Central Puget Sound
Open Space Valuation




EARTH ECONOMICS

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Authors:
Matt Chadsey, Zachary Christin, and Angela Fletcher

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Prepared By:
Earth Economics
107 North Tacoma Avenue
Tacoma, WA 98403
253-539-4801
www.eartheconomics.org
info@eartheconomics.org

Prepared For:
Regional Open Space Strategy
University of Washington
Seattle, WA
206-708-0512
www.openspacepugetsound.org
info@openspacepugetsound.org

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▼ The Snohomish River. Image credit: creative commons image by Tavis Jacobs.

Abstract

This report provides the results of the first ever open space valuation of Western Washington's Central Puget Sound region including King, Kitsap, Pierce, and Snohomish counties. Ten open space services, comparable with ecosystem services, are valued for each of 15 land cover types. These services are shown to represent a substantial and critical component of the regional economy, contributing $11.4 to $25.2 billion per year.

With a conservative approach, considering natural capital as a short-lived economic asset – something that depreciates over time, like a bridge or road, Central Puget Sound's minimum natural capital asset value is shown to be between $328 billion and $825 billion. However, unlike built capital, our open space is largely self-sustaining, renewable, and long-lived. Furthermore, as the region continues to grow, our open space resources will increase in value due to their greater scarcity. **By using a zero discount rate, over 100 years, the natural capital asset value of the Central Puget Sound region is as high as $2.6 trillion.**

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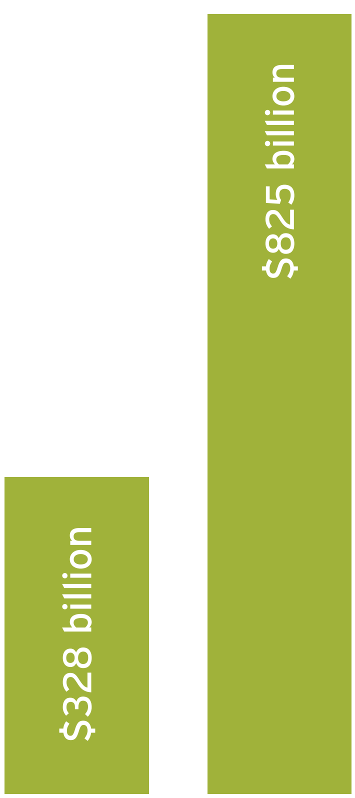
Executive Summary

Open space in the Central Puget Sound is a multi-billion dollar economic asset. The region that includes King, Kitsap, Pierce, and Snohomish counties has one of the nation's most robust and fastest growing economies. This economy—and every resident and business—is inextricably linked with the natural landscapes. Our open space provides goods and services like clean water and air, food, flood protection, raw materials, energy, opportunities for play, and many more. This natural capital—the open space that provides these many benefits—is one of our greatest assets. The Regional Open Space Strategy (ROSS) team has sponsored this valuation study to estimate the contribution that open space and its many services make to the Central Puget Sound economy each year.

The ROSS is a collaborative effort to integrate and advance the many activities underway to conserve and enhance the ecological, economic, recreational, and cultural vitality of the Central Puget Sound region. The effort is part of a growing national movement among urban and rural planners, policymakers, social scientists, and other partners advancing how investments in natural systems support a holistic approach to development and regional planning. The ROSS is creating this vision for regional open space and equipping our communities to implement and steward that goal. The project is facilitated by the University of Washington's Green Futures Lab and is funded by the Bullitt Foundation and The Russell Family Foundation.

Minimum natural capital asset value



If we take a conservative approach and consider natural capital as a short-lived economic asset—something that depreciates over time, like a bridge or road—**the minimum natural capital asset value of open space in Central Puget Sound is between $328 billion and $825 billion.** However, unlike built capital, our open space is largely self-sustaining, renewable, and long-lived. Furthermore, as the region continues to grow, our open space resources will increase in value due to their greater scarcity. **By using a zero discount rate, over 100 years, the natural capital asset value of the Central Puget Sound region is as high as $2.6 trillion.**

These are conservative estimates. This study uses benefit transfer methodology to assign annual dollar flows of goods and services from the region's open space to the local economy. Table 1 shows the calculated low and high dollar value attributed to each of the ROSS open space services. Table 2 shows the same results organized by land cover type. These values are both conservative and incomplete due to gaps in the research literature for particular land covers and open space service combinations. For example, the totals do not include the value of snowpack, the region's aquifers, or fully capture the recreational value of the region's urban lakes and rivers. Thus, the region's open space has far more value to reveal.

In addition to filling data gaps like those mentioned above, additional research is needed to better estimate the local interactions between open space and the economy, especially with respect to biodiversity, human health, and social equity. For example, wildlife corridors and salmon restoration projects depend on many unique local characteristics and must be evaluated using models, methods, and data beyond that available through the high-level benefit transfer methodology. As another example, the physical and mental health benefits of open space are well documented but are still difficult to value without detailed, local analysis.

The services and natural capital values in this report represent a first step in understanding the magnitude and importance of open space to the Central Puget Sound economy and communities. Clearly, Central Puget Sound's open space assets represent a substantial and critical component of the regional economy, $11.4 to $25.2 billion per year.

Table 1.
Open space service value estimates. Low and high estimates are in thousands of dollars per year.

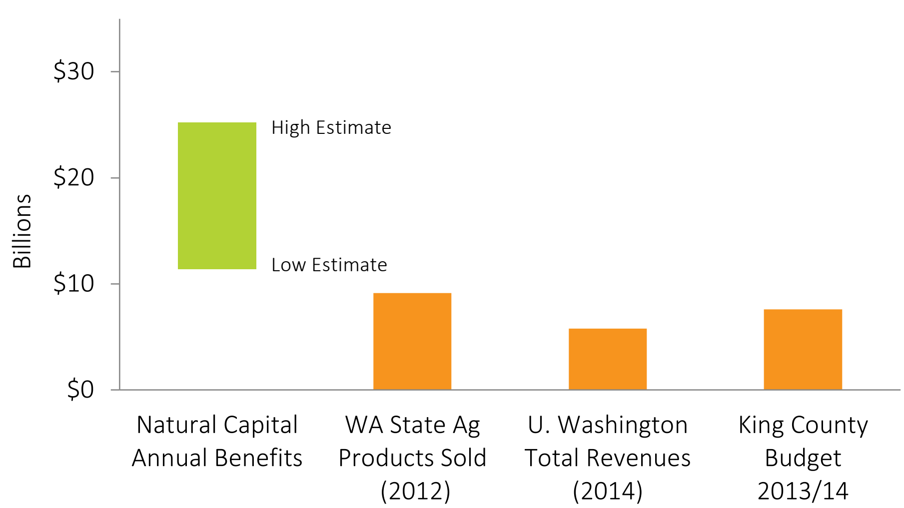
Service	Low	High
Aesthetic	2,293,975	9,509,713
Air	422,203	529,187
Food	1,860,499	4,194,473
Shelter	12,587	86,472
Water	41,168	50,352
Health	2,633,343	4,132,675
Play	23,279	155,093
Disaster Mitigation	73,984	111,407
Raw Materials	4,034,301	4,568,983
Waste	62,605	1,925,347
Total	**11,457,944**	**25,263,700**

Table 2. Open space service values by land cover. Dollar values are in thousands per year.

Land Cover		Acres	Low	High
Forest	Deciduous	130,779	$349,294	$695,782
	Evergreen	1,797,553	$4,594,833	$11,280,912
	Mixed	376,893	$970,465	$2,052,403
Wetlands	Emergent Herbaceous	23,777	$129,607	$1,083,597
	Woody	74,377	$474,995	$3,507,100
Shrub and Grasslands	Shrub	430,052	$188,793	$204,296
	Grassland/ Herbaceous	138,109	$134,857	$175,296
	Pasture/Hay	106,823	$7,326	$53,952
	Cultivated Crops	14,839	$1,222	$37,326
Open Water and Beach	Beach	28,987	$1,501,123	$1,546,772
	Lakes	55,392	$2,273	$180,345
	Reservoirs	2,775	$260	$2,370
	Rivers	13,492	$356,270	$367,462
	Saltwater	285,069	$2,649,788	$3,912,022
Developed	Open Space (urban park space)	20,795	$96,836	$164,067
Total		**3,499,712**	**$11,457,944**	**$25,263,700**

Figure 1 provides some perspective on both the magnitude and importance of this value by comparing the open space goods and services with other critical economic entities and indicators in the region. Beyond this financial contribution, healthy open space helps build the region's social and economic resilience in the face of climate change and rapid population growth by providing disaster mitigation, water, and waste services among many other benefits. Research from other regions demonstrates that continued and increasing investment in these resources can provide high returns and lead to more efficient capital investments and reduced incurred costs.

Figure 1. Central Puget Sound benefits and revenue comparison.



▲ Green River Natural Resources Area. Image credit: creative commons share-alike image by Joe Mabel.

Policy and Institutional Recommendations:

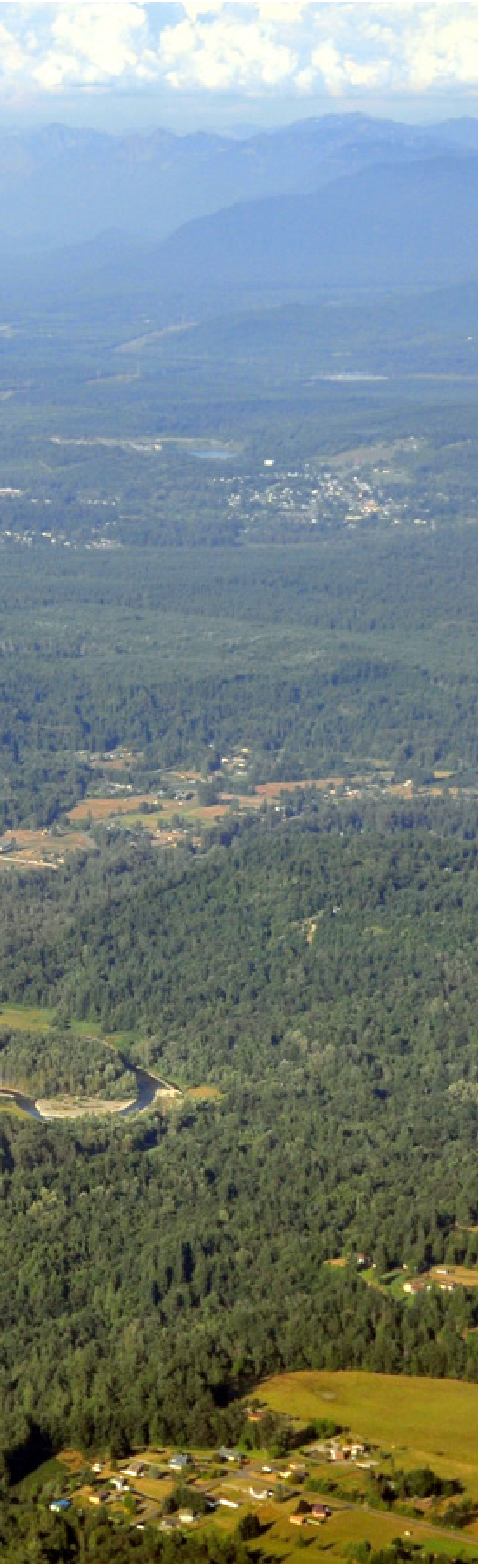
Work in the Puget Sound region and around the nation highlights the need to redesign our larger accounting, investment, and decision-making frameworks to ensure that we protect and expand vital natural capital resources over time. The high value of our open space services and magnitude of pending challenges from population growth and climate change suggest the following priorities:

1. **Educate Policy Makers and the Public:** Teaching people about the value of open space goods and services helps to build understanding about the synergy between the environment, communities, and the economy. Education also helps to garner public support for financing open space preservation and stewardship.

2. **Immediately Include Ecosystem Values in Land Use and Capital Planning Analysis:** Planners and policy makers can immediately use the values contained in this report to inform decisions regarding the purchase and stewardship of open space. Consideration of the value of open space services can improve economic analysis, as natural capital strategies often prove to be more cost-effective and robust solutions to our most challenging problems.

3. **Create a Governance and Financing Entity for Central Puget Sound:** Open space is a vast and valuable economic asset, essential to a healthy and prosperous economy, but is threatened by our rapidly increasing population. Open space is too important to be lost. The region needs a strong institution, clear governance, and a stable funding mechanism to effectively preserve this natural capital and retain healthy and resilient natural systems and economies.

This report is organized to present an overview of fundamental open space service valuation concepts, describe the study methodology, and share detailed valuation data. Finally, it provides observations and recommendations about the findings and how they can be used to inform more holistic, efficient, and productive open space policy and shift real dollars to the long-term stewardship and expansion of the region's open space.



Chapter 1

Study Overview and Purpose

◀ Aerial view of the Green River valley
Photo credit: creative commons share-alike image by Joe Mabel.

Regional Open Space Strategy Background

Open space is an economic asset that provides valuable goods and services.

Open space is an economic asset. Healthy landscapes provide valuable goods and services. Robust and resilient economies and communities depend on healthy and productive open space and the critical services it provides. From flood mitigation along the rivers and the coast to food, shelter, and opportunities for play, these open space services contribute billions of dollars per year to the northwest economy and far more intangible value to its communities. As environmental, social, and economic challenges become more prescient, policy leaders and planners need to understand and leverage the critical, strategic solutions that natural capital and open space services offer to the region.

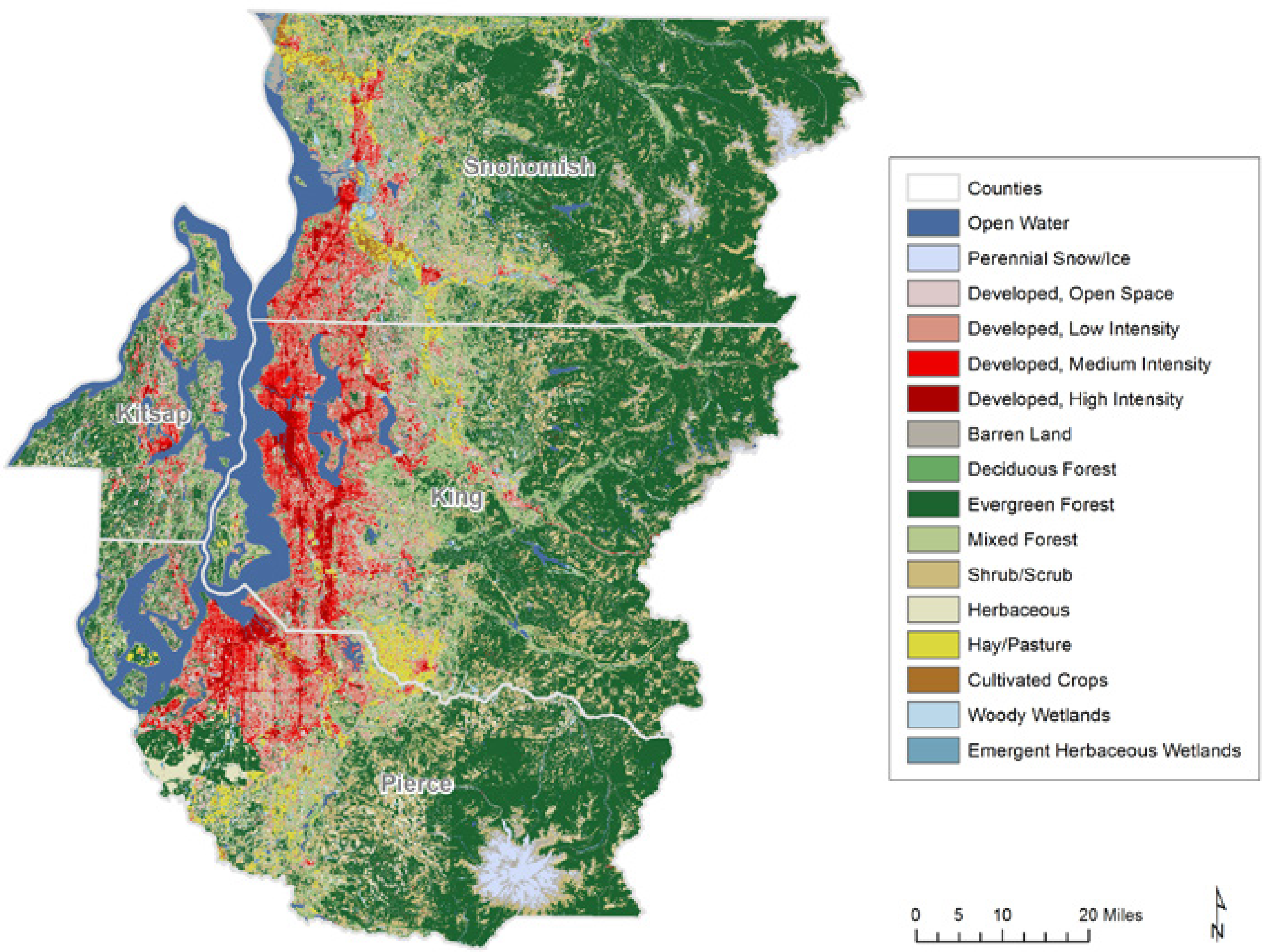
The Regional Open Space Strategy (ROSS) is a collaborative effort to integrate and elevate the many activities underway to conserve and enhance the ecological, economic, recreational, and cultural vitality of the Central Puget Sound region. In this context, open space includes public parks, local and regional trail systems, wetlands and water bodies, wilderness lands, resource lands for agriculture and timber production, as well as urban green spaces like parkways. The ROSS is part of a growing national movement among urban and rural planners, policymakers, social scientists, and other partners advancing how investments in natural systems support a holistic approach to regional planning.

