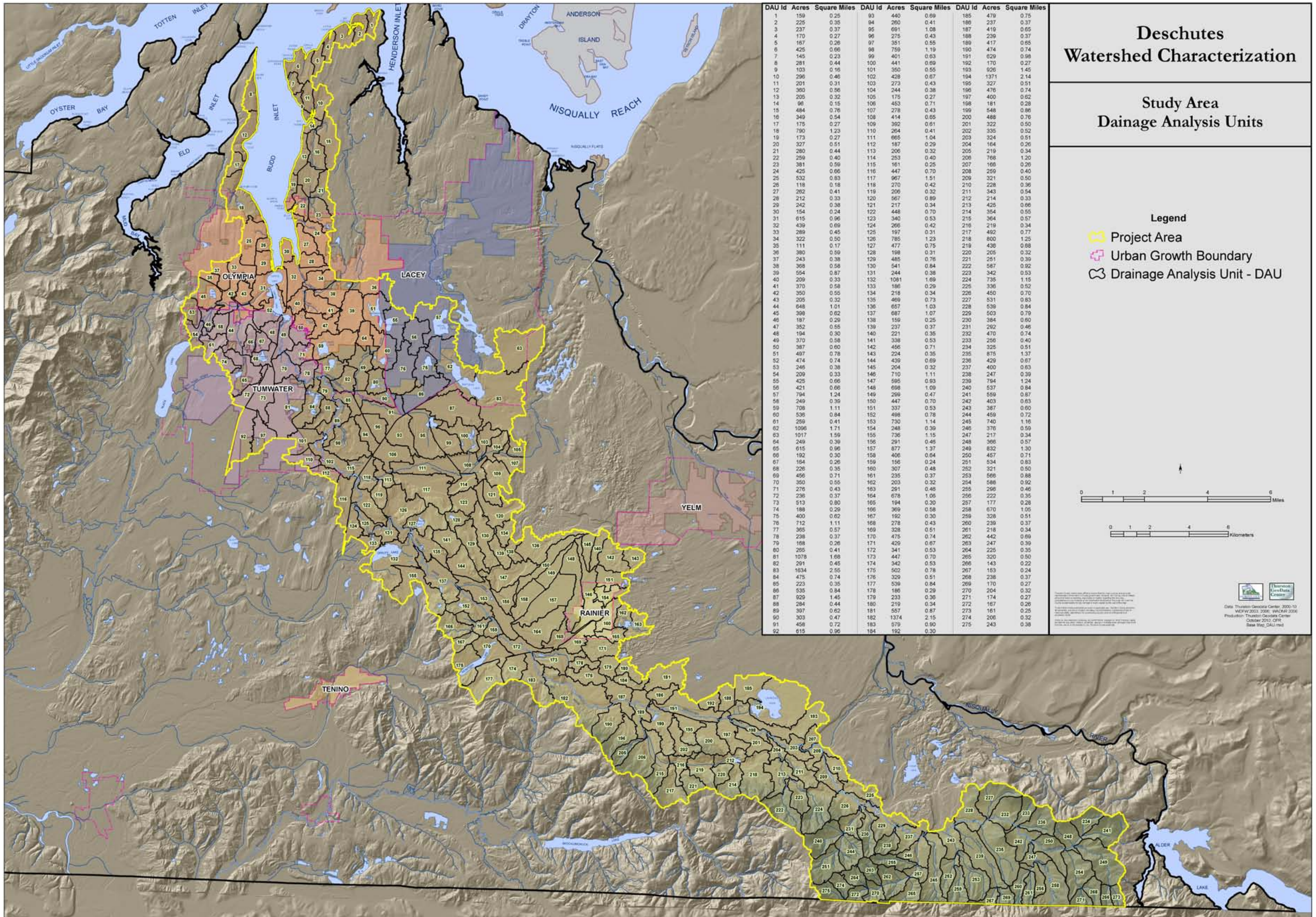

Figure 1.3 Deschutes River Watershed Study Area Drainage Analysis Units

Potential Restoration Opportunities

Potential natural resource restoration sites were determined by assessing several ecological and biological landscape indicators that were then used to assess the ecological processes and the biological elements at the DAU scale and sub-watershed scale.

Step One: Follow the Matrix and Pathways of Landscape Indicators (Matrix) to assess ecological processes at the DAU scale.

Step Two: Identify potential natural resource sites using aerial photos and other GIS data in the study area.

Step Three: Determine current state of all ecological processes at the DAU scale to determine their ecological benefit to maintain sites if restored.

Step Four: Rank natural resource sites for their environmental benefit if restored.

How were preservation and restoration sites identified?

The goal of this study was to determine natural resource sites that can be restored to provide greater function in the DAU to mitigate past disturbances, specifically the movement of water. All natural resource sites not ranked Moderate or High for restoration can be assumed to be of high ecological value for avoidance and preservation, or would provide little to no environmental benefit if restored.

