Nature's Value in Clallam County:

Policy Implications of the Economic Benefits of Feeder Bluffs and 12 Other Ecosystems

EARTH ECONOMICS

Prepared by:

EARTH ECONOMICS

107 N. Tacoma Ave
Tacoma, WA 98403
253-539-4801
www.eartheconomics.org | info@eartheconomics.org

November 2013

Suggested Citation:
Flores, L., Harrison-Cox, J., Wilson, S., Batker, D. 2013. Nature's Value in Clallam County: The Economic Benefits of Feeder Bluffs and 12 Other Ecosystems. Earth Economics: Tacoma, Washington.

Authors: Lola Flores, Jennifer Harrison-Cox, Sara Wilson and David Batker

Primary Data Contributors: Anne Shaffer at Coastal Watershed Institute, Dave Parks at Washington State Department of Natural Resources, and Clallam County Department of Community Development.

Acknowledgements:
Earth Economics would like to thank all who contributed valuable information to this project: Anne Shaffer and Nicole Harris from the Coastal Watershed Institute, Cathy Lear and Steve Gray from Clallam County, Dave Parks from Department of Natural Resources, George Kaminsky and Heather Barron from Department of Ecology, Kathryn Neal from the City of Port Angeles, Clea Rome from the WSU Extension, Ian Miller from WA Seagrant and Helle Andersen, formerly of CWI.

We deeply appreciate those who helped review and edit this document, Donna J. Nickerson, Aaron Schwartz, Cathy Lear, Anne Shaffer and Dave Parks.

We very much appreciate the professional project sponsorship and support: Margaret Mckeown project manager from the Department of Fish and Wildlife.

We would also like to thank our Board of Directors for their continued support of Earth Economics: David Cosman, Josh Farley, Ingrid Rasch, and Josh Reyneveld.

Earth Economics project team members for this study included: Tracy Stanton, Maya Kocian, Jonathan Kochmer, Rowan Schmidt, Zachary Christin, Nora Wahlund, Tedi Dickinson, Tania Briceno, TaNeashia Sudds; and our wonderful interns and volunteers: Lauren Travis, Anna Milliren, Hannah Fotherby, Danielle Begg, Yiyan Ge, Can Huynh, Bryan Hueber, Seth Wiggins and Deirdre Gabbay.

This project has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement PC 00J29801 to Washington Department of Fish and Wildlife. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

The authors are responsible for the content of this report.

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Layout by Angela Fletcher

Who We Are

Earth Economics

Earth Economics is a non-profit organization located in Tacoma, Washington, dedicated to researching and applying the economic solutions of tomorrow, today.

Earth Economics provides robust, science-based, ecologically sound economic analysis, policy recommendations and tools to positively transform regional, national and international economics, and asset accounting systems. Working with leading ecologists, economists and modelers, we serve a large circle of businesses, non-profits, government agencies, policy makers and media channels with research, reports, presentations, workshops and investigations. Our goal is to help communities shift away from the failed economic policies of the past, towards an approach that is both economically viable and environmentally sustainable.

Mission Statement: Earth Economics applies new economic tools and principles to meet challenges of the 21st century: achieving the need for just and equitable communities, healthy ecosystems, and sustainable economies.

Coastal Watershed Institute (CWI)