Developing strategies and alliances that effectively integrate multiple conservation and social objectives is a crucial task to make the region's initiatives more robust, economically vibrant, and ecologically sound, and to provide a framework for long-term stewardship. The ROSS is creating this vision for regional open space and equipping our communities to implement and steward that goal. The ROSS project is facilitated by the University of Washington's Green Futures Lab and is funded by the Bullitt Foundation and The Russell Family Foundation.

Regional Population and Geography

The ROSS encompasses 4.4 million acres (6,800 square miles) of highly productive northwest ecosystems within Snohomish, King, Pierce and Kitsap counties, also referred to as 'Central Puget Sound,' one of the state's most economically productive regions. The area stretches from Puget Sound and its vibrant estuaries to the Olympic and Cascade Mountain peaks and represents many ecosystems and land covers. Fed by mountain snowpack, Central Puget Sound is also home to a number of large river systems including the Snohomish, Cedar, Tolt, Green/Duwamish, and White/Puyallup to name a few. These watersheds provide critical habitat for many plants and animals while also supplying water and energy to the region.

Figure 2. Map of Central Puget Sound land cover. Provided by Katie Sauter Messick from ROSS.



The rapidly growing population of approximately 3.7 million people lives in areas ranging from the dense urban centers of Seattle, Bellevue, Everett, Bremerton, and Tacoma to lightly populated rural and agricultural lands. Population growth within and outside of the designated urban growth boundaries is dramatically reducing the amount of open space, especially contiguous parcels, while also degrading open space health, productivity, and resilience.[1]

▲ Aerial view of Arlington, WA and the surrounding landscape. Image credit: creative commons share-alike image by J. Brew.

Open Space Service Valuation Study Goal

The purpose of this valuation is to provide an estimate of the economic contribution that nature within the ROSS boundary makes to the region's economy and communities. Though this is a preliminary and conservative estimate for reasons described later in this report, the data provide important understanding and useful tools that policy makers can use immediately to craft more informed and efficient decisions about protecting open space and enhancing the economic contributions made by nature. Better decisions will help us to more effectively address the challenges of climate change, biodiversity loss, social equity, health, well-being, and economic vitality.

This report is organized to present an overview of fundamental ecosystem valuation concepts, describe the study methodology, and share detailed valuation data. Finally, it provides observations and recommendations about the findings and how they can be used to inform more holistic, efficient, and productive open space policy and shift real dollars to the long-term stewardship and expansion of the region's open space.

Farmland in Snohomish, WA. Image credit: creative commons image by Rachel Samanyi.

Chapter 2

Natural Capital Goods and Services Primer

◀ Trees in the Nisqually National Wildlife Refuge. Photo credit: Lola Flores.

What is Natural Capital?

Open space goods and services are defined as the benefits people derive from nature.

Economies depend upon built, human, and natural capital. A robust and resilient economy requires that all three forms of capital are healthy and are working productively and synergistically. The three types of capital are defined as follows:

Built Capital: Infrastructure, houses, cars, machinery, computers, and all of the other "tangible systems that humans design, build and use for productive purposes."[2]

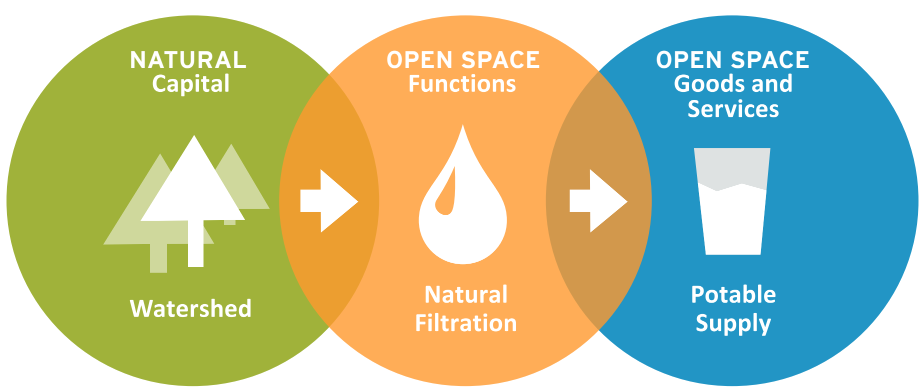
Human Capital: People with their education, health, skills, labor, knowledge, and talents.[i]

Natural Capital: "Minerals, energy, plants, animals, ecosystems, [climatic processes, nutrient cycles and other natural structures and systems] found on Earth that provide a flow of natural goods and services."[3]

Natural capital provides the economy with a flow of goods and services much like built and human capital. These **open space goods and services are defined as the benefits people derive from nature.** For example, natural capital assets within a watershed (e.g. forests, wetlands, and rivers) perform critical functions such as capturing, storing, conveying, and filtering rainfall destined for the water supply that humans need to survive. Without healthy natural capital, many of the services (benefits) that we currently receive for free could not exist and would need to be replaced with more costly built capital solutions, often having lower resilience and shorter longevity. If open space is lost, the economic goods and services it provides will also be lost. Figure 3 illustrates the relationship between natural capital assets, open space functions, and the production of open space goods and services.

i This report does not discuss the importance of human capital. However, people's health and well-being, as well as their work and enjoyment, are closely tied to the built and natural capital around them and are deeply intertwined with economic prosperity.

Figure 3. Goods and services flow from natural capital.



A Framework for Assessing Open Space Services

The ROSS definition of "Open Space" is an embracing term for a diverse spectrum of lands—public and private, spread across a rural and urban continuum—that creates the natural and built green infrastructure on which the region depends. This includes public parks, local and regional trail systems, wetlands and water bodies, wilderness lands, resource lands for agriculture and timber production, as well as urban green spaces like parkways, rain gardens, and green roofs.

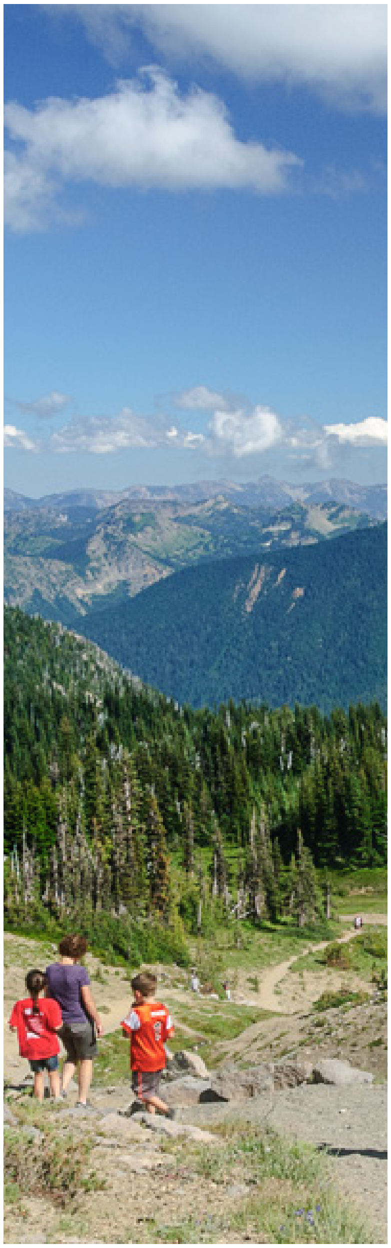
The ROSS has advanced the ecosystem service descriptions in the United Nation's Millennium Ecosystem Assessment[4] to develop a frame of "open space services" to better articulate and value the vast array of critical services and benefits that open space provides in the region. The ROSS has developed 16 open space categories shown in Figure 4. Each category has a defined set of benefits that can be found on the Open Space Puget Sound website, www.openspacepugetsound.org. The mapping between ROSS-Open Space Services and MEA ecosystem services is located in Appendix B: ROSS Open Space Service Mapping to Ecosystem Services.

Valuing Open Space Services

Estimating the economic value of an open space service requires that the service be identified in a particular area, quantified, and attributed economic value. For example, how much play (e.g. bird watching) is expected to occur within wetland areas in the Central Puget Sound region? First, the service must be assumed to occur in a particular type of land. Second, once identified, the magnitude of the service must be quantified. How often do people visit a wetland to watch birds and how long do they spend? Finally, once a quantity has been determined, an economic value for this service must be established via a variety of economic methods described in more detail below. How many dollars is a bird watching visit worth to the visitor and the local economy? This identification, quantification, and valuation process is repeated for each type of land cover (wetlands, forests, beach, etc.) and service (play, disaster mitigation, etc.) to generate a total value for the area.

Figure 4. ◄
ROSS Open Space Services

Though thousands of studies and values are available, there are still significant gaps in the available, peer-reviewed valuation literature for services that have been identified. Without data, these services are valued at zero today. Future studies to fill these gaps will likely increase values attributed to the region's natural capital and open space services significantly.



▲ Hiking in the Cascade Mountains. Image credit: creative commons image by Loren Kerns.

Understanding Open Space Values

Products like timber, drinking water, and crops have value established in the marketplace through traditional supply and demand. These market values reflect the costs associated with the natural, human, and built capital that go into producing them and a profit (unless it is a public utility providing the good at least cost).

In most cases this market value does not capture the many services that nature provides to the economy for free and are not traded in markets. There is no market for flood risk reduction, for example. Additionally, the typical water bill paid by citizens or businesses most often covers only the built-capital costs of pipes and buildings. The essential natural capital inputs for water supply, such as the natural catchment, filtering, conveyance, and storage of rainwater and snowmelt, are all not included in your bill. Yet if these open space services are lost, for example water quality is degraded because natural filtration is lost (due to paving or clearing), then structures, such as a water filtration plants must be built at great cost to replace the lost open space services. This "replacement cost" is one way of valuing forests and wetlands for their water filtration value.

Open space service valuation values these important non-market services in dollars so that they can be used side-by-side with traditional financial measures in policy making and analysis. Inclusion of these values facilitates more informed, holistic, and better planning and decision-making.

Valuation is challenging. Since these products and services are not traded on traditional markets, valuation requires primary studies where economists, ecologists, and social scientists employ a variety of techniques to identify and estimate economic value, described in more detail later in this report. As more primary research is generated over time, the open space values and valuation techniques will continue to be refined and gain additional accuracy.

▲ Top image: the White River, by Jennifer McFadden; Middle image: mudflats at the Nisqually estuary, by USFWS Pacific Region; Bottom image: a kayak on Anderson Island in Pierce County, by Matt Chadsey.

The following examples illustrate some of the ways that nature provides value to the economy.

Water

Watersheds provide fresh water for human consumption, agricultural production, and manufacturing. The water service encompasses surface and groundwater that supply drinking, irrigation, and industrial water supply. The watershed's natural capital (vegetation, soils, geology, rivers) and processes (percolation and evapotranspiration) contribute significantly to the quality, quantity and timing of the water supply. These open space benefits supporting water supply are estimated in this report.

Disaster Mitigation

Wetlands, grasslands, riparian buffers, and forests provide protection to downstream homes and businesses from flooding and other disturbances. These ecosystems are able to slow, absorb, and store large amounts of rainwater and runoff during storms. Changes in land use and the potential for more frequent storm events due to climate change make disaster mitigation a critical service to support economic development and protect our communities. Natural systems, such as forests and wetlands that reduce peak flood heights and flows, protect economic assets and save lives.

Play

Attractive landscapes, clean water, and fish and wildlife populations form the basis of the recreation economy. A recent report by Earth Economics, Economic Analysis of Outdoor Recreation in Washington State, identifies more than 300 outdoor recreation activities in Washington State that support 200,000 jobs and generate $21.5 billion in spending each year.[5] Tourism and recreation are often tied to aesthetic values of open space and natural areas. Recreational fishing, swimming, bird watching, hunting, and hiking are all activities that are supported and enhanced by healthy open space and related services.

Beyond Open Space Service Valuation

The Recreation Economy of Washington State

Washington State's rich outdoor recreation choices provide jobs to many families and businesses. A recent study, *Economic Analysis of Recreation in Washington State*, quantifies the contribution of outdoor recreation to Washington State's economy and way of life. According to the report, there were a total of about 446 million participant days a year spent on outdoor recreation in Washington, resulting in $21.6 billion dollars in annual expenditures. Of the recreation lands studied, local parks are the most common place for people to visit as well as the most accessible and least costly destination.

Outdoor recreation markets help connect urban and rural communities. These results show that investment in outdoor recreation and open space yields tremendous returns.

Open space service valuation provides important data about the value of natural capital and its services. Yet there are also benefits that cannot be estimated easily in dollars. The broad open space service definitions adopted by the ROSS are intended to capture difficult-to-quantify benefits and interactions beyond the land cover/open space service lens applied in this study. Here are a few examples:

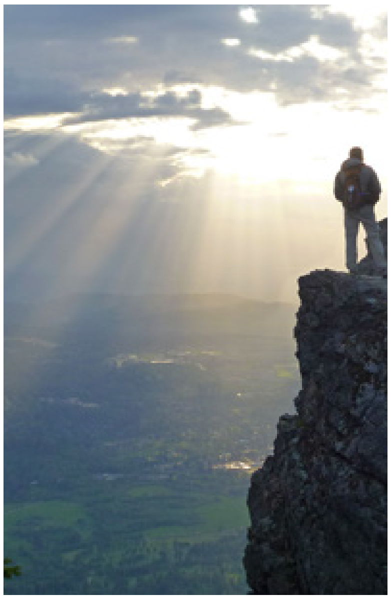
- **Habitat Corridors:** While localized habitat and land cover is important, biologists now understand that corridors that allow wildlife to travel through landscapes to access food, shelter, and mix previously isolated populations are of value to many species.[6] While these types of connections have been identified and quantified in the ecological literature, tools are not yet available to define, assess, and assign dollar values to these corridors.

- **Bicycle and Recreation Connectivity:** Bicycling and walking tracks through natural settings are often plagued with 'missing links.' Missing links occur when routes are interrupted by challenging, unsafe, or impassible natural or built obstacles. While there is clear value in making those connections, assessing the community impact and financial value of such connections to individual health and mobility remains a challenge.

- **Open Space Benefits to Individual and Community Health:** Connecting the availability and proximity of open space with child and adult health is another complex challenge for valuation. Several studies have suggested the benefits of open space for physical and mental health but generating financial benefit cost estimates of this value is still somewhat experimental.[7,8]

Data and tools to fill these gaps and others are being developed rapidly with new research and analytical methods. However, without this new data yet available, it is understood that values provided in this report are conservative and will only increase over time as better information is revealed by additional research.

Policy Applications and Implications of Natural Capital and Open Space Services



▲ Looking out from Mount Si. Image credit: creative commons share-alike image by J. Brew.