There are two essential steps to identify and assess natural resource sites; 1. Determine the ecological processes at the DAU scale using the Matrix; and 2. Identify all degraded natural resource sites in the study area. These two data sets are the foundation of the watershed characterization.

The matrix was used to identify DAUs that are "properly functioning" (PF), "at risk" (AR) or "not properly functioning" (NPF) for the five ecological processes (movement of water, wood, sediment, pollutants, and heat). The natural resource site (potential wetland, riparian, and floodplain restoration sites) datasets were determined primarily through aerial photo and LiDAR interpretation of the study area and supplemented by existing natural resource inventories, and locally identified natural resource recovery areas. See the revised watershed characterization methods document (Appendix A) for detailed descriptions of the methods specific to the development of each natural resource database.

How were preservation and restoration sites prioritized?

The focus of this work is to identify natural resource sites that can be restored with a high probability of success given their location in the landscape. All natural resource sites having a low restoration value can have a high avoidance and preservation value, or they would have little environmental benefit if restored.

Data on the following key environmental attributes were compiled on each candidate restoration site:

- Ecological process condition rankings
- Anticipated environmental benefits gained if the resource is restored
- Type of natural resource
- Site targeted for restoration in a local or regional recovery plan
- Site on or adjacent to publicly owned land
- The size of the candidate restoration site

Detailed methods for prioritizing natural resource restoration sites are described in Appendix A and detailed data and results are presented in Appendices B through X.

When developing the priority list for natural resource restoration, all potential riparian, wetland, and floodplain restoration sites were initially considered candidates for natural resource restoration. Attributes of each candidate site were then compared to criteria established for all landscape attributes. These sites were further evaluated based on the DAU ecological rank of PF, AR, or NPF. This process eliminated sites from further consideration and ranked remaining sites. The resulting potential natural resource sites environmental benefit lists are presented in Table 1.7.

The potential natural resource restoration site database consists of 3350 polygons that were created in ArcMap as a data layer, including:

- 2817unique wetland sites
- 486 unique riparian sites
- 47 unique floodplains sites

Table 1.7 Potential Natural Resource Restoration Sites

Sub-watershed	Wetlands	Riparian	Floodplain
Upper Deschutes	189	126	0
Lawrence Lake	300	77	7
Vail	399	86	4
Rainier	144	11	2
Offut Lake	365	63	19
Spurgeon Creek	227	27	1
Pattison Lake	135	9	0
Lower Deschutes	291	17	9
Percival Creek	270	18	1
Moxlie Creek	238	14	4
East Budd	231	24	0
West Budd	28	14	0
Total	2817	486	47

We initially considered all potential riparian, wetland, and floodplain restoration sites when developing the priority list. Attributes of each candidate site were then evaluated using established criteria. This process eliminated sites ranked Low from further consideration. Sites ranked Low are either of high quality avoidance and preservation sites, or if restored would provide little environmental benefit if restored.

After criteria were applied to the initial site database, a total of 2119 sites were further evaluated (see Table 1.8).

Table 1.8 Actual Natural Resource Restoration Opportunities

Sub-watershed	Wetlands	Riparian	Floodplain
Upper Deschutes	115	74	0
Lawrence Lake	205	52	7
Vail	230	47	4
Rainier	72	8	1
Offut Lake	163	38	17
Spurgeon Creek	148	23	0
Pattison Lake	64	5	0
Lower Deschutes	218	17	9
Percival Creek	222	10	1
Moxlie Creek	172	10	3
East Budd	148	14	0
West Budd	18	4	0
Total	1775	302	42

What are the preservation and restoration opportunities within the study area?

Based on the site's environmental ranking and the ecological process rank of the DAU that it resides in, a total of 2119 potential wetland, riparian, and floodplain restoration sites met minimum ranking criteria and were prioritized. These prioritized lists and data used in the prioritization process are presented in the following 12 chapters.

Were any of the sites given closer examination?

All identified sites will be field verified as still available. If sites are still available (haven't been developed), then an economical analysis will be completed to determine which sites are viable and practicable to pursue further for restoration and/or preservation opportunities.

How should this information be used?

The information in this report should be used as the first screening tool to evaluate restoration opportunities in the sub-watersheds in the study area. The prioritized sites list can be used to select projects that provide the greatest ecological benefit if enhanced. The information could also be used to identify Compensatory Mitigation sites and sites that could be purchased using Conversation Futures funds.

Conditions of Natural Resources in the Study Area

All the candidate floodplain, wetland, and riparian restoration sites using aerial photo interpretation have been analyzed, but only a limited number have had preliminary field verification. *The potential restoration site priority lists developed through watershed characterization should be considered as the starting point for a more extensive site assessment effort by project environmental staff or their consultant support.* This is recognition that the selection of the best potential restoration sites requires both a landscape-scale assessment and a detailed site-specific analysis.