CWI is a small 501c3 non-profit first formed in 1996. CWI's goal is to advance protection of intact and critical natural ecosystems thru long-term wise ecosystem management, nearshore restoration at the ecosystem level, and mentoring our next generation of scientists and managers, and citizen partnerships. Over our careers we at CWI have learned that -without exception- what is good for the environment is good for community. CWI has also learned that saving what we have is best for the ecosystem and economy-so CWI emphasizes protection,. We also know that when we are restoring, true restoration must occur at the ecosystem level to be successful.. Our experience is also that the majority of the community - which is growing rapidly - wants to be wise stewards but need the tools to do so. Our work is extremely challenging. Preservation and restoration can take decades-and that bureaucratic and political challenges (sometimes significant) are not reasons to quit. In total our work is to link senior scientists, managers, and citizens to motivate for the best, not just the easiest, management actions and solutions. Our work is never ending and crosses generations. Collectively CWI senior scientists have hundreds of years of experience managing and researching the natural history of this region CWI engages these scientists with college students, citizens, and landowners on the ground to understand how our natural ecosystems function and how to protect them while training the next generation of managers and scientists. We bring science to management in a rural, and sometimes extremely conservative, but ecologically critical region of the Pacific Northwest. Top priority work for CWI include coordinating the Elwha Nearshore Consortium, a group of scientists, citizens, and managers dedicated to understanding and promoting the nearshore restoration associated with the Elwha dam removals, and conduct unique and critical research to understand and promote nearshore habitat function, and define how to protect the nearshore functions, including cross regional fish use of nearshore habitats, and the importance of Dungeness and Elwha feeder bluffs for surf smelt. CWI also regularly sponsor's community forums on emerging and ongoing topics including Elwha nearshore science, management, and restoration, and net pen aquaculture. Nearshore ecosystem services are complex, compelling, and integral element of CWI's work. We are honored to be a partner in this new frontier of ecosystem management.

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Abbreviation List

AC	Avoided Cost
BTM	Benefit Transfer Methodology
CAA	Carbon Annuity Account
CH4	Methane
CO2	Carbon Dioxide
CV	Contingent Valuation
DOE	Department of Ecology
DNR	Department of Natural Resources
EIS	Environment Impact Statement
ES	Ecosystem Services
ESA	Endangered Species Act
ESV	Ecosystem Service Valuation
EVT	Ecosystem Valuation Toolkit
FEMA	Federal Emergency Management Agency
FI	Factor Income
GIS	Geographical Information Systems
GMA	Growth Management Act
GV	Group Valuation
HP	Hedonic Pricing
ICR	Inventory and Characterization Report
LID	Low Impact Development
LWD	Large Woody Debris
MLLW	Mean Lower Low Water
MRC	Marine Resource Committee
NLCD	National Land Cover Database
NNL	No Net Loss
NOLT	North Olympic Land Trust
NOSC	North Olympic Salmon Coalition
OWS	Over Water Structure
PNNL	Pacific Northwest National Laboratory
PSP	Puget Sound Partnership
RC	Replacement Cost
SCC	Social Cost of Carbon
SERVES	Simple and Effective Resource for Valuing Ecosystem Services
SMA	Shoreline Management Act
SMP	Shoreline Master Program
SRC	Shoreline Residential Conservancy
SRI	Shoreline Residential Intensive
TC	Travel Cost
UNEP	United Nation Environment Programme
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area

Important Coastal Definitions

Nearshore
The nearshore is defined as extending from the area of tidal influence in lower rivers and extending offshore to a depth of 30 m MLLW (Mean Lower Low Water). It includes the riparian zone.

Shoreline
Shorelands or Shoreland Areas mean those lands extending landward for 200 feet in all directions as measured on a horizontal plane from the OHWM; floodways and contiguous floodplain areas landward 200 feet from such floodways; and all wetlands and river deltas associated with the streams, lakes and tidal waters which are subject to the provisions of Chapter 90.58 RCW.

Shorelines are all of the water areas of the state as defined in RCW 90.58.030, including reservoirs and their associated shorelands, together with the lands underlying them except:

- Shorelines of statewide significance;
- Shorelines on segments of streams upstream of a point where the mean annual flow is 20 cubic feet per second (cfs) or less and the wetlands associated with such upstream segments; and
- Shorelines on lakes less than 20 acres in size and wetlands associated with such small lakes.

Ordinary High Water Mark or OHWM means that mark that will be found by examining the bed and banks of a lake or stream and ascertaining where the presence and action of waters are so common and usual, and so long continued in all ordinary years, as to mark upon the soil a character distinct from that of the abutting upland, in respect to vegetation as that condition exists on June 1, 1971, as it may naturally change thereafter, or as it may change thereafter in accordance with approved development. In any area where the OHWM cannot be found, the OHWM adjoining fresh water shall be the line of mean high water. For braided streams, the OHWM is found on the banks forming the outer limits of the depression within which the braiding occurs.