In 1930, the United States measures of Gross Domestic Product (GDP), unemployment, inflation, consumer spending, and money supply did not exist. This meant that economic policy was made without critical information. Once implemented, these measures allowed leaders to make more informed and effective decisions. Benefit-cost analysis and rate of return calculations also were developed to examine and compare investments in built assets such as roads, factories, and dams and for private corporate investments. Decision-makers were blind without these basic economic measures, which are now taken for granted and help guide investment at an enormous scale in today's economy.

Open space is an economic asset, the value of which has typically been unmeasured. The emergence of natural capital valuation tools and analysis is spurring a new revolution in our ability to understand and model economic resilience and efficiency. With detailed data about natural capital and open space services, policy makers have more complete information and can better understand the substantial benefits that come from natural capital and take steps to protect and expand this valuable resource to the benefit of the local economy and community. Open space valuation data, more commonly termed 'ecosystem services values,' are now accepted for many state and federal benefit-cost and environmental impact analyses. For example:

1. The United States Federal Emergency Management Agency (FEMA) became the first federal agency to adopt ecosystem service valuation in formal policy. Faced with rising natural disaster costs and climate uncertainty, FEMA approved Mitigation Policy FP-108-024-01 in June of 2013,[9] which allows the inclusion of ecosystem services in benefit-cost analysis for acquisition projects.

2. In 2008, the California Department of Water Resources (DWR) published an Economic Analysis Guidebook, which describes ecosystem service valuation methods and monetization strategies.[10]

3. The Office of Environmental Markets (OEM) was established within the USDA in response to the Food, Conservation, and Energy Act of 2008 (the "2008 Farm Bill"). One of the OEM's stated goals is to "...to build a market-based system for quantifying, registering, and verifying environmental benefits produced by land management activities."[11]

4. A coalition of water utilities, including Seattle Public Utilities has been communicating with the Governmental Accounting Standards Board[12] about the need for natural capital accounting standards, especially for water utilities, whose business model depends on healthy watersheds.

Chapter 3

ROSS Valuation Methods

Farmland in northern Kitsap County. Photo credit: creative commons share-alike image by Jonathan Miske.

Benefit Transfer Methodology

The goal of this study is to estimate the dollar value of open space services provided by natural capital in the Central Puget Sound region. This chapter outlines the methods used to produce these values.

Benefit Transfer Methodology (BTM) is a well-established methodology that indirectly estimates the value of ecological goods or services. BTM is frequently used because it can generate reasonable estimates quickly and at a fraction of the cost of conducting local, primary studies that may cost upwards of $50k to $100k per service/land cover combination.

The BTM process identifies previously published open space service values from comparable ecosystems and 'transfers' them to a study site, in this case the Central Puget Sound.[13] The BTM process is similar to a home appraisal in which the value and features of comparable, neighboring homes (2-bedrooms, garage, 1 acre, recently remodeled) are used to estimate the value of the home in question. As with home appraisals, the BTM results can be somewhat rough but quickly generate reasonable values appropriate for policy work and analysis.

The process begins by finding primary studies with comparable land cover classifications (wetland, forest, grassland, etc.) as compared with the study area. Any primary studies deemed to have incompatible assumptions or land cover types are excluded. Next, individual primary study values are adjusted and standardized for units of measure, inflation, and land cover classification to generate an "apples-to-apples" comparison.

Frequently, primary studies offer a range of values that reflect the uncertainty or breadth of features found in the research area. To recognize this variability and uncertainty, high and low dollars per acre values are included for each value provided in this report.

Primary Study Selection

Earth Economics maintains the largest and most comprehensive repository of published, peer-reviewed primary valuation studies in the world, Ecosystem Service Valuation Toolkit—EVT.[14] These studies each use techniques developed and vetted within environmental and natural resource economics communities over the last four decades. Table 3 provides descriptions of the most common valuation techniques and examples of how they have been analytically employed.

Earth Economics used several criteria to select appropriate primary study values for the Central Puget Sound including geographic location, demographic characteristics, and ecological characteristics of the primary study site.

- All values included in this analysis were derived from studies conducted in temperate ecosystems.
- Where available, ecosystem valuation studies based in Washington State were given preference.
- Where local studies were not available, valuations conducted within British Columbia and Oregon were then prioritized, followed by other studies in the United States.
- Finally, in the cases where no local or national figures were available, suitable studies from countries outside the United States were used, most of which were conducted in Canada.

All open space service values were then standardized to 2013 United States dollars using the Bureau of Labor Statistics Consumer Price Index Inflation Calculator.[15] Appendix C: Valuation References lists the primary studies used for value transfer estimates.

▼ **Table 3.** Common primary valuation methods.

Method	Description	Example
Market Price	Valuations are directly obtained from what people are willing to pay for the service or good on a private market.	Timber is often sold on a private market.
Replacement Cost	Cost of replacing open space services with man-made systems.	The cost of replacing a watershed's natural filtration services with a filtration facility.
Avoided Cost	Costs avoided or mitigated by open space services that would have been incurred in the absence of those services.	Wetlands buffer hurricane storm surge reducing coastal damage and subsequent recovery costs.
Production Approaches	Value created from an open space service through increased economic outputs.	Improvement in watershed health leads to an increase in commercial and recreational salmon catch.
Travel Cost	Derived from travel cost to consume or enjoy open space services, a reflection of the implied value of the service.	Parks attract tourists who must value the resource at least at the cost of travel incurred for the visit.
Hedonic Pricing	Value implied by what consumers are willing to pay for the service via related markets.	Housing prices along the coastline tend to exceed the prices of inland homes thus indicating open space services value of the coast (beach, saltwater, etc.).
Contingent Valuation	Value elicited by posing hypothetical valuation scenarios.	People are willing to pay for wilderness preservation to avoid development.

GIS Analysis Methods and Data

Land cover data was derived from the 2011 National Land Cover Database (NLCD 2011) published by the Multi-Resolution Land Characteristics Consortium.[16] This base layer was modified to refine the land cover categories used in the valuation as described in the following sections. Where land cover categories needed no refinement, the acreage for each was calculated using the *Zonal Geometry as Table* tool in ArcGIS.

Conditions

In this context a 'condition' is a technique to generate more granular land cover data so that study values can be applied in a more targeted manner. For example, a primary research value may apply specifically to forested *urban* parks, but not forested *rural* parks. Applying an 'urban' condition separates urban forests from other forested areas in the GIS land cover data so that this value can be applied to the appropriate acreages. Without this condition, such a study would most likely not be included at all because it would greatly overestimate value in the (larger) non-urban forest areas. For this report, conditions were set for proximity of land cover to urban, riparian, and agricultural lands. (Detailed assumptions and calculations can be found in Appendix A: Geographic Information System Data Analysis). As a rule, conditions and the ability to apply these more granular study values tends to increase the total values within those land cover/open space service combinations.

▼ Aerial view of Mount Rainier and the surrounding landscape. Image credit: creative commons image by Bernt Rostad.

GIS Land Cover Results

Following the methods described previously, Table 4 provides acreages by land cover type calculated within the ROSS study area.

Land Cover		King	Kitsap	Pierce	Snohomish	Total	% Total
Forest	Deciduous	38,177	19,523	21,345	51,735	130,780	2.97%
	Evergreen	576,295	92,387	451,823	676,499	1,797,004	40.86%
	Mixed	146,909	33,534	73,641	122,838	376,922	8.57%
Wetlands	Emergent Herbaceous	4,091	2,554	5,358	11,748	23,751	0.54%
	Woody	21,340	7,118	21,659	24,057	74,174	1.69%
Shrub and Grassland	Shrub	148,366	13,646	131,375	136,419	429,806	9.77%
	Grassland	34,990	10,247	59,935	32,863	138,034	3.14%
	Pasture	30,889	1,779	29,119	45,041	106,828	2.43%
	Cropland	1,702	30	2,789	10,317	14,839	0.34%
	Urban Greenspace	12,700	1,649	3,972	2,474	20,795	0.47%
Water and Beach	Beach	3,295	8,813	7,071	10,636	29,815	0.68%
	Lake	36,583	1,634	8,487	8,921	55,626	1.26%
	Reservoir, inaccessible	2,360	0	0	0	2,360	0.05%
	Reservoir, accessible	232	58	81	1	372	0.01%
	River	3,668	9	3,555	6,755	13,987	0.32%
	Saltwater	72,373	98,974	68,511	44,034	283,892	6.45%
Developed	High Intensity	30,916	2,582	16,493	10,258	60,250	1.37%
	Low Intensity	128,128	26,891	81,546	63,610	300,175	6.83%
	Medium Intensity	72,132	8,059	41,981	30,348	152,519	3.47%
	Open Space	85,926	31,648	70,304	68,279	256,156	5.82%
Other	Barren Land	24,320	693	28,285	38,064	91,361	2.08%
	Perennial Snow/Ice	1,120	0	27,993	9,487	38,599	0.88%
Study Area Total						**4,398,045**	**100%**

▲ **Table 4.**
Calculated acreage for central Puget Sound. Total acreage in this table may not match acreage found later in the report. The small differences are due to GIS-induced rounding errors.

Valuation Methodology

For each land cover/service/condition combination (e.g. evergreen forest-play-urban) the appropriate studies were applied to generate a high and low dollar value per acre-year. Next, the calculated per acre values are multiplied by the number of acres fitting the combination. The result is an annual value of this service for the particular land type in question. For example, urban Evergreen Forest areas within ROSS have an annual, low value for Play of $533/acre over a total of 44,485 acres yielding a total annual low estimate of $23.7M.

Table 5 summarizes the land cover/open space service combinations that were valued in this analysis.

A combination not included in the analysis does not necessarily mean the ecosystem does not produce that service. It also does not indicate that the service is not valuable. Many ecosystem services that clearly have economic value have not been assigned a value due to the lack of primary, peer-reviewed data. For example, aquifers provide free water storage, conveyance, and water purification, all highly valuable

Table 5. Open space services valued in Central Puget Sound. Blank cells indicate open space service/land cover combinations that are not valued in this report.

	Forest			Wetlands		Scrub/Grassland					Open Water/Beach				
	Deciduous	Evergreen	Mixed	Emergent Herbaceous	Woody	Shrub/Scrub	Grassland/Herbaceous	Pasture/Hay	Cultivated Crops	Urban Greenspace	Saltwater/Estuary	Lakes	Reservoir	Rivers	Beach
Aesthetic	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Air	•	•	•												
Disaster Mitigation	•	•	•	•	•	•	•	•	•		•				
Food								•	•		•				
Health	•	•	•				•	•	•		•				
Play	•	•	•	•	•	•	•			•	•	•	•	•	•
Raw Materials	•	•	•												
Shelter	•	•	•	•	•	•	•	•			•			•	
Waste	•	•	•	•	•	•	•								
Water	•	•	•	•	•	•	•			•		•	•	•	

attributes. However, there are no valuation studies of aquifers, and so they are reflected as having zero economic value. Similarly, forests, wetlands and open water likely provide food and habitat services but, again, this value has yet to be valued in the primary research. This lack of available information underscores the need for investment in conducting local primary valuations—see Appendix E: Study Limitations for a detailed discussion of study limitations.

Valuation Detail Tables

For every land cover/service/condition combination, a detailed valuation table was created. Each row in the table sums all of the available low and high values for the open space service, e.g. Play. The values for each open space service are then summed to provide the grand total dollars/acre/year amount. In total, 64 similar tables represent all of the combinations evaluated in this report. Due to space constraints, these detail tables are not included in the report but can be made available upon request.

Certain combinations may have limited peer-reviewed data available, as is the case of Shrub land shown in Table 6 In this case, values were available in only two of ten open space service categories. However, the application of conditions allows additional values specific to areas bordering rivers, agricultural land, and dense urban areas to be included as shown in Table 7. In this case, a $17,000 value for urban wildlife viewing and hiking could be applied to the shrub land in urban areas as well as values for water and waste, among others.

Table 6. Example of a detailed valuation table: shrub with no conditions applied.

Land Cover	**Shrub**	
Conditions	**No Conditions**	
Study Set	**sh**	
Open Space Service	**Low Estimate ($/acre/year)**	**High Estimate ($/acre/year)**
Aesthetic		
Air		
Disaster Mitigation	$94	$94
Food		
Health		
Play		
Raw Materials		
Shelter	$34	$34
Waste		
Water		
Carbon Sequestration	$87	$87
Total $/acre/year	**$129**	**$129**

Table 7. Example of a detailed valuation table: shrub with three conditions applied.

Land Cover	Shrub	
Conditions	**Agriculture, Riparian, and Urban**	
Study Set	**sharu**	
Open Space Service	**Low Estimate ($/acre/year)**	**High Estimate ($/acre/year)**
Aesthetic	$247	$1,209
Air		
Disaster Mitigation	$132	$158
Food		
Health		
Play	$17,576	$17,643
Raw Materials		
Shelter	$37	$90
Waste	$48	$1,941
Water	$150	$690
Carbon Sequestration	$87	$87
Total $/acre/year	**$18,189**	**$21,731**

By calculating the number of acres of each land cover type, estimating the value of each service across those acres, and setting appropriate restricting conditions, an annual dollar value can be derived. This is like an annual flow of income from natural capital. From this annual flow of benefits, the value of the natural capital assets that provide this flow of benefits can be calculated. This is called the 'asset value.'

Asset Valuation Methodology and Net Present Value

Net present value provides a measure of the expected benefits flowing from the study area's natural capital over time. This type of asset value calculation is useful for revealing the scope and scale of benefits to the regional economy and communities. This calculation also includes the carbon stock (storage) for each land cover type calculated with a similar BTM method.

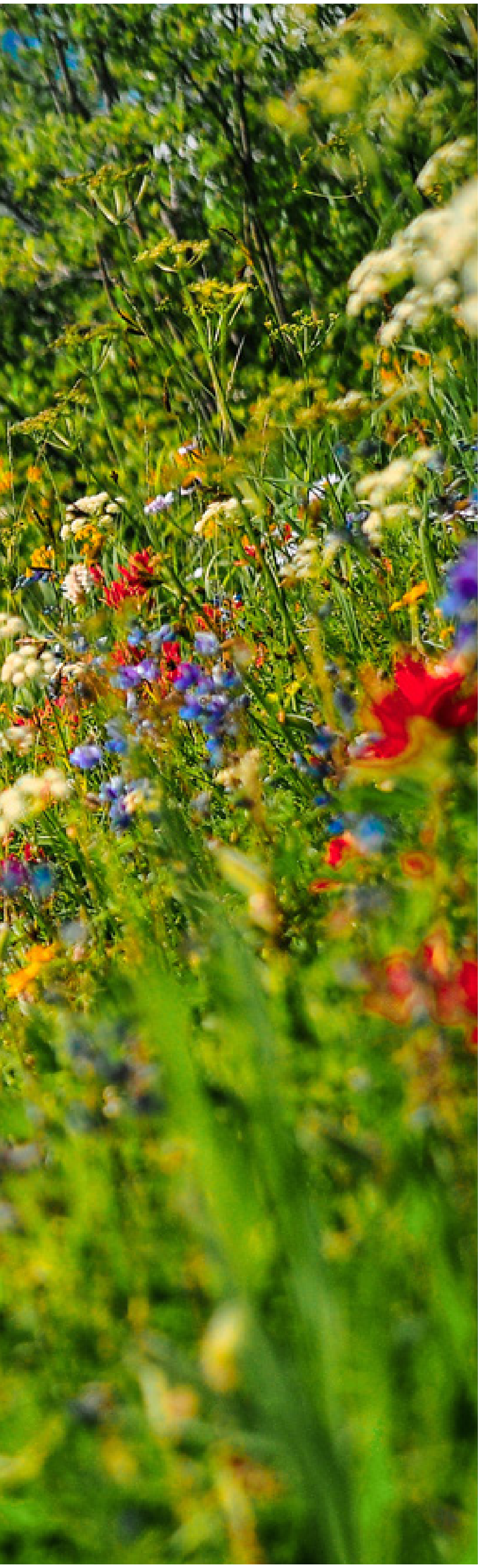
Net present value can be calculated over different time frames and with different discount rates depending on the purpose of the analysis and nature of the project. In the case of natural capital valuations, we use a 100-year time frame to recognize the long-term stability and productivity of a healthy ecosystem though it would be reasonable to use a much longer time frame.