Watershed characterization products are limited by the number, location, and extent of potential wetland, floodplain, and riparian restoration sites within the study area to mitigate past development. The goal of a watershed characterization is to eliminate or reduce the need for hard stormwater infrastructures, such as a conveyance system to engineered ponds, and use the natural function of the resources to mitigate the current built environment.

What are the conditions in the Deschutes Watershed study area?

The Deschutes River study area drains approximately170 sq miles. The following sub-watersheds are included in the study area: Upper Deschutes, Lawrence Lake, Vail Rainier, Offut Lake, Spurgeon Creek, Pattison Lake, Lower Deschutes, Percival Creek, Moxlie Creek, Budd, West East Budd, as well as various unnamed tributaries (see Figure 1.2 Study Area Sub-Watersheds).

The headwaters of the Deschutes River are located in the Snoqualmie National Forest, within Lewis County. The lower portion of the river flows through the City of Tumwater and the City of Olympia, draining into Capitol Lake and eventually into Budd Inlet. The Deschutes River drains a total of approximately 170 square miles. The Deschutes watershed is in the Budd/Deschutes Watershed Resource Inventory Area 13 (WRIA 13) (TRPC, 2008). The Deschutes River is the largest drainage system within this WRIA (Haring and Konovsky, 1999).

Budd Inlet is located between Henderson Inlet to the east and Eld Inlet to the west. The inlet is about 7 miles long and has an average width of 1.15 miles. The average depth is 27 feet with a maximum depth of 110 feet occurring near the mouth of the inlet. The inlet is classified as a shallow, poorly mixing estuary. The circulation and mixing pattern in the inlet are primarily driven by a two-layer system; the lower water column flows south toward the head of the inlet, and the upper water column flows north toward the mouth. A variety of land uses occur along the shoreline at the lower portion (southern end) of the inlet; these include undeveloped park shoreline, marinas, residences, and industrial facilities. This urbanized portion of the shoreline accounts for about one-third of the total shoreline. The upper portion (northern end) of the inlet is largely suburban in nature (Thurston County Advance Planning and Historic Preservation (TCAPHP 1995).

The Budd Inlet/Deschutes Watershed is comprised of 143 identified streams that provide over 256 linear miles of drainage. The Deschutes River with its associated tributaries is the largest drainage system within the watershed. The 52 mile long river drains approximately 166 square miles or about 84% of the total watershed. Other notable streams within the Budd Inlet drainage are Percival/Black Lake Ditch, Ellis, Moxlie/Indian, Adams, Mission and Schneider creeks.

The drainage basin of the Deschutes River drops from the highest point within the watershed, at an elevation of 3,870 feet near Cougar Mountain, to the lowest point near sea level at the river's mouth at Capitol Lake. The upper extent of the river (RM 41 to 52) has a moderately steep gradient. The river drops rapidly over Deschutes Falls at river mile 41, forming a total barrier to fish passage (Williams et al. 1975). Much of the upper watershed lies in the transient snow zone of 1,100 to 3,600 feet elevation. Transient snow zones are areas where rain-on-snow precipitation events are relatively common, making it difficult for hydrologists to estimate runoff and infiltration. The lower 41 miles of drainage consists of a broad prairie-type valley floor that flows mostly through open farmland interspersed with dense stands of mixed deciduous and coniferous growth (Roberts and Pett, 2008).

Pre-development land cover

In 1853, natural beds of Olympia oysters were found in Budd Inlet, and soon a new industry began. The Brenner brothers were among the first settlers to industrialize the oyster. The Callow Act and the Bush Act enabled all occupants of the oyster lands to own their property, and deeds were awarded to both the Indians and the white settlers. As other industry started to appear on the Sound, a pulp mill began operation in Shelton in 1927, adversely affecting the shellfish industry in the south Sound. Members of the Olympia Oyster Growers Association took on the long battle to keep the delicate Olympia Oyster alive. Experimentation with Pacific oysters showed that it was a hardier species and soon brought improvement to the industry (Eld Inlet Watershed Action Plan, October 1989)

Current conditions

Approximately, 11% percent of the entire Deschutes River Watershed study area is covered by the built environment (see Figure 1.4 and 1.5, Classification Percent Totals for the Deschutes River Watershed Study Area).