Drift Cell
The division of the shoreline in several sectors depending on their net shore drift. Each drift cell includes a sediment source (erosional bluff, river mouth), an area of sediment transport, and an area of sediment accumulation (accretion).

Net Shore Drift
Is the long-term, overall effect of shore drift occurring over a period of time along a particular segment of marine shoreline. Net shore drift is typically described at a drift cell scale. Net shore drift is influenced by patterns of water movement along a coastline and patterns of wave-induced movement into a coastline.

Feeder Bluff
A primary sediment input area that can feed miles of beaches.

Spit
A spit refers to a deposition landform found off coasts. Also known as a type of bar or beach.

Marine Riparian Areas
Lands adjacent to marine shorelines, wetlands and other aquatic systems. Marine nearshore environments are highly resource-rich and economically important.

Sources:
http://www.clallam.net/realestate/assets/applets/CH09_Abbreviate_Glossary_FINAL2012.pdf
http://www.co.mason.wa.us/oakland_bay/pdfs/beaches_bluffs.pdf
http://wsg.washington.edu/mas/pdfs/rip_functions-benefits.pdf

Executive Summary

Our natural environment provides things we need to survive — breathable air, drinkable water, food, security from flood and storm, and stable atmospheric conditions. Natural systems also provide things essential for every economy to survive, such as oxygen, water and raw materials. Ecosystem services provide substantial economic value that, when managed thoughtfully, will be provided in perpetuity to future generations at very little cost.

> Ecosystem goods and services, simply called ecosystem services, are the economic benefits that natural systems provide to people.

Clallam County, in the northwestern most region of Washington State, is blessed with some of the most beautiful, diverse, and productive working and natural landscapes in the country. Of the 2,670 square miles in Clallam County, 931 square miles of shorelines feature salmon-spawning streams, dramatic sea stacks, beaches, and towering coastal cliffs called feeder bluffs. Forestry and fisheries are foundational industries of the regional economy. Olympic National Forest, Olympic National Park and the Dungeness Recreation Area provide millions acres of recreation lands to hike, camp, dive, rock climb, go boating, ride horses, canoe, snowshoe and many more activities. Nature in Clallam County draws tourists from around the world, as well as retirees, artists and others who come to call the region their home.

Nearshore ecosystems provide a particularly valuable suite of ecosystem services. The County's 254 miles of marine shoreline ranges almost the entire length of the Strait of Juan de Fuca to Discovery Bay and the North Pacific Coast. Marine waters off the coast are abundant in fish and invertebrates that support commercial and recreational fishing industries, and provide habitat to marine mammals and birds that draw wildlife watching enthusiasts, beachcombers, kayakers and scuba divers. Eelgrass, for example, provides bank stabilization, water purification, food provisioning, habitat for fish and Dungeness crab, and nursery areas for juvenile crab and fish species.

Coastline ecosystems are extremely vulnerable to the impacts of increasing development and climate change, such as sea level rise, and ocean acidification. Clallam County is currently faced with increased bluff erosion and a fragmented shoreline, threatening key ecosystems that support economic activity.

When ecosystem services are lost, communities pay. Poorly placed development on top of bluffs and in close proximity to the waterfront can increase the likelihood of costly and life-threatening landslides. Land clearing and grading changes the natural drainage patterns and increases water run-off from these affected bluffs. Subsequent actions taken to stabilize bluffs through the construction of bulkheads and seawalls hinder sediment transport, reduce habitat and intensify the erosion process on nearby beaches and adjacent shorelines/bluffs.

When natural storm protection, salmon productivity, surface water conveyance or drinking water services are lost, communities are taxed to fund the storm water systems, levees, hatcheries and filtration plants that must be built. Real costs are incurred to replace services that were previously free and, unfortunately, these replacement services are often less efficient than the natural services they replace.