A discount rate is also applied in the calculation. Use of a discount rate assumes that the goal of the economic analysis is to maximize present value. From the perspective of present value maximization, current dollars are deemed more valuable than future dollars, next year, or in year 90, for example. The net present value in this report was calculated with two discount rates: 0% and 3.50%.[17] Discounting at 3.50%, the 2014 Army Corps of Engineers' project standard, likely underestimates value when applied to natural capital, because with adequate stewardship and protection natural capital can provide value to society over longer periods of time compared with built capital such as roads and bridges that typically deteriorate over time.[18,19]

In addition, discounting makes the implicit assumption that benefits to people in the future are worth less than benefits to people in the present. In other words, a glass of clean water enjoyed by someone today is far more valuable than a glass of clean water enjoyed by someone in 50 years. In reality, due to relative scarcity of natural capital and growing demand caused by population growth, natural capital tends to become more valuable over time due purely to scarcity. For example, in the late 19th century water was an abundant resource with plenty for all. Today, water is scarce, has a relatively high value and must be managed to meet many demands. Further, some people have an ethical objection to discounting future value. Yakama Tribal Elder Jim Russell has stated "We will never value any future generation as less valuable than our generation."[20]

If the benefits provided across time are not discounted, that supports an assumption that natural capital assets provide a sustainable flow of benefits across generations.[21,22] Provided that the natural capital of a watershed is not degraded or depleted, the flow of value will likely continue far into the future, and can be better represented using a 0% discount rate.

► Children at Kubota Garden in Seattle, WA. Image credit: creative commons image by the Seattle Municipal Archives.



Chapter 4

Valuation Findings

Paradise in Mount Rainier National Park. Photo credit: Rachel Samanyi.

Annual Open Space Service Value by Land Cover Type

This section provides detailed valuation results by land cover and open space service type, estimates of the region's carbon storage, and a calculation of the net present value of goods and services over a 100-year timeframe. In addition to the results, observations about the results and data gaps are provided.

These values are real. If forest filtration of drinking water were lost, Seattle, Tacoma and other cities would have to build water filtration plants. If wetlands are lost so are their disaster mitigation properties and that would either result in higher damage costs or the need to build and maintain built capital to control flooding. The values demonstrate the critical roles that forest, wetlands, and the region's open water play in the economy and the importance of stewarding these critical resources.

Table 8 provides a summary of the totals in the following valuation tables. Table 9 and Table 10 present a low and high dollar estimate of each open space service found on an acre of the specified land cover. To generate these numbers, all of the applicable peer-reviewed values (low and high) are summed to create an aggregate low and high value estimate. The appendices include a full bibliography of included studies (Appendix C: Valuation References) and the values provided by each study (Appendix D: Study Values by Author.) The per-acre view helps to identify the most valuable combinations even though some may only cover small geographic areas.

Table 11 and Table 12 provide the same data with each value multiplied by the appropriate number of acres to yield the total annual dollar value per combination within the region. This view is important to identify both the services and land cover types that contribute most to the overall economy.

Service	Low	High
Aesthetic	2,293,975	9,509,713
Air	422,203	529,187
Disaster Mitigation	1,860,499	4,194,473
Food	12,587	86,472
Health	41,168	50,352
Play	2,633,343	4,132,675
Raw Materials	23,279	155,093
Shelter	73,984	111,407
Waste	4,034,301	4,568,983
Water	62,605	1,925,347
Total	**11,457,944**	**25,263,700**

▲ **Table 8.**
Summary open space service values.

Table 9.
Open space service values per acre per year for aesthetic, air, disaster mitigation, food, and health.

Land Cover	Condition			Aesthetic		Air		Disaster Mitigation		Food		Health	
	Agriculture	Riparian	Urban	Low	High	Low	High	Low	High	Low	High	Low	High
Deciduous Forest				$342	$3,183	$190	$190	$808	$1,085	$0	$0	$13	$13
	A			$649	$649	$190	$190	$749	$1,085	$0	$0	$13	$13
		R		$247	$1,209	$190	$190	$215	$1,085	$0	$0	$13	$13
			U	$263	$2,135	$30	$1,043	$808	$1,085	$0	$0	$13	$13
	A	R		$247	$1,209	$190	$190	$215	$1,085	$0	$0	$13	$13
		R	U	$263	$2,135	$30	$1,043	$808	$1,085	$0	$0	$13	$13
	A		U	$263	$2,135	$30	$1,043	$749	$1,085	$0	$0	$13	$13
	A	R	U	$247	$2,135	$30	$1,043	$215	$1,085	$0	$0	$13	$13
Evergreen Forest				$342	$3,183	$190	$190	$755	$1,563	$0	$0	$13	$13
	A			$649	$649	$190	$190	$697	$1,563	$0	$0	$13	$13
		R		$247	$1,209	$190	$190	$163	$1,563	$0	$0	$13	$13
			U	$263	$2,135	$30	$1,043	$755	$1,563	$0	$0	$13	$13
	A	R		$247	$1,209	$190	$190	$163	$1,563	$0	$0	$13	$13
		R	U	$247	$2,135	$30	$1,043	$163	$1,563	$0	$0	$13	$13
	A		U	$263	$2,135	$30	$1,043	$697	$1,563	$0	$0	$13	$13
Mixed Forest	A	R	U	$247	$2,135	$30	$1,043	$163	$1,563	$0	$0	$13	$13
				$342	$3,183	$190	$190	$734	$1,112	$0	$0	$13	$13
	A			$649	$649	$190	$190	$676	$1,112	$0	$0	$13	$13
		R		$247	$1,209	$190	$190	$142	$1,112	$0	$0	$13	$13
			U	$263	$2,135	$30	$1,043	$734	$1,112	$0	$0	$13	$13
	A	R		$247	$1,209	$190	$190	$142	$1,112	$0	$0	$13	$13
		R	U	$247	$2,135	$30	$1,043	$142	$1,112	$0	$0	$13	$13
	A		U	$263	$2,135	$30	$1,043	$676	$1,112	$0	$0	$13	$13
	A	R	U	$247	$2,135	$30	$1,043	$142	$1,112	$0	$0	$13	$13
Emergent Herbaceous Wetlands				$36	$6,300	$0	$0	$8	$6,261	$0	$0	$0	$0
	A			$36	$6,300	$0	$0	$8	$6,261	$0	$0	$0	$0
		R		$36	$6,300	$0	$0	$9	$6,271	$0	$0	$0	$0
			U	$9,947	$13,797	$0	$0	$8	$7,597	$0	$0	$0	$0
	A	R		$36	$6,300	$0	$0	$9	$6,271	$0	$0	$0	$0
		R	U	$9,947	$13,797	$0	$0	$9	$7,607	$0	$0	$0	$0
	A		U	$9,947	$13,797	$0	$0	$8	$7,597	$0	$0	$0	$0
	A	R	U	$9,947	$13,797	$0	$0	$9	$7,607	$0	$0	$0	$0
Woody Wetlands				$36	$6,300	$0	$0	$8	$6,170	$0	$0	$0	$0
	A			$36	$6,300	$0	$0	$8	$6,170	$0	$0	$0	$0
		R		$36	$6,300	$0	$0	$9	$6,180	$0	$0	$0	$0
			U	$9,947	$13,797	$0	$0	$8	$7,506	$0	$0	$0	$0
	A	R		$36	$6,300	$0	$0	$9	$6,180	$0	$0	$0	$0
		R	U	$9,947	$13,797	$0	$0	$9	$7,516	$0	$0	$0	$0
	A		U	$9,947	$13,797	$0	$0	$8	$7,506	$0	$0	$0	$0
	A	R	U	$9,947	$13,797	$0	$0	$9	$7,516	$0	$0	$0	$0

Table 9, continued

Open space service values per acre per year for aesthetic, air, disaster mitigation, food, and health.

Land Cover	Condition			Aesthetic		Air		Disaster Mitigation		Food		Health	
	Agriculture	Riparian	Urban	Low	High	Low	High	Low	High	Low	High	Low	High
Shrub				$0	$0	$0	$0	$94	$94	$0	$0	$0	$0
	A			$0	$0	$0	$0	$94	$94	$0	$0	$0	$0
		R		$247	$1,209	$0	$0	$132	$158	$0	$0	$0	$0
			U	$0	$0	$0	$0	$94	$94	$0	$0	$0	$0
	A	R		$247	$1,209	$0	$0	$132	$158	$0	$0	$0	$0
		R	U	$247	$1,209	$0	$0	$132	$158	$0	$0	$0	$0
	A		U	$0	$0	$0	$0	$94	$94	$0	$0	$0	$0
	A	R	U	$247	$1,209	$0	$0	$132	$158	$0	$0	$0	$0
Grassland/ Herbaceous				$1	$1	$0	$0	$37	$94	$0	$0	$14	$14
	A			$1	$1	$0	$0	$37	$94	$0	$0	$0	$0
		R		$1	$1,209	$0	$0	$5,462	$5,555	$0	$0	$311	$311
			U	$1	$1	$0	$0	$37	$94	$0	$0	$0	$0
	A	R		$1	$1,209	$0	$0	$8,576	$8,669	$0	$0	$311	$311
		R	U	$1	$1,209	$0	$0	$5,462	$5,555	$0	$0	$311	$311
	A		U	$1	$1	$0	$0	$37	$94	$0	$0	$0	$0
	A	R	U	$1	$1,209	$0	$0	$5,462	$5,555	$0	$0	$311	$311
Pasture/Hay	A			$0	$103	$0	$0	$10	$236	$42	$147	$17	$17
Cultivated Crops	A			$0	$75	$0	$0	$6	$155	$62	$2,089	$14	$196
Beach				$45,366	$45,366	$0	$0	$0	$0	$0	$0	$0	$0
Lakes				$2	$248	$0	$0	$0	$0	$0	$0	$0	$0
Reservoir				$2	$248	$0	$0	$0	$0	$0	$0	$0	$0
"Reservoirs (no access)"				$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Rivers				$31	$860	$0	$0	$0	$0	$0	$0	$0	$0
Saltwater				$4	$1,748	$0	$0	$342	$368	$25	$139	$24	$47
Open Space (urban park space)			U	$1,668	$4,563	$0	$0	$3	$341	$0	$0	$0	$0

Table 10. ▼

Open space service values per acre per year for play, raw materials, shelter, waste, and water.

Land Cover	Condition			Play		Raw Materials		Shelter		Waste		Water	
	Agriculture	Riparian	Urban	Low	High	Low	High	Low	High	Low	High	Low	High
				$535	$545	$16	$18	$2	$6	$726	$726	$0	$0
	A			$533	$543	$0	$0	$0	$0	$726	$726	$0	$0
		R		$238	$543	$0	$0	$3	$112	$48	$1,941	$118	$550
Deciduous Forest			U	$533	$543	$0	$0	$0	$0	$726	$726	$379	$713
	A	R		$238	$543	$0	$0	$3	$56	$48	$1,941	$150	$690
		R	U	$533	$543	$0	$0	$0	$0	$726	$726	$379	$713
	A		U	$533	$543	$0	$0	$0	$0	$726	$726	$379	$713
	A	R	U	$238	$543	$0	$0	$0	$0	$48	$1,941	$529	$1,404
				$533	$543	$10	$88	$3	$13	$726	$726	$0	$0
	A			$533	$543	$0	$0	$1	$7	$726	$726	$0	$0
		R		$238	$543	$0	$0	$4	$119	$48	$1,941	$118	$550
Evergreen Forest			U	$533	$543	$0	$0	$1	$7	$726	$726	$379	$713
	A	R		$238	$543	$0	$0	$4	$63	$48	$1,941	$150	$690
		R	U	$238	$543	$0	$0	$4	$63	$48	$1,941	$496	$1,263
	A		U	$533	$543	$0	$0	$1	$7	$726	$726	$379	$713
	A	R	U	$238	$543	$0	$0	$4	$63	$48	$1,941	$529	$1,404
				$533	$543	$18	$18	$2	$6	$726	$726	$0	$0
	A			$533	$543	$0	$0	$0	$0	$726	$726	$0	$0
		R		$238	$543	$0	$0	$3	$112	$48	$1,941	$118	$550
Mixed Forest			U	$533	$543	$0	$0	$0	$0	$726	$726	$379	$713
	A	R		$238	$543	$0	$0	$3	$56	$48	$1,941	$150	$690
		R	U	$238	$543	$0	$0	$3	$56	$48	$1,941	$496	$1,263
	A		U	$533	$543	$0	$0	$0	$0	$726	$726	$379	$713
	A	R	U	$238	$543	$0	$0	$3	$56	$48	$1,941	$529	$1,404
				$9,000	$19,936	$0	$0	$14	$46	$356	$5,202	$51	$18,316
	A			$426	$1,557	$0	$0	$2	$35	$356	$5,202	$51	$18,316
		R		$628	$1,825	$0	$0	$5	$91	$356	$5,202	$51	$18,316
Emergent Herbaceous Wetlands			U	$426	$1,557	$0	$0	$0	$0	$356	$5,202	$51	$18,316
	A	R		$628	$1,825	$0	$0	$5	$91	$356	$5,202	$51	$18,316
		R	U	$628	$1,825	$0	$0	$0	$0	$356	$5,202	$51	$18,316
	A		U	$426	$1,557	$0	$0	$0	$0	$356	$5,202	$51	$18,316
	A	R	U	$628	$1,825	$0	$0	$0	$0	$356	$5,202	$51	$18,316
				$9,000	$19,936	$0	$0	$14	$27	$182	$4,507	$51	$18,316
	A			$426	$1,557	$0	$0	$2	$15	$182	$4,507	$51	$18,316
		R		$628	$1,825	$0	$0	$24	$127	$486	$5,228	$169	$18,866
Woody Wetlands			U	$426	$1,557	$0	$0	$0	$0	$182	$4,507	$51	$18,316
	A	R		$628	$1,825	$0	$0	$5	$71	$486	$5,228	$150	$690
		R	U	$628	$1,825	$0	$0	$5	$71	$486	$5,228	$169	$18,866
	A		U	$426	$1,557	$0	$0	$2	$15	$182	$4,507	$51	$18,316
	A	R	U	$628	$1,825	$0	$0	$5	$71	$486	$5,228	$201	$19,006

Table 10, continued

Open space service values per acre per year for play, raw materials, shelter, waste, and water.

Land Cover	Condition			Play		Raw Materials		Shelter		Waste		Water	
	Agriculture	Riparian	Urban	Low	High	Low	High	Low	High	Low	High	Low	High
Shrub				$0	$0	$0	$0	$34	$34	$0	$0	$0	$0
	A			$0	$0	$0	$0	$34	$34	$0	$0	$0	$0
		R		$201	$268	$0	$0	$56	$146	$48	$1,941	$118	$550
			U	$17,374	$17,374	$0	$0	$34	$34	$0	$0	$0	$0
	A	R		$201	$268	$0	$0	$37	$90	$48	$1,941	$150	$690
		R	U	$17,576	$17,643	$0	$0	$0	$0	$48	$1,941	$118	$550
	A		U	$17,374	$17,374	$0	$0	$34	$34	$0	$0	$0	$0
	A	R	U	$17,576	$17,643	$0	$0	$37	$90	$48	$1,941	$150	$690
Grassland/ Herbaceous				$0	$0	$0	$0	$34	$91	$53	$53	$2	$2
	A			$0	$0	$0	$0	$34	$91	$53	$53	$2	$2
		R		$201	$14,431	$0	$0	$37	$147	$6,178	$20,129	$2	$2
			U	$17,374	$17,374	$0	$0	$34	$91	$53	$53	$2	$2
	A	R		$201	$14,431	$0	$0	$37	$147	$6,178	$20,129	$2	$2
		R	U	$14,431	$17,374	$0	$0	$0	$0	$6,178	$20,129	$2	$2
	A		U	$17,374	$17,374	$0	$0	$34	$91	$53	$53	$2	$2
	A	R	U	$14,431	$17,374	$0	$0	$37	$147	$6,178	$20,129	$2	$2
Pasture/Hay	A			$0	$0	$0	$0	$0	$3	$0	$0	$0	$0
Cultivated Crops	A			$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Beach				$6,420	$7,995	$0	$0	$0	$0	$0	$0	$0	$0
Lakes				$6	$2,239	$0	$0	$0	$0	$0	$0	$33	$769
Reservoir				$599	$599	$0	$0	$0	$0	$0	$0	$33	$769
"Reservoirs (no access)"				$0	$0	$0	$0	$0	$0	$0	$0	$33	$769
Rivers				$22,881	$22,881	$0	$0	$3,489	$3,489	$0	$0	$5	$6
Saltwater				$660	$3,165	$0	$0	$2	$17	$8,239	$8,239	$0	$0
Open Space (urban park space)			U	$2,549	$2,549	$0	$0	$0	$0	$0	$0	$437	$437

Table 11.
Total open space service values per year for aesthetic, air, disaster mitigation, food, and health. Dollar values are in thousands.