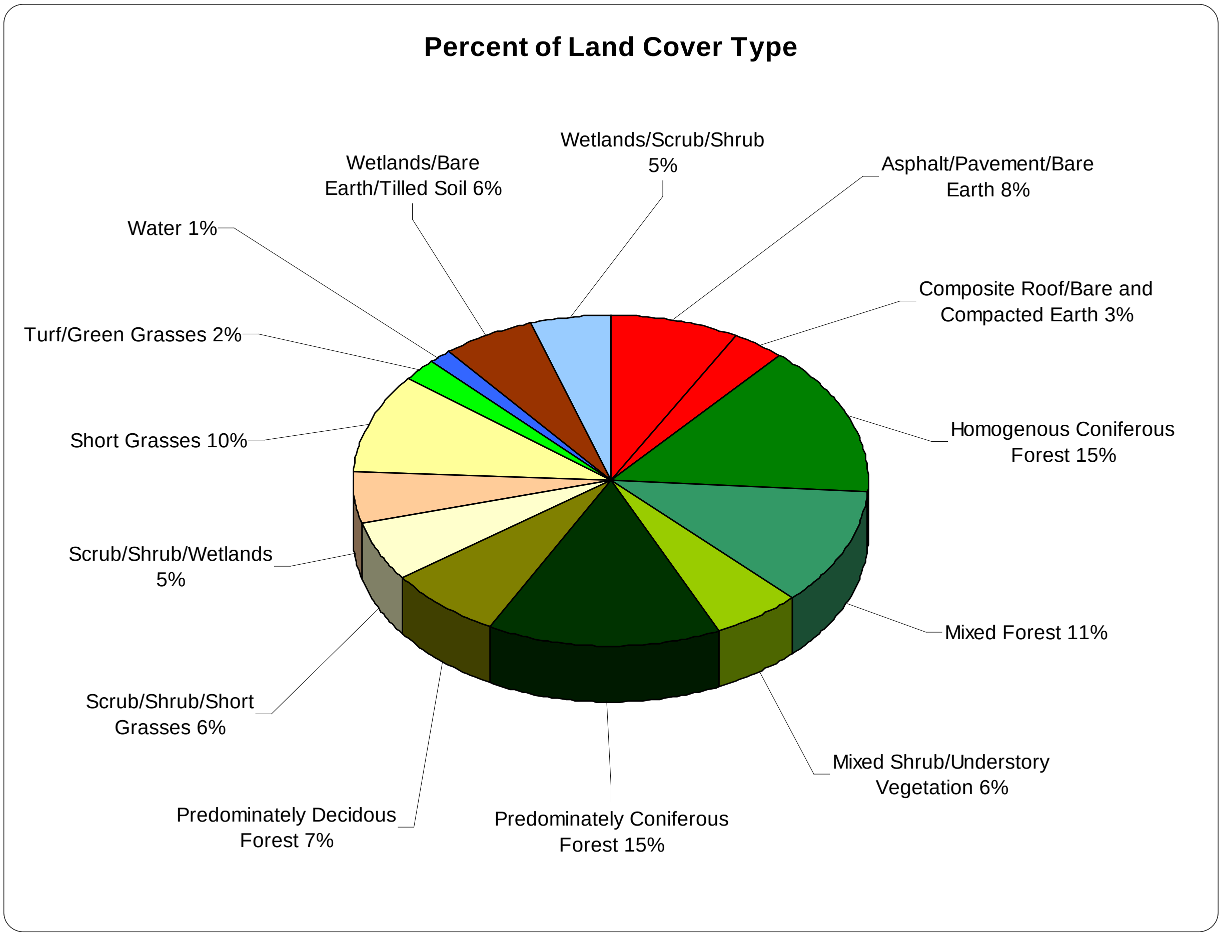

Figure 1.4 Classification Percent Totals for Deschutes Study Area

Land cover data derived from 2009 SPOT imagery.