In order to understand the real economic costs of damaged natural systems in decision and policy-making, it is increasingly common to consider ecosystems as economic assets. Although it is impossible to capture the full intrinsic value of ecosystems purely in dollar terms, dollar values for ecosystem services can replace the default value of $0.00 in common decision-making frameworks such as Benefit-Cost Analysis and policy frameworks such as Shoreline Master Program planning.

Key Findings

The ecosystem services present in all of Clallam County include water regulation, water supply, air quality and climate stability, food, raw materials, medicines, soil retention, soil formation, control of pests and diseases, waste treatment, habitat and nursery, pollination, recreation and tourism, and cultural, scientific and educational values.

Two types of natural capital valuation were deployed to assess the economic value of Clallam's natural systems. First, using biophysical data, the economic value of nearshore processes, including sediment provided by feeder bluffs to beaches downstream, was calculated. This 'primary' valuation of Clallam nearshore ecosystems is the first of its kind. Next, a full natural capital appraisal of all ecosystem services found across all Clallam County's land cover types was calculated.

Nearshore Valuation

Carbon storage and sequestration, creation of habitat, and forage fish supportive value of Clallam's nearshore ecosystems contribute more than $15 million annually to the local and regional economies. Commercial and recreational fishing provide $20 million annually. Services provided by feeder bluff ecosystems contribute between $99,000 and $506,000 every year within the Dungeness and Elwha drift cells. The large range in economic values for nearshore ecosystems reflects the health of the shoreline and the presence or absence of shoreline armoring.

Annual Flow of Value

Ecosystems provide a flow of value into the future. The most conservative estimate of the flow of value to the local and regional economy from Clallam County's combined ecosystem services is $18 billion every year. When we consider all ecosystem services on a national scale and assume the ecosystems are in very good functional health, the flow of value from Clallam's ecosystems can be as much as $52 billion per year.

Stock or Asset Value

Natural capital can also be given an asset value, similar to built infrastructure that captures its value over time. Applying a 4% discount rate over 100 years, the asset value of Clallam County's natural capital is between $451 billion to $1.2 trillion dollars depending on the health of the ecosystem.

Informing Decision-Making

Investing in the conservation of working and natural landscapes can diminish the risk posed by future erosion and climate instability, avoiding expensive mitigation expenses for cities, the county and ultimately tax payers. Economic valuation can inform policy development and implementation, such as Shoreline Master Planning. The ecosystem service values provided in this study are defensible and applicable to decision-making at every jurisdictional level.

Recent heavy storm surges such as those experienced along the eastern seaboard in September 2012, and the threat of climate change, have focused attention on the delicate state of the shoreline in Washington. Because bluff erosion is a natural and dominant feature along exposed shorelines, landowners are concerned not only about environmental degradation due to increased development but also about the safety and value of their homes along the coast. Many property owners have lost acres of land due to natural erosion and struggle with very expensive installation and maintenance costs of the very bulkheads and seawalls that are increasing erosion of their neighbor's bluffs. Analysis of the Port Angeles landfill site showed the armored section of bluff (seawall) provides up to $5.94 per foot in economic benefits, compared to unarmored sections, which provide $18.90 per foot, over three times the value.

With the Shoreline Master Plan (SMP) update due for completion in 2014, private property landowners, local governments, non-profit organizations and community members have actively engaged in discussions about the merits and means of protecting the nearshore environment. This analysis contributes vital information to better understand the economic context of project planning and decision-making, No Net Loss policy, buffer setbacks and other requirements, particular to shoreline ecosystems and critical areas throughout the county. Clallam County is seizing the opportunity of the SMP update to work with landowners and community members to increase protection of crucial nearshore areas that protect property, save lives and contribute tangibly to the local economy.

Recommendations

Discovering and measuring the value of natural capital in Clallam County is essential to enhancing effective and efficient natural resource management. Valuation of natural benefits leads to their protection and provides measures to influence policy development and decision-making. However, valuation is only a first step in the process of developing policies, measures and indicators that support discussions about the tradeoffs in investments of public and private money that ultimately shape the regional economy for generations to come.