Land Cover	Condition			Aesthetic		Air		Disaster Mitigation		Food		Health	
	Agriculture	Riparian	Urban	Low	High	Low	High	Low	High	Low	High	Low	High
Deciduous Forest				$27,159	$253,008	$15,140	$15,140	$64,187	$86,212	$	$	$1,049	$1,049
	A			$17,513	$17,513	$5,137	$5,137	$20,207	$29,253	$	$	$356	$356
		R		$456	$2,232	$352	$352	$398	$2,002	$	$	$24	$24
			U	$5,310	$43,062	$609	$21,043	$16,287	$21,875	$	$	$266	$266
	A	R		$135	$661	$104	$104	$118	$593	$	$	$7	$7
		R	U	$117	$952	$13	$465	$360	$484	$	$	$6	$6
	A		U	$342	$2,769	$39	$1,353	$972	$1,407	$	$	$17	$17
	A	R	U	$7	$58	$1	$28	$6	$29	$	$	$	$
Evergreen Forest				$577,035	$5,375,559	$321,681	$321,681	$1,275,649	$2,639,948	$	$	$22,283	$22,283
	A			$23,373	$23,373	$6,857	$6,857	$25,091	$56,270	$	$	$475	$475
		R		$6,860	$33,602	$5,294	$5,294	$4,535	$43,446	$	$	$367	$367
			U	$11,349	$92,029	$1,301	$44,972	$32,558	$67,378	$	$	$569	$569
	A	R		$100	$490	$77	$77	$66	$633	$	$	$5	$5
		R	U	$128	$1,104	$16	$539	$84	$808	$	$	$7	$7
	A		U	$275	$2,227	$31	$1,088	$727	$1,631	$	$	$14	$14
	A	R	U	$6	$56	$1	$27	$4	$41	$	$	$	$
Mixed Forest				$92,946	$865,866	$51,815	$51,815	$199,722	$302,594	$	$	$3,589	$3,589
	A			$38,099	$38,099	$11,176	$11,176	$39,657	$65,268	$	$	$774	$774
		R		$1,620	$7,937	$1,250	$1,250	$932	$7,302	$	$	$87	$87
			U	$9,548	$77,423	$1,094	$37,835	$26,624	$40,337	$	$	$478	$478
	A	R		$172	$842	$133	$133	$99	$774	$	$	$9	$9
		R	U	$117	$1,016	$14	$497	$68	$530	$	$	$6	$6
	A		U	$579	$4,693	$66	$2,294	$1,486	$2,445	$	$	$29	$29
	A	R	U	$7	$58	$1	$28	$4	$30	$	$	$	$
Emergent Herbaceous Wetlands				$308	$53,388	$	$	$67	$53,052	$	$	$	$
	A			$393	$68,143	$	$	$85	$67,715	$	$	$	$
		R		$16	$2,722	$	$	$4	$2,709	$	$	$	$
			U	$53,055	$73,591	$	$	$42	$40,524	$	$	$	$
	A	R		$6	$1,014	$	$	$1	$1,010	$	$	$	$
		R	U	$716	$993	$	$	$1	$548	$	$	$	$
	A		U	$6,077	$8,430	$	$	$5	$4,642	$	$	$	$
	A	R	U	$179	$248	$	$	$	$137	$	$	$	$
Woody Wetlands				$1,390	$240,782	$	$	$301	$235,787	$	$	$	$
	A			$713	$123,459	$	$	$155	$120,898	$	$	$	$
		R		$214	$37,102	$	$	$51	$36,392	$	$	$	$
			U	$73,028	$101,295	$	$	$58	$55,111	$	$	$	$
	A	R		$62	$10,691	$	$	$15	$10,487	$	$	$	$
		R	U	$8,544	$11,851	$	$	$7	$6,457	$	$	$	$
	A		U	$6,853	$9,506	$	$	$5	$5,172	$	$	$	$
	A	R	U	$865	$1,200	$	$	$1	$654	$	$	$	$

Table 11, continued

Total open space service values per year for aesthetic, air, disaster mitigation, food, and health. Dollar values are in thousands.

Land Cover	Condition			Aesthetic		Air		Disaster Mitigation		Food		Health	
	Agriculture	Riparian	Urban	Low	High	Low	High	Low	High	Low	High	Low	High
Shrub				$	$	$	$	$37,101	$37,101	$	$	$	$
	A			$	$	$	$	$2,413	$2,413	$	$	$	$
		R		$973	$4,766	$	$	$520	$623	$	$	$	$
			U	$	$	$	$	$636	$636	$	$	$	$
	A	R		$98	$479	$	$	$52	$63	$	$	$	$
		R	U	$24	$117	$	$	$13	$15	$	$	$	$
	A		U	$	$	$	$	$61	$61	$	$	$	$
	A	R	U	$6	$31	$	$	$3	$4	$	$	$	$
Grassland/ Herbaceous				$140	$140	$	$	$4,332	$11,098	$	$	$1,686	$1,686
	A			$17	$17	$	$	$510	$1,307	$	$	$	$
		R		$1	$748	$	$	$3,381	$3,439	$	$	$193	$193
			U	$6	$6	$	$	$197	$504	$	$	$	$
	A	R		$	$195	$	$	$1,381	$1,396	$	$	$50	$50
		R	U	$	$87	$	$	$393	$400	$	$	$22	$22
	A		U	$1	$1	$	$	$23	$58	$	$	$	$
	A	R	U	$	$22	$	$	$98	$100	$	$	$6	$6
Pasture/Hay	A			$	$10,966	$	$	$1,105	$25,161	$4,435	$15,714	$1,770	$1,770
Cultivated Crops	A			$	$1,116	$	$	$95	$2,299	$923	$30,999	$204	$2,911
Beach				$1,315,017	$1,315,017	$	$	$	$	$	$	$	$
Lakes				$86	$13,718	$	$	$	$	$	$	$	$
Reservoir				$	$69	$	$	$	$	$	$	$	$
"Reservoirs (no access)"				$	$	$	$	$	$	$	$	$	$
Rivers				$420	$11,597	$	$	$	$	$	$	$	$
Saltwater				$1,023	$498,415	$	$	$97,504	$104,776	$7,229	$39,759	$6,818	$13,296
Open Space (urban park space)			U	$34,691	$94,894	$	$	$34	$3,871	$	$	$	$

Table 12.
Total open space service values per year for play, raw materials, shelter, waste, and water. Dollar values are in thousands.

Land Cover	Condition			Play		Raw Materials		Shelter		Waste		Water	
	Agriculture	Riparian	Urban	Low	High	Low	High	Low	High	Low	High	Low	High
				$42,558	$43,342	$1,287	$1,459	$151	$440	$57,742	$57,742	$	$
	A			$14,367	$14,633	$	$	$	$	$19,593	$19,593	$	$
		R		$439	$1,002	$	$	$5	$206	$89	$3,583	$217	$1,014
Deciduous Forest			U	$10,743	$10,942	$	$	$	$	$14,651	$14,651	$7,642	$14,386
	A	R		$130	$297	$	$	$1	$31	$26	$1,062	$82	$378
		R	U	$238	$242	$	$	$	$	$324	$324	$169	$318
	A		U	$691	$704	$	$	$	$	$942	$942	$492	$925
	A	R	U	$6	$15	$	$	$	$	$1	$52	$14	$38
				$899,632	$916,695	$16,999	$148,641	$4,927	$21,184	$1,226,819	$1,226,819	$	$
	A			$19,174	$19,530	$	$	$37	$252	$26,150	$26,150	$	$
		R		$6,611	$15,081	$	$	$100	$3,302	$1,339	$53,936	$3,266	$15,272
Evergreen Forest			U	$22,959	$23,385	$	$	$44	$302	$31,311	$31,311	$16,333	$30,744
	A	R		$96	$220	$	$	$1	$25	$20	$786	$61	$280
		R	U	$123	$281	$	$	$2	$33	$25	$1,003	$257	$653
	A		U	$556	$566	$	$	$1	$7	$758	$758	$395	$744
	A	R	U	$6	$14	$	$	$	$2	$1	$50	$14	$36
				$144,899	$147,583	$4,993	$4,993	$517	$1,504	$197,609	$197,609	$	$
	A			$31,254	$31,833	$	$	$	$	$42,624	$42,624	$	$
		R		$1,561	$3,561	$	$	$19	$734	$316	$12,739	$771	$3,607
Mixed Forest			U	$19,316	$19,673	$	$	$	$	$26,342	$26,342	$13,741	$25,865
	A	R		$166	$378	$	$	$2	$39	$34	$1,351	$104	$480
		R	U	$113	$258	$	$	$1	$27	$23	$924	$236	$601
	A		U	$1,171	$1,193	$	$	$	$	$1,597	$1,597	$833	$1,568
	A	R	U	$6	$15	$	$	$	$2	$1	$52	$14	$38
				$76,270	$168,937	$	$	$116	$393	$3,021	$44,081	$433	$155,211
	A			$4,612	$16,838	$	$	$24	$378	$3,855	$56,264	$553	$198,108
		R		$271	$788	$	$	$2	$39	$154	$2,247	$22	$7,913
Emergent Herbaceous Wetlands			U	$2,274	$8,304	$	$	$	$	$1,901	$27,747	$273	$97,698
	A	R		$101	$294	$	$	$1	$15	$57	$838	$8	$2,949
		R	U	$45	$131	$	$	$	$	$26	$375	$4	$1,319
	A		U	$261	$951	$	$	$	$	$218	$3,178	$31	$11,191
	A	R	U	$11	$33	$	$	$	$	$6	$94	$1	$330
				$343,979	$761,911	$	$	$522	$1,017	$6,949	$172,238	$1,955	$700,007
	A			$8,356	$30,506	$	$	$43	$297	$3,563	$88,314	$1,002	$358,923
		R		$3,697	$10,749	$	$	$140	$748	$2,863	$30,785	$993	$111,100
Woody Wetlands			U	$3,131	$11,430	$	$	$	$	$1,335	$33,088	$376	$134,477
	A	R		$1,065	$3,097	$	$	$8	$121	$825	$8,871	$254	$1,171
		R	U	$539	$1,568	$	$	$4	$61	$418	$4,490	$145	$16,206
	A		U	$294	$1,073	$	$	$2	$10	$125	$3,105	$35	$12,620
	A	R	U	$55	$159	$	$	$	$6	$42	$455	$17	$1,654

Table 12, continued

Total open space service values per year for play, raw materials, shelter, waste, and water. Dollar values are in thousands.

Land Cover	Condition			Play		Raw Materials		Shelter		Waste		Water	
	Agriculture	Riparian	Urban	Low	High	Low	High	Low	High	Low	High	Low	High
Shrub				$	$	$	$	$13,498	$13,498	$	$	$	$
	A			$	$	$	$	$878	$878	$	$	$	$
		R		$794	$1,058	$	$	$220	$576	$190	$7,651	$463	$2,166
			U	$117,015	$117,015	$	$	$232	$232	$	$	$	$
	A	R		$80	$106	$	$	$15	$36	$19	$769	$59	$273
		R	U	$1,705	$1,711	$	$	$	$	$5	$188	$11	$53
	A		U	$11,224	$11,224	$	$	$22	$22	$	$	$	$
	A	R	U	$457	$459	$	$	$1	$2	$1	$50	$4	$18
Grassland/ Herbaceous				$2	$2	$	$	$4,038	$10,723	$6,181	$6,181	$281	$281
	A			$	$	$	$	$476	$1,263	$728	$728	$33	$33
		R		$125	$8,933	$	$	$23	$91	$3,824	$12,460	$1	$1
			U	$92,674	$92,674	$	$	$183	$487	$281	$281	$13	$13
	A	R		$32	$2,323	$	$	$6	$24	$995	$3,241	$	$
		R	U	$1,039	$1,251	$	$	$	$	$445	$1,449	$	$
	A		U	$10,616	$10,616	$	$	$21	$56	$32	$32	$1	$1
	A	R	U	$260	$313	$	$	$1	$3	$111	$362	$	$
Pasture/Hay	A			$	$	$	$	$15	$341	$	$	$	$
Cultivated Crops	A			$	$	$	$	$	$	$	$	$	$
Beach				$186,106	$231,755	$	$	$	$	$	$	$	$
Lakes				$332	$124,033	$	$	$	$	$	$	$1,855	$42,594
Reservoir				$167	$167	$	$	$	$	$	$	$9	$215
"Reservoirs (no access)"				$	$	$	$	$	$	$	$	$84	$1,919
Rivers				$308,711	$308,711	$	$	$47,073	$47,073	$	$	$66	$81
Saltwater				$188,047	$902,320	$	$	$610	$4,900	$2,348,558	$2,348,558	$	$
Open Space (urban park space)			U	$28,941	$28,941	$	$	$	$	$	$	$4,962	$4,962

The values found in Table 9 through Table 12 represent a critical starting point for understanding and valuing open space services in the Central Puget Sound. The values clearly demonstrate that the many land cover types found in the region each support multiple open space services. The results also demonstrate that the values vary significantly from near zero to some highly valuable combinations contributing more than $10,000/acre/year to the local economy. For example, the high value for the Waste service is driven by water quality improvement benefits in our abundant evergreen forests, $726/acre-year, and by nitrogen and phosphorous removal in the marine environment, $8,239/acre-year. Conversely, the total for Shelter is low due to the fact that published values for Shelter are typically lower than $100/acre-year with values of some land covers below $5/acre-year. Yet, in both cases the estimates are conservative due to gaps in published data.

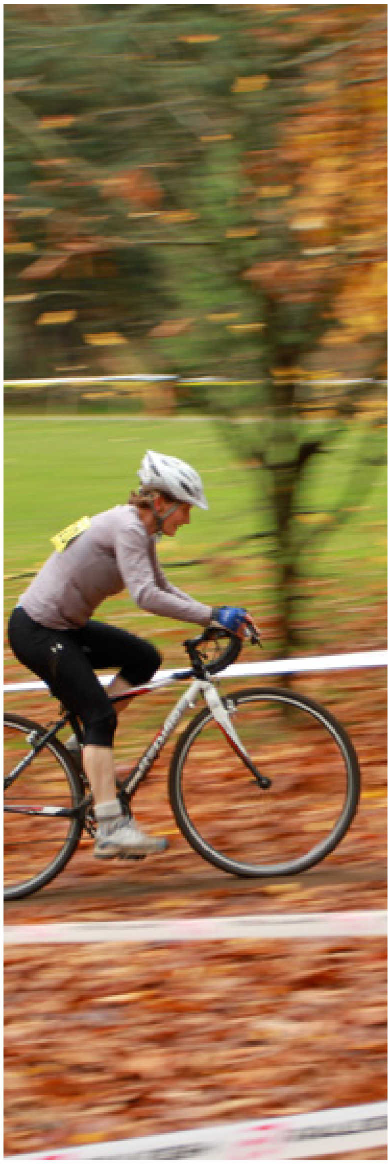
Understanding the values in context with the peer-reviewed data available and assumptions made is important. Some combinations show substantial range between the low and high per acre estimates. A large range may either indicate differing methods applied in the primary research or natural variation in ecosystems due to habitat age, health, and make-up. Often ranges can be narrowed by filtering BTM studies to better match local conditions or via additional primary research to generate a truly local value.

Table 13. Studies available by open space service.

Open Space Service	# Studies Applied
Aesthetic	30
Air	4
Disaster Mitigation	21
Food	5
Health	11
Play	44
Raw Materials	5
Shelter	16
Waste	17
Water	12

Another observation is that the relative value of one land cover type or open space service to another as shown in these tables may be real or may be an artifact of data gaps. Table 13 shows the number of studies applied to each open space service type in this valuation. The air, food, and raw materials categories have significantly fewer studies available than other categories. Fewer studies likely result in some land cover/service categories not having any data or having a very wide range in values. Even open space service categories with multiple studies will undervalue the service if the studies are narrowly focused. For example, Play studies are largely focused on hunting, hiking, bird watching, and fishing but do not provide values for many other recreational activities that would increase the total value. A more detailed discussion of potential study limitations is included in Appendix E: Study Limitations.