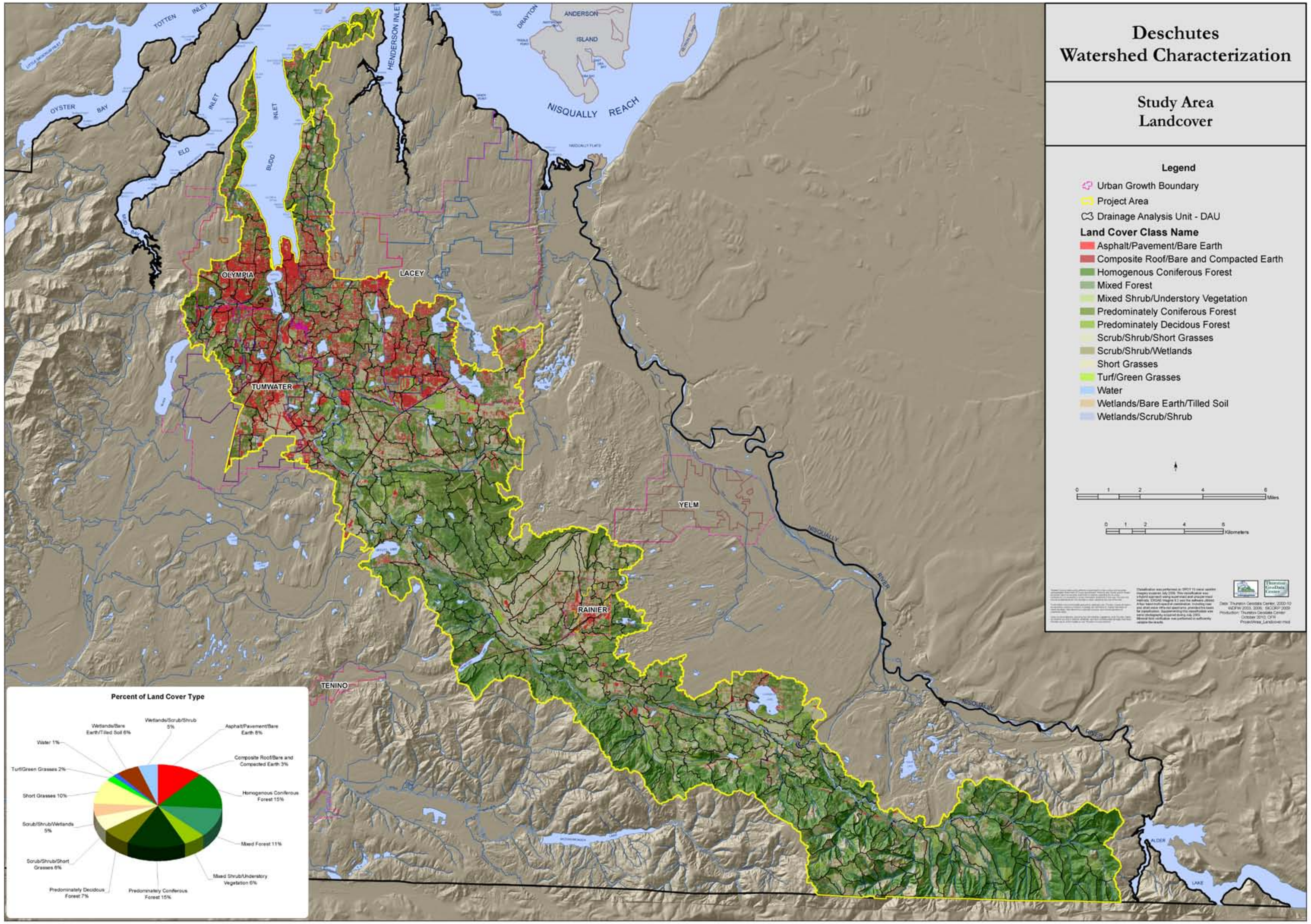

Figure 1.5 Deschutes River Watershed Study Area Land Cover

In addition to classifying land cover in the study area, 16 landscape indicators were evaluated (see Figure 1.3 Landscape Indicators). We analyzed the condition of each of the following indicators within each DAU:

1. Forest Land Cover
2. Prairie Resources
3. Wetlands-Assimilative capacity and hydro alteration
4. Total Impervious Surface (TIA)
5. Riparian Zones
6. Steep Slopes
7. Habitat Connectivity
8. Impaired Water Bodies
9. Benthic Indices of Biotic Indicators (BIBI)
10. Road Density
11. Stream Crossings
12. Stream Channel Straightening
13. Floodplain Decoupling
14. Bare Soils
15. Heat
16. Pollutants