Natural assets are not indestructible and they are under pressure in Clallam County. Adopting the following recommendations will help ensure the flow of economic value of Clallam County's natural capital continues in perpetuity:

— **Perform ecosystem service valuation per designated shoreline reach.** Use this study to identify and value the services present in each reach to help prioritize decisions and efforts. Valuing each reach may also enable integration of ESV to SMP updates (for example designation of critical areas, augmentation of vegetated buffers and revision of regulatory policies).

— **Protect and restore natural capital.** Conservation is a low cost alternative to restoration of a damaged system. Conservation and sustainable management of Clallam County's natural and working landscapes as a key investment for the future economy.

— **Apply ecosystem service valuation results to support funding investment in natural assets.** The values provided in this study can be used to calculate the rate of return on conservation and restoration investment. These values should be reported to the community, to funders and stakeholders. With the Earth Economics' EVT (Ecosystem Valuation Toolkit), a web-based tool assessed at http://esvaluation.org, values in this report can be regularly updated Clallam ESV v1.5.docx as new data is made available.

— **Adopt an ecosystem services approach to rural economic development.** Include sustainable forestry, forest product development, agriculture, and access to quality outdoor recreation in all aspects of economic and infrastructure planning. Formally tie ecosystem services to long-term and sustainable jobs and track job metrics. Conservation, restoration, and landowner stewardship incentive projects can and should be effectively linked to economic advancement, sustainability and long-term job creation.

— **Review institutional options for planning and management of natural assets.** Facilitate discussions about institutional improvements and coordinate activities between agencies to promote investment in natural capital and landowner incentives. Ecosystem services can be a guide for improvement by setting a context wherein alternative goals, such as transportation planning, salmon restoration, natural flood control, storm water conveyance and water quality can be simultaneously improved, thus avoiding infrastructure conflict.

Introduction

Nearshore ecosystems in Washington State, including those of Clallam County, provide significant contributions to the local, regional and state economy by providing storm protection, erosion control, critical habitat for fisheries, water filtration, and raw materials.[1]

With coastline on both the Pacific Ocean and the Strait of San Juan de Fuca, nearshore ecosystems in Clallam County are truly unique, with countless bluffs, beaches, estuaries, intertidal areas, salt-water marshes and wetlands. The aesthetic beauty and incredible recreational diversity of the shoreline make Clallam County a natural treasure for residents and visitors. However, these coastlines are at risk. Due to both natural biological processes and land use development patterns, nearshore ecosystems are becoming increasingly fragile. Conserving the beauty and attributes the shoreline provides is not only a priority for residents but also a smart economic investment to ensure healthy sustainable economic growth and a continued high quality of life for Clallam's residents.

Western Washington State is defined by the Columbia River to the south, Strait of Juan de Fuca to the north, the Pacific Ocean to the west, Puget Sound and Mt. Rainier to the east and south. On the Olympic Peninsula, and more specifically Clallam County the natural landscapes along shorelines, and mountains provide a rich quality of life for county residents; benefits generated by diverse ecosystems serve as the foundation for the stable and growing Clallam County economy.

Figure 1. Map of Washington State in United States

Source: http://blog.kingsoutdoorworld.com/2012/11/01/125-top-trophy-counties-for-hunting-big-game/ (July, 2013)

Figure 2. Map of Clallam County in WA State

Source: Clallam County, Planning department (November, 2012)

Recently, private property landowners, local governments, non-profit organizations and community members have actively expressed interest in protecting the nearshore environment. Storm surges such as those experienced along the eastern seaboard in September 2012, and the threat of climate change have focused attention on the delicate state of the shoreline in Washington.[2] Landowners are concerned not only about environmental degradation due to increased development but also about the safety and value of their homes on the coast. Bluff erosion is a natural and dominant feature along exposed shorelines such as the bluffs found in Clallam County; many property owners have lost acres of land due to natural erosion. With the Shoreline Master Program update due for completion in 2014, Clallam County has the rare opportunity to increase protection of crucial nearshore areas and ensure a high quality of life for Clallam County residents and visitors for decades to come.