▼ Bikers in Woodland Park, Seattle. Image credit: Matt Chadsey.



Finally, open space values represent only the non-market value of open space and do not include the market value of important regional products like crops and timber. For example, in the Central Puget Sound, farms produced $134.8 million of crops in 2012.[23] While these represent significant values derived from agricultural land; they primarily represent the value of human and built capital inputs such as product transportation, worker salaries, processing equipment, sales facilities, etc. To avoid overestimating open space services by mixing with human and built capital values, the market values for crops and timber are not included in this report. The critical message here is that open space services represent additional value not typically measured.

Other observations from the results:

- **Aesthetic Services Provide Significant Benefits:** Proximity to beaches, saltwater, lakes, and forests is highly valued by people. The most obvious representation of this value is in the direct impact on home values in proximity to saltwater and beaches. Interestingly, this benefit flows inland beyond the properties with direct view and access to these services. In this report a conservative aesthetic value for beaches has been used ($45,000/acre/year) though research from the East Coast of the United States has reported values as high as $1.7 million/acre/year.[24] True value for the ROSS study area is likely much higher than reported here, especially in highly developed urban areas.

- **Wetlands Are Highly Productive and Valuable:** Wetlands, both herbaceous and woody, provide high relative value per acre across many services from play to water supply and waste. These values highlight the economic importance and value of preserving wetlands.

- **Rivers, Grassland, and Shrublands Are Highly Valuable for Play:** Especially in urban areas, these land cover types provide great recreational value for birders, hunters, hikers, and others exploring the outdoors.

▼ Lake Washington. Image credit: creative commons image by Kurt Clark.

Data gaps in the results also indicate potential areas for future research and primary valuation studies for critical regional assets:

- **Food Values Are Not Available for Many Land Covers:** Continued review of the primary research on food and inclusion of applicable studies will help to more fully represent the total value of this service.

- **Urban Lakes Are Clearly Undervalued:** While saltwater and beach land cover indicate high aesthetic value and the resulting increase in neighborhood property values, the same type of studies are not available for urban lakes including Lakes Washington, Union, Tapps, Sammamish, and others. When these studies become available, there will likely be a significant increase in aesthetic values attributed to these natural capital assets.

- **Ecosystem Health Is Not Evaluated:** Clearly, the health of an ecosystem directly affects the quality and quantity of services provided. A robust and healthy wetland is much more productive than a polluted, barren one. The standards and analysis tools required to conduct BTM based on ecosystem health assessment do not yet exist. Formalizing these techniques is a leading topic in the field today.

- **Open Space Benefits to Human Physical and Mental Health:** Many health studies suggest an important positive benefit of access to open space on individual mental and physical health via increased opportunity to exercise and stress reduction documented after visits to open space areas.[25,26] While the medical data appears robust, few studies are currently available that allow application of the BTM technique to economically value the impact of open space on health expenditures in an efficient and robust way. Again, once these types of studies are available, the calculated value of open space service will increase. Health benefits can also be better valued when evaluating smaller study areas where more detail can be included.

Summary Open Space Values by Land Cover and Condition

Table 14. Detailed land cover values with conditions.

In Table 14, the value by land cover type shows the effect that conditions (urban, riparian, agriculture) had on land cover dollar/acre values. The high and low values per acre are also included for each combination.

Land Cover	Conditions			Acres	Annual Per Acre Value		Total Annual Value ($ in thousands)	
	Agriculture	Riparian	Urban		Low	High	Low	High
Deciduous Forest				79,480	2,633	5,767	209,272	458,392
	A			26,969	2,862	3,207	77,172	86,485
		R		1,846	1,072	5,642	1,980	10,415
	A	R		547	1,104	5,727	604	3,133
		R	U	446	2,752	6,259	1,228	2,792
	A		U	1,297	2,694	6,259	3,494	8,118
Deciduous Forest Total				**130,779**			**349,294**	**695,782**
Evergreen Forest				1,688,678	2,573	6,320	4,345,025	10,672,810
		R		27,791	1,021	6,128	28,371	170,300
			U	43,099	2,701	6,745	116,423	290,690
	A	R		405	1,053	6,213	427	2,516
		R	U	517	1,239	8,564	641	4,428
	A	R	U	26	1,272	8,705	33	226
Evergreen Forest Total				**1,797,553**			**4,594,833**	**11,280,912**
Mixed Forest				272,003	2,559	5,792	696,090	1,575,553
	A			58,670	2,788	3,235	163,584	189,774
		R		6,564	999	5,670	6,558	37,218
	A	R		696	1,031	5,755	718	4,005
		R	U	476	1,217	8,107	579	3,859
	A		U	2,198	2,621	6,287	5,761	13,818
	A	R	U	27	1,250	8,247	34	223
Mixed Forest Total				**376,893**			**970,465**	**2,052,403**

Table 14, continued ▼

Detailed land cover values with conditions.

Land Cover	Conditions			Acres	Annual Per Acre Value		Total Annual Value ($ in thousands)	
	Agriculture	Riparian	Urban		Low	High	Low	High
Emergent Herbaceous Wetlands				8,474	9,466	56,061	80,215	475,063
	A			10,816	880	37,671	9,523	407,446
		R		432	1,085	38,005	469	16,418
			U	2,670	10,789	46,469	28,805	124,072
	A	R		454	1,085	38,005	493	17,254
		R	U	231	10,991	46,747	2,539	10,799
	A		U	641	10,789	46,469	6,915	29,786
	A	R	U	59	10,991	46,747	648	2,758
Emergent Herbaceous Wetlands Total				**23,777**			**129,607**	**1,083,597**
Woody Wetlands				38,218	9,291	55,255	355,096	2,111,742
	A			19,596	706	36,865	13,832	722,398
		R		5,889	1,351	38,525	7,958	226,875
			U	7,342	10,614	45,682	77,927	335,400
	A	R		1,697	1,314	20,294	2,229	34,439
		R	U	859	11,243	47,302	9,657	40,633
	A		U	689	10,616	45,698	7,315	31,486
	A	R	U	87	11,275	47,443	981	4,128
Woody Wetland Total				**74,377**			**474,995**	**3,507,100**
Shrub				392,672	129	129	50,599	50,599
	A			25,538	129	129	3,291	3,291
		R		3,942	802	4,272	3,160	16,840
			U	6,735	17,503	17,503	117,883	117,883
	A	R		396	815	4,357	323	1,725
		R	U	97	18,120	21,500	1,758	2,085
	A		U	646	17,503	17,503	11,307	11,307
	A	R	U	26	18,189	21,731	473	565
Shrub Total				**430,052**			**188,793**	**204,296**
Grassland/ Herbaceous				117,459	142	256	16,659	30,111
	A			13,835	127	242	1,763	3,348
		R		619	12,193	41,785	7,547	25,865
			U	5,334	17,502	17,616	93,354	93,965
	A	R		161	15,307	44,899	2,464	7,229
		R	U	72	26,385	44,582	1,900	3,210
	A		U	611	17,502	17,616	10,694	10,763
	A	R	U	18	26,422	44,729	476	805
Grassland/ Herbaceous Total				**138,109**			**134,857**	**175,296**

Table 14, continued

Detailed land cover values with conditions.

Land Cover	Conditions			Acres	Annual Per Acre Value		Total Annual Value ($ in thousands)	
	Agriculture	Riparian	Urban		Low	High	Low	High
Pasture/Hay	A			106,823	69	505	7,326	53,952
Cultivated Crops	A			14,839	82	2,515	1,222	37,326
Beach				28,987	51,786	53,361	1,501,123	1,546,772
Lakes				55,392	41	3,256	2,273	180,345
Reservoir				279	634	1,616	177	451
"Reservoirs (no access)"				2,496	33	769	84	1,919
Rivers				13,492	26,406	27,236	356,270	367,462
Saltwater				285,069	9,295	13,723	2,649,788	3,912,022
"Open Space (urban park space)"			U	20,795	4,657	7,890	96,836	164,067
Central Puget Sound Total				**3,499,712**			**11,457,944**	**25,263,700**

Valuation by land cover type provides important insight into the ways in which nature, local communities, and the economy interact. The data above yield some interesting observations;

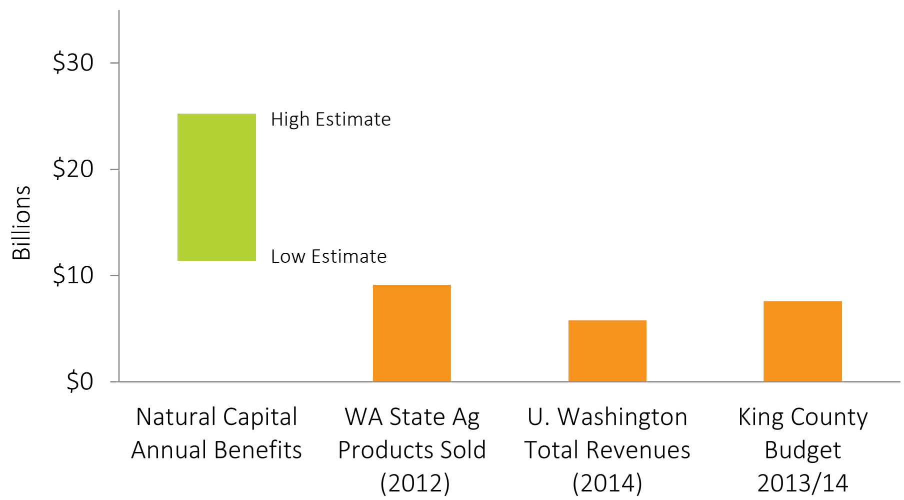
- **Proximity to Populated Areas Results in Higher Values:** Values tend to be higher for land cover that is close to population centers. Scarcity and increased number of beneficiaries of open space services help to explain this phenomenon (i.e. greater demand relative to supply). Compared with remote open space, a park in a densely populated urban area will most likely have higher values for play (more visitors), aesthetic value (increased value of neighboring homes), and health (air quality.) Due to this effect, there is often a robust financial return in projects that preserve and enhance the parks and open space closest to our population centers. Furthermore, this return will likely increase with population growth and greater density over time.

- **Riparian Areas Provide Significant Flood Protection Value:** The open space service value along riparian areas is quite large, representing their ability to attenuate flows and store storm water and reduce the frequency and extent of residential and commercial flooding. Riparian areas also provide an important service in filtering waste and nutrients before it can reach a river. Again, healthy natural capital is especially valuable near urban areas due to the increased density and high worth of structures typical in those areas.

- **Data Availability Influences Results:** As discussed above, lower value is not always a true representation of the value of a particular land cover and service combination. Some combinations simply have not been studied to the same level of detail as others.

By any measure, open space services contribute enormous value to the Central Puget Sound economy. Each and every year the open space goods and services provide at least $11.4 billion to $25.2 billion to the regional economy and likely much more. Figure 5 provides some perspective on both the magnitude and importance of this value by comparing the open space goods and services with other critical economic entities and indicators in the region.

Figure 5. Central Puget Sound annual benefits and revenue comparison.[27,28,29]



Beyond this financial contribution, healthy open space helps build the region's social and economic resilience in the face of climate change and rapid population growth by providing disaster mitigation, water, and waste services among many other benefits. Furthermore, research from other regions demonstrates that continued and increasing investment in these resources can provide high returns and lead to more efficient capital investments and reduced incurred costs.[30,31]

Carbon Storage Estimates

Table 15 provides the value estimates by land cover for the total carbon stored in the Central Puget Sound's open space.

With the rapidly changing climate, storage of carbon has become a vital open space service. As expected, the Central Puget Sound forests account for the vast majority of carbon stored in the region. The ranges of low and high estimates for carbon storage shown above reflect the variability in forest age and make-up. More detailed analysis of the Central Puget Sound forest profile would be needed to narrow this range.

Table 15. Carbon storage in central Puget Sound. Total dollar values are in thousands.

Land Cover		Acres	Low ($/acre)	High ($/acre)	Total Low	Total High
Forest	Deciduous	130,779	5,166	37,082	675,625	4,849,521
	Evergreen	1,797,553	2,915	57,559	5,239,554	103,465,896
	Mixed	376,893	6,637	35,967	2,501,391	13,555,675
Wetlands	Emergent Herbaceous	23,777	5,401	6,847	128,415	162,812
	Woody	74,377	5,401	6,847	401,697	509,295
Shrub and Grasslands	Shrub	430,052	5,988	5,988	2,575,339	2,575,339
	Grassland/Herbaceous	138,109	2,584	4,083	356,940	563,861
	Pasture/Hay	106,823	159	176	16,962	18,779
	Cultivated Crops	14,839	1,641	3,658	24,346	54,280
Developed	Open Space (urban park space)	20,795	79	9,090	1,651	189,032
Total					**11,921,920**	**125,944,491**

Total Asset Value

The ecosystem service values provide an estimate of the "yearly income" or the annual flow of benefits provided to the local economy. This would be like the value of yearly rent for a house. Considering this value across time provides the ability to appraise the full value of an asset (like the appraised value of a house).

The net present value is a critical measure of the overall magnitude of any economic asset. The asset value is a broad measure of the economic value that open space in the Central Puget Sound region provides. This is not the "intrinsic" value of open space. It is an estimate of the value of open space as an economic asset. It provides an idea of the critical role open space provides in the economy.

The net present value of the region's open space is $328.3 billion to $825.3 billion, calculated with a discount rate of 3.5%, a conservative estimate. The asset value using the 0% discount rate totals $1.1 trillion to $2.6 trillion. This total represents the value of open space services in the Central Puget Sound over the next 100 years plus the total value of the carbon stock stored in the region's open space, primarily forests. As discussed above, if ecosystems are well maintained, their productive life can extend well beyond this end-point.

Table 16. Asset values of the central Puget Sound region. Values are in billions of dollars.

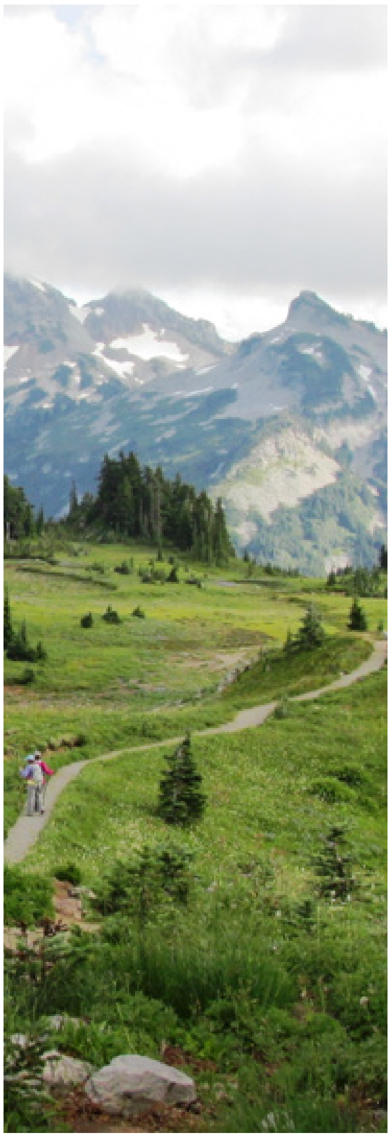
Value	3.5%		0%	
	Low	High	Low	High
Carbon Storage	$11.9	$125.9	$11.9	$125.9
Net Present Value	$316.9	$698.7	$1,145.8	$2,526.4
Total	**$328.8**	**$824.6**	**$1,157.7**	**$2,652.3**

Chapter 5

Recommendations and Next Steps

Lavender in Clearview, WA near Snohomish. Photo credit: creative commons image by Rachel Samanyi.

Conclusion and Next Steps



▲ Hiking on the Lakes Trail in Mount Rainier National Park. Image credit: creative commons share-alike image by J. Brew.