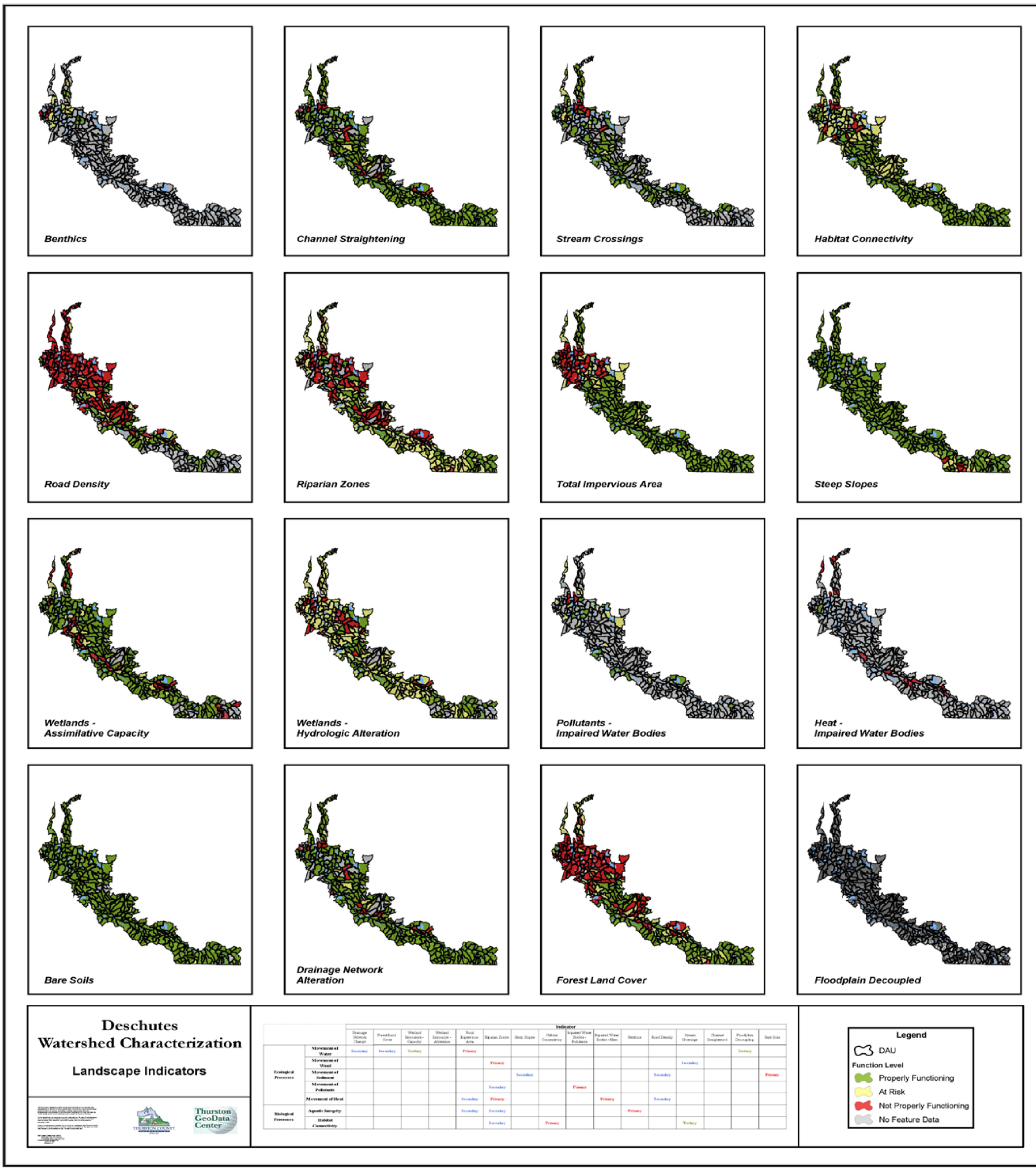

Figure 1.6 Deschutes River Watershed Study Area Landscape Indicators

The current condition of each DAU was determined to be “properly functioning”, “at risk” or “not properly functioning” based on the values detailed in the MPI (see Appendix A, Table 7 for complete details).

Hydrogeology and groundwater recharge

The geology of WRIA 13 is fairly uniform throughout the drainages. Glacial ice scoured the Puget Sound lowlands at least four times, retreating most recently only 10,000-12,000 years ago. The main glacial advances of the Salmon Springs and the later Vashon glaciations were most important to the area. Each time the massive glaciers advanced, they dammed the outlet of Puget Sound and created a vast lake that drained south into the Black River valley. “Rock flour,” the finely ground remains of rocks pulverized by glacier action, settled on the bottom of this glacial lake. These deposits became the commonplace blue clays of the Puget lowlands. The great weight of the glaciers compacted underlying sediments into a concrete-like material called “glacial till” (unsorted sand, gravel, and boulders in a silt and clay matrix, a.k.a. hardpan). As the glaciers melted, the runoff deposited thick layers of sand and gravel known as “outwash” (moderately to well sorted sands and gravels). Each of these glacially deposited materials—clay, till and outwash—is present in the basins in various combinations. Outwash provides the formations that hold groundwater, and all three provide the parent material for most soils (Roberts et al 2008).

Water quality

The Deschutes River is found on the Category 5 303(d) list of impaired waterbodies for temperature and fecal coliform. The Deschutes is also found on the Category 4 list for instream flow violations. The Deschutes is being monitored at its mouth above Tumwater Falls as part of Thurston County’s long-term monitoring (Thurston County, 2006).

Washington Department of Ecology has included the Deschutes River in a total maximum daily load study (TMDL) which began in 2003. The TMDL project will identify pollution sources and recommend remedies for correction. Interim results are recently available from the TMDL study (Roberts and Pelletier, 2007). These indicate that the Deschutes River does fall below the target dissolved oxygen standard of 8.0 mg/L. The river is also warmer than the water quality standards would allow in the summer.

Nutrient concentrations in the river tend to increase as sample sites moved downstream (Roberts and Pelletier, 2007). This represented steady loading of the river. However, nutrient concentrations decreased when entering Capitol Lake, which indicated the lake acts to settle and assimilate nutrients.