Central Puget Sound's open space is critical to the health and resilience of the regional economy and communities. The natural capital and open space services supply our water, treat our waste, support mental and physical health, and meet many other vital needs. Without healthy and productive open space, our economy and our communities would suffer and would be less resilient in the face of future challenges.

The process of calculating these values highlighted a number of data gaps and next steps that will improve study resolution and comprehensiveness.

- **Complete Localized Valuations:** Conduct site-specific studies that combine the values in this report with more robust models and data specific to particular land cover types, services, and project geographies. These studies will be able to more fully value the complex interactions of open space services in support of human health, biodiversity and social equity. Tools and techniques developed in each study can then be applied to other, related projects and geographies.

- **Fill Data Gaps:** New primary studies and methods are published monthly around the world. There is an opportunity to review and incorporate new studies to fill in data gaps, especially in the areas of Air, Water, Food, and Raw Materials.

- **Scenario Modeling:** Due to population growth and climate change, the economy's interdependence with natural capital is growing more significant and complex. To truly understand available policy options to steward and enhance open space, scenarios must be modeled to test 'no-action' with planned interventions and the resulting benefits and cost on long-term values and outcomes. By using data in this report to analyze policy alternatives, policy makers can gain more robust data needed to understand and choose the most cost-effective and productive path forward.

Policy and Institutional Recommendations

▲ Orcas under the Tacoma Narrows Brdige. Image credit: creative commons image by Make Charest.

Work in the Puget Sound region and around the nation highlights the need to redesign our larger accounting, investment, and decision-making frameworks to ensure that we protect and expand vital natural capital resources over time. The high value of our open space services and magnitude of pending challenges from population growth and climate change suggest the following priorities:

- **Educate Policy Makers and the Public:** Teaching people about the value of open space goods and services helps to build understanding about the synergy between the environment, communities, and the economy. Education also helps to garner public support for financing open space preservation and stewardship.

- **Immediately Include Ecosystem Values in Land Use and Capital Planning Analysis:** Planners and policy makers can immediately use the values contained in this report to inform decisions regarding the purchase and stewardship of open space. Consideration of the value of open space services can improve economic analysis, as natural capital strategies often prove to be more cost-effective and robust solutions to our most challenging problems.

- **Create a Governance and Financing Entity for Central Puget Sound:** Open space is a vast and valuable economic asset, essential to a healthy and prosperous economy, but is threatened by our rapidly increasing population. Open space is too important to be lost. The region needs a strong institution, clear governance, and a stable funding mechanism to effectively preserve this natural capital and retain healthy and resilient natural systems and economies.

Appendices

Driftwood on a beach in Kitsap County. Photo credit: creative commons share-alike image by Jonathan Miske.

Appendix A
Geographic Information System Data Analysis

Accurate and comprehensive land cover data is critical to the valuation as the land cover types and proximity to other features, like urban space, drive the calculations. In addition to the GIS work described in the body of the report, the following corrections and filtering were required to generate the appropriate land cover values.

Conditions

We defined three categories of conditions to refine the natural land cover types of forests, scrub/shrub, herbaceous plants and wetlands. These restrictions include riparian areas, agricultural areas, and urban areas. Table 17 shows the data layers used to define these conditions.

Table 17. ▼
Data layers chosen to represent conditions

Condition	Data layer	Description	Source
Riparian	SMA_streams	Streams adopted by county shoreline management act plans. Generally larger streams. Buffered to 100 feet.	Washington Department of Ecology
Riparian	GNIS_streams	Derived by selecting all streams named in the GNIS column of the National Hydrography Dataset (NHD). Includes smaller streams higher up in each watershed. Buffered to 50 feet.	Washington Department of Ecology
Riparian	Major_water	NHD water bodies. Buffered to 50 feet.	Washington Department of Ecology
Agriculture	intact_ag_parcels_v6	Agricultural areas over 40 acres were derived by merging the agricultural parcels and selecting the resulting contiguous agricultural land over 40 acres. Not buffered.	American Farmland Trust
Urban	CityUGA	City and Urban Growth Area boundaries. Not buffered.	Washington Department of Ecology

Three data layers represented the riparian condition. The process of creating a single mask for this restriction involved clipping the GNIS_streams layer to eliminate duplication of streams in the SMA_streams layer and then clipping both layers to eliminate places where stream lines crossed water body polygons. The layers were then buffered (100 feet for SMA streams, 50 feet for the others) and combined to form one mask for the riparian 'condition.'

Acreage within each possible combination of conditions was calculated for the following land cover types: Deciduous Forest, Evergreen Forest, Mixed Forest, Scrub/Shrub, Herbaceous, Emergent Herbaceous Wetlands and Woody Wetlands. This was accomplished by first calculating acreage where the three restrictions overlapped (agriculture, urban, and riparian). Next, the acreage in pairs of restrictions was calculated, subtracting the area from the first calculation. The acreage in each single condition was subtracted from earlier calculated acreages. Finally, the areas within all conditions were subtracted from the total acreage for each land cover type, resulting in the acreage of each land cover type outside of conditions areas.

Corrections to NLCD

In addition to adding conditions to certain land cover types, further refinement of some NLCD land cover types was required. The acreage of beaches was extracted from barren land (NLCD category 31), the acreage of urban parks was determined from developed open space (NLCD category 21), and open water (NLCD category 11) was divided into the Puget Sound, streams, reservoirs, and lakes.

The Barren Land category of NLCD includes beaches as well as other barren lands such as rock and gravel. Beaches were pulled out from the data by buffering saltwater at 1,500 feet and extracting all barren land within that buffer. The remaining Barren Land area was calculated by subtracting beaches from the total Barren Land area.

To capture urban greenspace that might not show up as one of the natural land cover types, we used the parks and open space layer from the Puget Sound Regional Council (psrc_parksos) as a mask and calculated the acreage of all “developed” NLCD categories within the urban growth area. We then subtracted this acreage from each of these categories (light development, medium development, heavy development, and developed open space). The remainder, “urban greenspace,” now includes all open space land covers within developed areas, not just “developed, open space.”

The Open Water category was broken down into four components. The category for Saltwater/ Estuary was called out by using the Extract by Mask tool and using Puget Sound polygons from the NHD dataset as the mask. Reservoirs were called out using the same tool with all NHD water body polygons with “reservoir” in the name as the mask. Rivers proved more complicated. Since land cover categorized as Open Water along streams did not always follow the lines of the stream layers, we used the GNIS streams layer buffered to 1,000 feet as the mask in order to capture as much of the variation as possible. We then edited the resulting dataset to remove pixels obviously not part of a stream course. Finally, we subtracted the areas of Puget Sound, rivers and reservoirs from the total acreage of the Open Water category and defined the remainder as Lake.

Appendix B
ROSS Open Space Service Mapping to Ecosystem Services

Table 18. ▼
Mapping of ROSS services to Millennium Assessment Ecosystem Services

ROSS Open Space Service	Ecosystem Service
Aesthetic	Cultural
Air	Air Quality
Disaster Mitigation	Climate Stability
	Moderation of Extreme Events
	Soil Retention
Food	Food
	Pollination
Health	Biological Control
Play	Recreation and Tourism
Raw Materials	Energy and Raw Materials
Shelter	Habitat and Nursery
Waste	Waste Treatment
Water	Water Regulation
	Water Supply

Appendix C
Valuation References

This appendix includes all studies included in the valuation calculations.
Some studies may represent multiple values and land covers.

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Appendix D
Study Values by Author

The following table reports the high and low values used for each land cover service combination.

Table 19. ▼
Study values by service and author.

Land Cover	ROSS Service	Author(s)	Low ($/acre/year)	High ($/acre/year)
Beach	Aesthetic	Gopalakrishnan et al. 2011	45,366	45,366
	Play	Kline and Swallow 1998	6,420	7,995
Crop	Aesthetic	Bergstrom et al. 1985	29	75
		Bergstrom and Ready 2009	0	2
	Disaster Mitigation	Moore and McCarl 1987	5	5
		Pimentel et al. 1995	120	120
	Food	Faux and Perry 1999	17	214
		Piper 1997	42	42
		Wilson 2010	147	147
		Winfree et al. 2011	45	1,875
	Health	Cleveland et al. 2006	14	196
		Pimentel et al. 1997	17	17
		Pimentel 1998	52	78
Pasture	Aesthetic	Bastian et al. 2002	0	7
		Bergstrom and Ready 2009	0	2
		Ready et al. 1997	90	103
	Disaster Mitigation	Moore and McCarl 1987	5	5
	Food	Piper 1997	42	42
		Wilson 2010	147	147
	Health	Pimentel et al. 1997	17	17
	Shelter	Bastian et al. 2002	0	3
Deciduous Forest	Aesthetic	Costanza et al. 2006	649	649
		McPherson et al. 1999	263	1,251
		McPherson and Simpson 2002	341	2,135
		Qiu and Prato 1998	247	1,209
		Swanson and Loomis 1996	342	3,183
	Air	McPherson et al. 1998	30	30
		McPherson et al. 1999	1,043	1,043
		McPherson and Simpson 2002	77	166
		Wilson 2010	190	190

Table 19, continued

Study values by service and author.

Land Cover	ROSS Service	Author(s)	Low ($/acre/year)	High ($/acre/year)
Deciduous Forest (continued)	Disaster Mitigation	Brenner-Guillermo 2007	59	59
		Everard and Jevons	10	10
		Moore and McCarl 1987	1	1
		Olewiler 2004	1	4
		Wilson 2010	578	578
		Zavaleta 2000	44	60
	Health	Pimentel 1998	2	11
	Play	Colby and Smith-Incer 2005	201	268
		Prince and Ahmed 1989	37	46
		Shafer et al. 1993	3	496
	Raw Materials	Pimentel 1998	18	18
		Schmidt et al. 2014	16	16
	Shelter	Knowler et al. 2003	19	56
		Tanguay et al. 1995	2	6
		Wilson 2010	0	1
		Wu and Skelton-Groth 2002	3	56
	Waste	Lant and Tobin 1989	176	1,941
		Qiu and Prato 1998	48	458
		Wilson 2010	726	726
		Zhongwei 2006	262	263
	Water	McPherson et al. 1999	379	713
		Zavaleta 2000	32	550
Evergreen Forest	Aesthetic	Costanza et al. 2006	649	649
		McPherson et al. 1999	263	1,251
		McPherson and Simpson 2002	341	2,135
		Qiu and Prato 1998	247	1,209
		Swanson and Loomis 1996	342	3,183
	Air	McPherson et al. 1998	30	30
		McPherson et al. 1999	1,043	1,043
		McPherson and Simpson 2002	77	166
		Wilson 2010	190	190
	Disaster Mitigation	Brenner-Guillermo 2007	59	59
		Everard and Jevons	10	10
		Moore and McCarl 1987	1	1
		Olewiler 2004	1	4
		Wilson 2010	578	578
		Zavaleta 2000	44	60

Table 19, continued

Study values by service and author.

Land Cover	ROSS Service	Author(s)	Low ($/acre/year)	High ($/acre/year)
Evergreen Forest (continued)	Health	Pimentel 1998	2	11
		Boxall 1995	0	0
		Colby and Smith-Incer 2005	201	268
		Haener and Adamowicz 2000	0	0
		Prince and Ahmed 1989	37	46
		Shafer et al. 1993	496	496
	Raw Materials	Haener and Adamowicz 2000	4	9
		Pimentel 1998	18	18
		Schmidt et al. 2014	79	79
	Shelter	Haener and Adamowicz 2000	0	7
		Knowler et al. 2003	19	56
		Tanguay et al. 1995	2	6
		Wilson 2010	0	1
		Wu and Skelton-Groth 2002	3	56
	Waste	Lant and Tobin 1989	176	1,941
		Qiu and Prato 1998	48	458
		Wilson 2010	726	726
		Zhongwei 2006	262	263
	Water	McPherson et al. 1999	379	713
		Zavaleta 2000	32	550
Mixed Forest	Aesthetic	Costanza et al. 2006	649	649
		McPherson et al. 1999	263	1,251
		McPherson and Simpson 2002	341	2,135
		Qiu and Prato 1998	247	1,209
		Swanson and Loomis 1996	342	3,183
	Air	McPherson et al. 1998	30	30
		McPherson et al. 1999	1,043	1,043
		McPherson and Simpson 2002	77	166
		Wilson 2010	190	190
	Disaster Mitigation	Brenner-Guillermo 2007	59	59
		Everard and Jevons	10	10
		Moore and McCarl 1987	1	1
		Olewiler 2004	1	4
		Wilson 2010	578	578
		Zavaleta 2000	44	60
	Health	Pimentel 1998	2	11

Table 19, continued

Study values by service and author.

Land Cover	ROSS Service	Author(s)	Low ($/acre/year)	High ($/acre/year)
Mixed Forest (continued)	Play	Colby and Smith-Incer 2005	201	268
		Prince and Ahmed 1989	37	46
		Shafer et al. 1993	496	496
		Swanson and Loomis 1996	48	48
		Wilson 2010	49	49
	Raw Materials	Pimentel 1998	18	18
	Shelter	Knowler et al. 2003	19	56
		Tanguay et al. 1995	2	6
		Wilson 2010	0	1
		Wu and Skelton-Groth 2002	3	56
	Waste	Lant and Tobin 1989	176	1,941
		Qiu and Prato 1998	48	458
		Wilson 2010	726	726
		Zhongwei 2006	262	263
	Water	McPherson et al. 1999	379	713
		Zavaleta 2000	32	550
Grassland	Aesthetic	Costanza et al. 2006	1	1
		Qiu and Prato 1998	247	1,209
	Disaster Mitigation	Everard and Jevons	10	10
		Gascoigne et al. 2011	7	7
		Olewiler 2004	1	4
		Rein 1999	36	3,810
	Health	Costanza et al. 2006	14	14
		Rein 1999	23	289
	Play	Boxall 1995	0	0
		Breffle et al. 1998	17,374	17,374
		Colby and Smith-Incer 2005	201	268
		Rein 1999	14,431	14,431
	Shelter	Gascoigne et al. 2011	34	34
		Olewiler 2004	91	91
		Wu and Skelton-Groth 2002	3	56
	Waste	Costanza et al. 2006	53	53
		Rein 1999	20,129	20,129
		Zhongwei 2006	6,178	10,713
	Water	Costanza et al. 2006	2	2
Shrub	Aesthetic	Qiu and Prato 1998	247	1,209

Table 19, continued

Study values by service and author.

Land Cover	ROSS Service	Author(s)	Low ($/acre/year)	High ($/acre/year)
Shrub (continued)	Disaster Mitigation	Everard and Jevons	10	10
		Gascoigne et al. 2011	7	7
		Olewiler 2004	1	4
		Zavaleta 2000	44	60
	Play	Breffle et al. 1998	17,374	17,374
		Colby and Smith-Incer 2005	201	268
	Shelter	Gascoigne et al. 2011	34	34
		Knowler et al. 2003	19	56
		Wu and Skelton-Groth 2002	3	56
	Waste	Lant and Tobin 1989	176	1,941
		Qiu and Prato 1998	48	458
		Zhongwei 2006	262	263
	Water	Zavaleta 2000	32	550
Emergent Herbaceous Wetland	Aesthetic	Johnston et al. 2002	6,874	9,273
		Mahan 1997	9,947	9,947
		Mazzotta 1996	5,820	13,797
		Qiu and Prato 1998	247	1,209
		Thibodeau and Ostro 1981	36	116
		Whitehead 1990	972	6,300
	Disaster Mitigation	Everard and Jevons	10	10
		Industrial Economics, inc. 2011	0	15
		Ko 2007	517	517
		Leschine et al. 1997	1,620	7,398
		Olewiler 2004	1	4
		Roberts and Leitch 1997	622	622
		Thibodeau and Ostro 1981	6,061	6,061
	Play	Colby and Smith-Incer 2005	201	268
		Cooper and Loomis 1991	12	294
		Creel and Loomis 1992	1,592	10,008
		Gupta and Foster 1975	51	51
		Jaworski and Raphael 1978	95	1,300
		Kreutzwiser 1981	167	167
		Shafer et al. 1993	90	90
	Shelter	Jaworski and Raphael 1978	11	11
		van Kooten and Schmitz 1992	2	35
		Wu and Skelton-Groth 2002	3	56
	Waste	Industrial Economics, inc. 2011	113	113
		Thibodeau and Ostro 1981	4,487	4,487
		Wilson 2010	11	652

Table 19, continued

Study values by service and author.

Land Cover	ROSS Service	Author(s)	Low ($/acre/year)	High ($/acre/year)
Emergent Herbaceous Wetland (continuted)	Water	Brander et al. 2013	99	1,043
		Gupta and Foster 1975	51	51
		Roberts and Leitch 1997	133	133
		Thibodeau and Ostro 1981	18,316	18,316
Woody Wetland	Aesthetic	Johnston et al. 2002	6,874	9,273
		Mahan 1997	9,947	9,947
		Mazzotta 1996	5,820	13,797
		Qiu and Prato 1998	247	1,209
		Thibodeau and Ostro 1981	36	116
		Whitehead 1990	972	6,300
	Disaster Mitigation	Everard and Jevons	10	10
		Industrial Economics, inc. 2011	0	15
		Ko 2007	517	517
		Leschine et al. 1997	1,620	7,398
		Olewiler 2004	1	4
		Roberts and Leitch 1997	622	622
		Thibodeau and Ostro 1981	6,061	6,061
		Zavaleta 2000	44	60
	Play	Colby and Smith-Incer 2005	201	268
		Cooper and Loomis 1991	12	294
		Creel and Loomis 1992	1,592	10,008
		Gupta and Foster 1975	51	51
		Jaworski and Raphael 1978	95	1,300
		Kreutzwiser 1981	167	167
		Shafer et al. 1993	90	90
	Shelter	Jaworski and Raphael 1978	11	11
		Knowler et al. 2003	19	56
		van Kooten and Schmitz 1992	2	15
		Wu and Skelton-Groth 2002	3	56
	Waste	Breaux et al. 1995	182	4,507
		Lant and Tobin 1989	176	1,941
		Qiu and Prato 1998	48	458
		Zhongwei 2006	262	263
	Water	Brander et al. 2013	99	1,043
		Gupta and Foster 1975	51	51
		Roberts and Leitch 1997	133	133
		Thibodeau and Ostro 1981	18,316	18,316
		Zavaleta 2000	32	550

Table 19, continued

Study values by service and author.

Land Cover	ROSS Service	Author(s)	Low ($/acre/year)	High ($/acre/year)
Urban Greenspace	Aesthetic	Bolitzer and Netusil 2010	1,668	2,511
		Johnston et al. 2002	1,701	2,940
		Mazzotta 1996	1,832	3,449
		Opaluch et al. 1999	4,563	4,563
	Play	Brenner-Guillermo 2007	2,549	2,549
	Water	Trust for Public Land 2011	437	437
Lake	Aesthetic	Berman and Armagost 2013	248	248
		Young and Shortle 1989	2	2
	Play	Burt and Brewer 1971	2,092	2,239
		Kealy and Bishop 1986	21	21
		Mullen and Menz 1985	241	241
		Ribaudo and Epp 1984	653	653
		Young and Shortle 1989	6	6
	Water	Costanza et al. 2006	33	769
River	Aesthetic	Berman and Armagost 2013	507	507
		Kulshreshtha and Gillies 1993	31	860
	Play	Loomis 2002	22,881	22,881
	Shelter	Berrens et al. 2000	3,489	3,489
	Water	Delfino et al. 2007	5	6
Reservoir	Aesthetic	Berman and Armagost 2013	248	248
		Young and Shortle 1989	2	2
	Play	Piper 1997	599	599
	Water	Costanza et al. 2006	33	769
Saltwater/Estuary	Aesthetic	Costanza et al. 2006	4	1,748
	Disaster Mitigation	Costanza et al. 2006	342	342
	Food	Armstrong et al. 2003	25	139
	Health	Costanza et al. 2006	24	47
	Play	Bockstael et al. 1989	0	55
		Hayes et al. 1992	1,122	1,744
		Johnston et al. 2002	171	386
		Kildow et al. 2004	205	457
		Lipton 2004	3	3
		Opaluch et al. 1999	108	244
		Whitehead et al. 1997	10	94
	Shelter	Kahn and Buerger 1994	2	17
		Olewiler 2004	9,050	9,050

Table 20.
Carbon capture rates by land cover and author

Land Cover	Author	Low (metric ton Carbon/acre/year)	High (metric ton Carbon/acre/year)
Cropland	Liu et al. 2012	0.097	0.097
	Smith et al. 2001	0.012	0.25
Pasture	DeLonge et al. 2013	0.87	1.65
	Ryals and Silver 2013	0.28	0.63
	Schuman et al. 2002	0.04	0.24
Deciduous Forest	Smith et al. 2006	1.22	3.20
Evergreen Forest	Smith et al. 2006	0.85	6.61
Mixed Forest	Smith et al. 2006	0.85	6.61
	Smith et al. 2006	1.22	3.20
	Heath et al. 2003	0.02	0.21
	Liu et al. 2012	0.08	0.38
Grassland	Liu et al. 2012	0.21	0.62
Shrubland	Liu et al. 2012	0.62	0.62
Urban Greenspace	Davies et al.	0.02	2.52
Emergent Wetland	Chmura et al. 2003	0.25	1.38
	Bridgeham et al. 2006	0.83	0.89
	Crooks et al. 2014	0.23	1.42
	Bridgeham et al. 2006	0.07	0.07
	Liu et al. 2012	0.11	0.77
	Bridgeham et al. 2006	0.05	0.29
Woody Wetland	Bridgeham et al. 2006	0.07	0.07
	Liu et al. 2012	0.11	0.77
	Bridgeham et al. 2006	0.05	0.29
Saltwater	Duarte et al. 2005	0.18	0.18
	Nellemann et al. 2009	0.0001	0.0001

Table 21. ▼
Carbon storage rates by land cover and author

Land Cover	Author	Low (metric ton Carbon/acre)	High (metric ton Carbon/acre)
Cropland	Liu et al. 2012	11.71	26.10
	Manley et al. 2005	2.90	27.80
	Tufekcioglu et al	0.46	0.65
Pasture	Ryals and Silver 2013	1.13	1.25
Deciduous Forest	Smith et al. 2006	36.87	264.62
Evergreen Forest	Smith et al. 2006	20.80	410.76
Mixed Forest	Smith et al. 2006	20.80	410.76
	Smith et al. 2006	36.87	264.62
	Liu et al. 2012	84.42	94.62
Grassland	Liu et al. 2012	18.44	29.14
Shrubland	Graham et al. 2004	0.89	72.03
	Heath et al. 2003	42.73	42.73
Urban Greenspace	Davies et al. 2011	0.57	64.87
Emergent Wetland	Crooks et al. 2014	21.73	94.53
	Bridgeham et al. 2006	66.15	197.25
	Liu et al. 2012	38.54	48.87
	Bridgeham et al. 2006	422.87	609.21
Woody Wetland	Bridgeham et al. 2006	66.15	197.25
	Liu et al. 2012	38.54	48.87
	Bridgeham et al. 2006	422.87	609.21

Appendix E
Study Limitations

The results of this study have important and significant implications on the restoration and management of natural capital. A benefit transfer methodology estimates the economic value of a given ecosystem (e.g., wetlands) from prior studies of that ecosystem type. Like any economic analysis, this methodology has strengths and weaknesses. While these limitations must be noted, they should not detract from the core finding that ecosystems produce a significant economic value to society. Some arguments against benefit transfer include:

- Every ecosystem is unique; per-acre values derived from another location may be irrelevant to the ecosystems being studied.

- Even within a single ecosystem, the value per acre depends on the size of the ecosystem; in most cases, as the size decreases, the per-acre value is expected to increase and vice versa. (In technical terms, the marginal cost per acre is generally expected to increase as the quantity supplied decreases; a single average value is not the same as a range of marginal values).

- Gathering all the information needed to estimate the specific value for every ecosystem within the study area is not feasible. Therefore, the true value of all of the wetlands, forests, pasture land, etc. in a large geographic area cannot be ascertained. In technical terms, we have far too few data points to construct a realistic demand curve or estimate a demand function.

- To value all, or a large proportion, of the ecosystems in a large geographic area is questionable in terms of the standard definition of exchange value. We cannot conceive of a transaction in which all or most of a large area's ecosystems would be bought and sold. This emphasizes the point that the value estimates for large areas (as opposed to the unit values per acre) are more comparable to national income account aggregates and not exchange values. These aggregates (i.e. GDP) routinely impute values to public goods for which no conceivable market transaction is possible. The value of open space services of large geographic areas is comparable to these kinds of aggregates (see below).

Proponents of the above arguments recommend an alternative valuation methodology that amounts to limiting valuation to a single ecosystem in a single location. This method only uses data developed expressly for the unique ecosystem being studied, with no attempt to extrapolate from other ecosystems in other locations. An area with the size and landscape complexity of the study area makes this approach to valuation extremely difficult and costly. Responses to the above critiques can be summarized as follows (see Howarth and Farber, 2002 for more detailed discussion[32]):

- While every wetland, forest, or other ecosystem is unique in some way, ecosystems of a given type, by their definition, have many things in common. The use of average values in ecosystem valuation is no more or less justified than their use in other macroeconomic contexts; for instance, the development of economic statistics such as Gross Domestic or Gross State Product. This study's estimate of the aggregate value of open space services is a valid and useful (albeit imperfect, as are all aggregated economic measures) basis for assessing and comparing these services with conventional economic goods and services.

- The results of the spatial modeling analysis described in other studies do not support an across-the-board claim that the per-acre value of forest or agricultural land depends on the size of the parcel. While the claim does appear to hold for nutrient cycling and other services, the opposite position holds up fairly well for what ecologists call "net primary productivity" or NPP, which is a major indicator of ecosystem health. It has the same position, by implication, of services tied to NPP—where each acre makes about the same contribution to the whole, regardless of whether it is part of a large plot of land or a small one. This area of inquiry needs further research, but for the most part, the assumption that average value is a reasonable proxy for marginal value is appropriate for a first approximation. Also, a range of different parcel sizes exists within the study site, and marginal value will average out.

- As employed here, the prior studies we analyzed encompass a wide variety of time periods, geographic areas, investigators, and analytic methods. Many of them provide a range of estimated values rather than single-point estimates. The present study preserves this variance; no studies were removed from the database because their estimated values were deemed to be "too high" or "too low." Limited sensitivity analyses were also performed. This approach is similar to determining an asking price for a piece of land based on the prices of comparable parcels; even though the property being sold is unique, realtors and lenders feel justified in following this procedure to the extent of publicizing a single asking price rather than a price range.

- The objection to the absence of even an imaginary exchange transaction was made in response to the study by Costanza et al. (1997) of the value of all of the world's ecosystems.[33] Leaving that debate aside, one can conceive of an exchange transaction in which, for example, all of, or a large portion of a watershed was sold for development, so that the basic technical requirement of an economic value reflecting the exchange value could be satisfied. Even this is not necessary if one recognizes the different purpose of valuation at this scale—a purpose that is more analogous to national income accounting than to estimating exchange values (Howarth and Farber 2002).

In this report, we have displayed our study results in a way that allows one to appreciate the range of values and their distribution. It is clear from inspection of the tables that the final estimates are not precise. However, they are much better estimates than the alternative of assuming that open space services have zero value, or, alternatively, of assuming they have infinite value. Pragmatically, in estimating the value of open space services, it seems better to be approximately right than precisely wrong.

These objections seem to be difficult to reconcile, but that may not be so. Just as a human life is priceless, so are ecosystems – yet people are paid for the work they do. Valuation is important for giving nature proper credit for the work it does. Consider the value of one open space service, such as photosynthesis, and the ecosystem good it produces: atmospheric oxygen. Given the choice between breathable air and possessions, informal surveys have shown the choice of oxygen over material goods is unanimous. This indicates that people immensely value photosynthesis and atmospheric oxygen—and oxygen production is only one of many open space services and goods.

General Limitations

- **Static Analysis.** This analysis is a static, partial equilibrium framework that ignores interdependencies and dynamics, though new dynamic models are being developed. The effect of this omission on valuations is difficult to assess.

- **Increases in Scarcity.** The valuations probably underestimate shifts in the relevant demand curves as the sources of open space services become more limited. The values of many ecological services rapidly increase as they become increasingly scarce.[34] If open space services are scarcer than assumed here, their value has been underestimated in this study. Such reductions in supply appear likely as land conversion and development proceed; climate change may also adversely affect the ecosystems, although the precise impacts are more difficult to predict.

- **Existence Value.** The approach does not fully include the infrastructure or existence value of ecosystems. It is well known that people value the existence of certain ecosystems, even if they never plan to use or benefit from them in any direct way. Estimates of existence value are rare; including such future estimates will obviously increase the total values.

- **Other Non-Economic Values.** Economic and existence values are not the sole decision-making criteria. A technique called multi-criteria decision analysis is available to formally incorporate economic values with other social and policy concerns (see Janssen and Munda, 2002 and de Montis et al., 2005 for reviews).[35,36] Having economic information on open space services usually helps this process because traditionally, only opportunity costs of foregoing development or exploitation are counted against non-quantified environmental concerns.

GIS Limitations

- **GIS Data.** Since this valuation approach involves using benefit transfer methods to assign values to land cover types based, in some cases, on their contextual surroundings, one of the most important issues with GIS quality assurance is reliability of the land cover maps used in the benefits transfer, both in terms of categorical precision and accuracy.

- **GIS Accuracy.** The source GIS layers are assumed to be accurate but may contain some minor inaccuracies due to land use changes done after the data was sourced, inaccurate satellite readings, and other factors.

- **GIS Layer Precision.** The absence of certain GIS layers that matched the land cover classes used in the Earth Economics database created the need for multiple datasets to be combined.

- **Ecosystem Health.** There is the potential that ecosystems identified in the GIS analysis are fully functioning to the point where they are delivering higher values than those assumed in the original primary studies, which would result in an underestimate of current value. On the other hand, if ecosystems are less healthy than those in primary studies, this valuation will overestimate current value.

- **Spatial Effects.** This open space service valuation assumes spatial homogeneity of services within ecosystems, i.e., that every acre of forest produces the same open space services. This is clearly not the case. Whether this would increase or decrease valuations depends on the spatial patterns and services involved. Solving this difficulty requires spatial dynamic analysis. More elaborate system dynamic studies of open space services have shown that including interdependencies and dynamics leads to significantly higher values (Boumans et al., 2002), as changes in open space service levels ripple throughout the economy.

Benefit Transfer/Database Limitations

- **Incomplete coverage.** That not all ecosystems have been valued or studied well is perhaps the most serious issue, because it results in a significant underestimate of the value of open space services. More complete coverage would almost certainly increase the values shown in this report, since no known valuation studies have reported estimated values of zero or less.

- **Selection Bias.** Bias can be introduced in choosing the valuation studies, as in any appraisal methodology. The use of a range partially mitigates this problem.

- **Consumer Surplus.** Because the benefit transfer method is based on average rather than marginal cost, it cannot provide estimates of consumer surplus. However, this means that valuations based on averages are more likely to underestimate total value.

Primary Study Limitations

- **Willingness-to-pay Limitations.** Some estimates are based on current willingness-to-pay or proxies, which are limited by people's perceptions and knowledge base. Improving people's knowledge base about the contributions of open space services to their welfare would almost certainly increase the values based on willingness-to-pay, as people would realize that ecosystems provided more services than they had previously known.

- **Price Distortions.** Distortions in the current prices used to estimate open space service values are carried through the analysis. These prices do not reflect environmental externalities and are therefore again likely to be underestimates of true values.

- **Non-linear/Threshold Effects.** The valuations assume smooth responses to changes in ecosystem quantity with no thresholds or discontinuities. Assuming (as seems likely) that such gaps or jumps in the demand curve would move demand to higher levels than a smooth curve, the presence of thresholds or discontinuities would likely produce higher values for affected services.[37] Further, if a critical threshold is passed, valuation may leave the normal sphere of marginal change and larger-scale social and ethical considerations dominate, such as an endangered species listing.

- **Sustainable Use Levels.** The value estimates are not necessarily based on sustainable use levels. Limiting use to sustainable levels would imply higher values for open space services as the effective supply of such services is reduced.

If the above problems and limitations were addressed, the result would most likely be a narrower range of values and significantly higher values overall. At this point, however, it is impossible to determine more precisely how much the low and high values would change.

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