Table 1.9 Deschutes River on the 2008 303(d) list for Freshwater Bodies

Waterbodies	Parameter	Listing ID	Township	Range	Section
Deschutes River	Temperature	48726	15N	03E	10
Deschutes River	Temperature	48724	16N	02E	29
Deschutes River	Dissolved Oxygen	47756	16N	02E	30
Deschutes River	Fecal Coliform	46210	16N	02E	30
Deschutes River	Temperature	7595	16N	01E	26
Reichel Creek	Dissolved Oxygen	47714	16N	01E	26
Reichel Creek	Fecal Coliform	45566	16N	01E	26
Reichel Creek	Temperature	48666	16N	01E	26
Deschutes River	Temperature	48721	16N	01E	22
Deschutes River	Temperature	48720	16N	01E	20
Deschutes River	Fecal Coliform	9881	16N	01E	18
Deschutes River	Temperature	9439	16N	01E	18
Unnamed tributary to Deschutes River	Temperature	7591	16N	01E	18
Deschutes River	Temperature	48718	16N	01W	40
Deschutes River	Temperature	48717	16N	01W	2
Deschutes River	Temperature	48715	17N	01W	28
Tempo Lake Outlet	Temperature	48696	17N	01W	28
Deschutes River	Temperature	48714	17N	01W	29
Deschutes River	Fecal Coliform	46500	17N	01W	19
Deschutes River	Dissolved Oxygen	47754	17N	01W	19
Deschutes River	Temperature	48713	17N	01W	19
Spurgeon Creek	Fecal Coliform	46061	17N	01W	19
Deschutes River	Temperature	48712	17N	01W	13
Deschutes River	Fecal Coliform	46499	17N	01W	7
Deschutes River	Dissolved Oxygen	47753	17N	01W	7
Deschutes River	Temperature	48711	17N	01W	7
Deschutes River	Temperature	48710	17N	02W	7
Chambers Creek	Fecal Coliform	45560	18N	02W	36
Deschutes River	Dissolved Oxygen	10894	18N	02W	60
Percival Creek	Temperature	48727	18N	02W	55
Percival Creek	Dissolved Oxygen	48085	18N	02W	55
Percival Creek	Fecal Coliform	46103	18N	02W	55
Percival Creek	Temperature	42321	18N	02W	21
Black Lake Ditch	Dissolved Oxygen	47761	18N	02W	21
Black Lake Ditch	Temperature	48733	18N	02W	21
Percival Creek	Dissolved Oxygen	48086	18N	02W	21
Percival Creek	Fecal Coliform	46108	18N	02W	21

Waterbodies	Parameter	Listing ID	Township	Range	Section
Percival Creek	Temperature	48249	18N	02W	28
Percival Creek	Temperature	48729	18N	02W	34
Black Lake Ditch	Temperature	48734	18N	02W	29
Black Lake Ditch	Dissolved Oxygen	47762	18N	02W	32
Black Lake Ditch	Temperature	48735	18N	02W	32
Black Lake Ditch	pH	50990	18N	02W	32
Indian Creek	Fecal Coliform	45213	18N	02W	24
Indian Creek	Fecal Coliform	46410	18N	02W	52
Moxlie Creek	Fecal Coliform	45252	18N	02W	41
Moxlie Creek	Fecal Coliform	46432	18N	02W	56
Mission Creek	Fecal Coliform	46102	18N	02W	53
Mission Creek	Fecal Coliform	45212	18N	02W	64
Ellis Creek	Fecal Coliform	45480	18N	02W	53
Adams Creek	Fecal Coliform	45695	19N	02W	26
Adams Creek	Fecal Coliform	45462	19N	02W	25
Adams Creek	pH	50965	19N	02W	25
Butler Creek, SW Fork	Fecal Coliform	45342	18N	02W	66
Butler Creek	Fecal Coliform	45471	18N	02W	66
Schneider Creek	Fecal Coliform	45559	18N	02W	59

Fish Resources

The Deschutes River and Budd Inlet watershed support important shellfish and anadromous fish populations. Five salmonid species use the study area for spawning and rearing: steelhead trout, searun and resident cutthroat trout, coho salmon, hatchery chinook, and chum salmon (Haring and Konovsky, 1999), although historically Tumwater Falls presented a natural barrier to fish passage. The Washington Department of Fisheries constructed a fish ladder in 1954 (General Administration, 2002). Chum salmon primarily rely on small, low-gradient streams feeding directly into Budd Inlet. Chinook salmon primarily use the lower and middle mainstem of the Deschutes River and Percival Creek. The middle and upper reaches of the watershed are used by coho salmon, steelhead trout, and searun and resident cutthroat trout. Resident trout are common in the tributaries above barriers to anadromous salmonids.

The Chinook that occur in the Deschutes River are of hatchery origin (Haring and Konovsky, 1999). Chinook were introduced into the river in the 1950s and are released at the Deschutes Hatchery with limited release upstream (Haring and Konovsky, 1999). Coho populations also are not native to the Deschutes River and occurrences within the river have declined since their introduction between the 1940s and 1981. There have been no coho releases into the river since 1981 and natural production numbers have remained low for this waterbody. A watershed assessment of coho survival determined several factors were critical to restoring coho habitat and increasing survival rates: reduction of fine sediment rates in the Deschutes River; riparian revegetation and restoration to decrease summer water temperatures; and increasing large woody debris (LWD) availability along the river (Anchor, 2008).

Instream and Riparian Habitats

The Deschutes River Watershed is managed for timber harvest, farmland, and urban growth. Clear-cutting in the upper Deschutes Watershed over time has contributed to increased flow, accelerated rates of erosion, and sedimentation issues in the Deschutes River. By 1976, sediment loads had increased at the dam located above the river's tidal flats and restricted activities relating to fish rearing and recreation along the river and in the lake. A streambank erosion survey was conducted during 1982 and 1983 and determined that the majority of eroding material consisted of fine sands, silts, and clays that were transported along the river and deposited in Capitol Lake. A portion of eroding material was composed of coarse gravels, cobbles, and boulders, which were generally not transported to the lake. Almost fifty percent of sites contributing to erosion occurred between Lake Lawrence (River Mile [RM] 30) and the Deschutes Falls (RM 41). A subsequent study using statistical modeling was conducted to determine whether surface erosion from unpaved, primarily forested roads in the Budd/Deschutes basin was contributing to high sediment load in the Deschutes River. Fine sediment within the river were found to originate from a variety of sources, including: erosion of glacial terrace banks; erosion and landslide occurrences due to record flood events; bank erosion in tributaries; increased levels of shoreline armoring that may contribute to scour; and other anthropogenic factors associated with shoreline modification and infrastructure that may lead to runoff, landslides, and downstream sediment input (Raines, 2007).

Shellfish Resources

Species of shellfish known to occur within Budd Inlet important to recreational and commercial harvesters are geoducks, manila, native littleneck, butter clams, cockles, mussels, squid, red rock crabs, and oysters (Zulauf et al., 1990).

The Washington Department of Health (DOH) monitors levels of fecal coliform bacteria in the marine waters to determine suitability for shellfish harvesting. The department also periodically surveys shorelines and drainages to look for pollution problems that might affect the growing areas. The Washington State Department of Health (DOH) has closed most of Budd Inlet (south of Burfoot County Park) to shellfish harvest (DOH, 2008).

References

Anchor Environmental, LLC. 2008. Final Deschutes River Watershed Recovery Plan: Effects of Watershed Habitat Conditions on Coho Salmon Production. Prepared for Squaxin Island Tribe Natural Resources Department.

Angermeier, P. L. and I. Schlosser. 1995. Conserving aquatic biodiversity: beyond species and populations. In: Evolution and the Aquatic Ecosystem: Defining Unique Units in Population Conservation. Nielsen, J. L. (ed.) American Fisheries Society Symposium 17:402-414

Baranski 2002. personal communication

Beechie, T. and S. Bolton. 1999. An approach to restoring salmonid habitat-forming processes in Pacific Northwest watersheds. Fisheries 24(4):6-24.

Department of Health. 2008. Shellfish Safety Information, Marine Closure Zones. www.doh.wa.gov/ehp/sf/default.htm.

Ebersole, J. L., W. Liss, and C. Frissell. 1997. Restoration of stream habitats in the Western United States: restoration as re-expression of habitat capacity. Environmental Management 21(1):1-14

Eld Inlet Watershed Action Plan, October. 1989

Frissell, C. A. 1996. A new strategy for watershed restoration and recovery of Pacific salmon in the Pacific Northwest. In: Watershed and Salmon Habitat Restoration Projects: Guidelines for Managers of State Trust Lands. Dominguez, L. (ed.). Washington Department of Natural Resources. Olympia, WA 90 pp.

General Administration. 2002. Capitol Lake, A Vision for the Next Ten Years.

Haring and Konovsky, 1999. The Washington State Conservation Commission report on Habitat Limiting Factors for WRIA 13

Kuttle, 2002. Salmonid Habitat Limiting Factors Water Resource Inventory Area (WRIA) 14

Montgomery, D. R. 1995. Input- and out-oriented approaches to implementing ecosystem management. Environmental Management 19(2):183-188.

National Research Council (NRC). 2009. *Urban Stormwater Management in the United States*. The National Academies Press, Washington, DC.

Raines, M. 2007. Deschutes River Bank Erosion: 1991 to 2003. Report submitted to the Squaxin Island Tribe Natural Resources Department and Washington Department of Ecology.

Reeves, G. H., L. Benda, K. Burnett, P. Bisson, and J. Sedell. 1995. A disturbance-based ecosystem approach to maintaining and restoring freshwater habitats of evolutionarily significant units of anadromous salmonids in the Pacific Northwest. In: Evolution and the Aquatic Ecosystem: Defining Unique Units in Population Conservation. Nielsen, J. L. (ed.). American Fisheries Society Symposium 17:334-349.

Thurston Regional Planning Council. 2006. South Puget Sound Forum Indicators Report

Washington Department of Fish and Wildlife and Western Washington Treaty Tribes. 1994

Washington State Department of Ecology. 2007. Tributaries to Totten, Eld, and Skookum Inlets: Fecal Coliform Bacteria and Temperature Total Maximum Daily Load Study. Publication No. 06-03-007

Williams, R.W., R.M. Laramie, and J.J. Ames. 1975. A Catalogue of Washington Streams and Salmon Utilization. Volume 1—Puget Sound Region. Washington Department of Fisheries.

Zulauf, A., T. Nelson, L. Tamayo, J. Perkins, and B. McIntosh. 1990. Deschutes/Budd Inlet Watershed—Thurston County, Washington. Prepared for the Deschutes/Budd Inlet Watershed Management Committee.