Cape Alava

During the completion of this study an important ecological event took place in Clallam County: the removal of two large dams along the Elwha River resulting in a colossal amount of sediment being released into the Strait of Juan the Fuca on a daily basis through the mouth of the Elwha. The Elwha nearshore has been documented to be severely degraded due to long standing sediment starvation because of shoreline armoring (prior to alteration more than 85% of sediment in the littoral system came from the Elwha feeder bluffs). Sediment delivery is a large, but temporary, restoration event. Since sediment is directly related to shoreline health and stability, it is worth mentioning the unique ecological attributes of sediment deposits. This will be further discussed and related to economic benefits throughout this report.

Cape Alava at sunset

Eroded Bluff on Clallam County Coastline

Elwha Dam Removal, 2012

Report Overview

- **Part I: An introduction to Clallam County's geography, history, demographics, socio-economics, natural resource management and regional biodiversity.** This section provides an in-depth introduction to key ecological aspects of the report. The nearshore ecosystems and important physical processes are defined. The ecology of sediment transport and natural deposition along the shoreline is described with local examples of the Elwha and Dungeness drift cells. This section also highlights the biodiversity of the nearshore, where crucial ecosystems come into play such as beaches and bluffs, eelgrass and kelp beds and other important marine vegetation. The Elwha River and the removal of the dams is also an essential topic in this section; a brief history of the area is provided, followed by a discussion of the impacts before and after the dams were removed.

- **Part II: Ecosystem Services in Clallam County.** This section provides the economic foundation by explaining ecological economic principles. An identification and description of each of the 23 ecosystem services found in Clallam County is provided, along with detailed methodology for those services that were identified and valued with original calculations.

- **Part III: Valuation of Clallam County.** This section provides an overview of the methodology utilized to quantify economic value and the results of both of two economic valuations performed:

  A 'primary' valuation of feeder bluff ecosystems. Using biophysical data, the economic value of sediment provided by coastal cliffs to beaches down current was calculated. The term feeder bluff is applied particularly to headlands and bluffs of the Puget Sound and the Strait of Juan de Fuca. However, feeder bluffs are found up and down the Pacific coastline. This economic valuation of feeder bluff ecosystems is the first of its kind.

  A 'benefit transfer' economic valuation of ecosystem services found across all Clallam County's landcovers. Benefit transfer method utilizes a secondary valuation method where a range of values is calculated similar to an appraisal for each ecosystem service identified.

- **Part IV: Applying Valuation Findings to Policy and Investment Decisions.** It is possible to integrate economic valuation into the Shoreline Master Program (SMP) and No Net Loss (NNL) policy. This section provides a summary of what these policies are and how economic valuation can inform, enhance or improve the SMP in Clallam County.

- **Part V: Conclusions.** This section highlights study findings and report conclusions.

About this Report

This study provides the first comprehensive economic assessment of Clallam County's natural landscapes. The study has been designed to inform the diversity of interested parties involved in land use policy and conservation investment.

The results of this study can be used to inform the county's SMP update and will enable stakeholders to better understand the economic importance of land use policies such as No Net Loss (NNL), setbacks, and other requirements along the shoreline and within other critical areas throughout Clallam County.

Important Note: The science of ecosystem service valuation is rapidly improving. While this report provides the very latest data at the time of publishing, new biophysical and socio-economic data is being made available all the time. For the very latest ecosystem service values, please visit http://esvaluation.org.

By understanding the important role of ecosystems and demonstrating the economic value in conserving them, planners and community leaders are able to integrate complex ecological issues into the public dialog and make more informed decisions.

Table 1. Dollar Values of ES produced per year by riparian buffer and intertidal area in Port Angeles landfill site.

Land-cover Description	Acres	$Low/acre	$High/acre	Low total	High total
Riparian Buffer	84.3	$2,500	$5,049	$210,726	$425,602
Intertidal	20.8	$1,572	$30,100	$32,691	$626,079

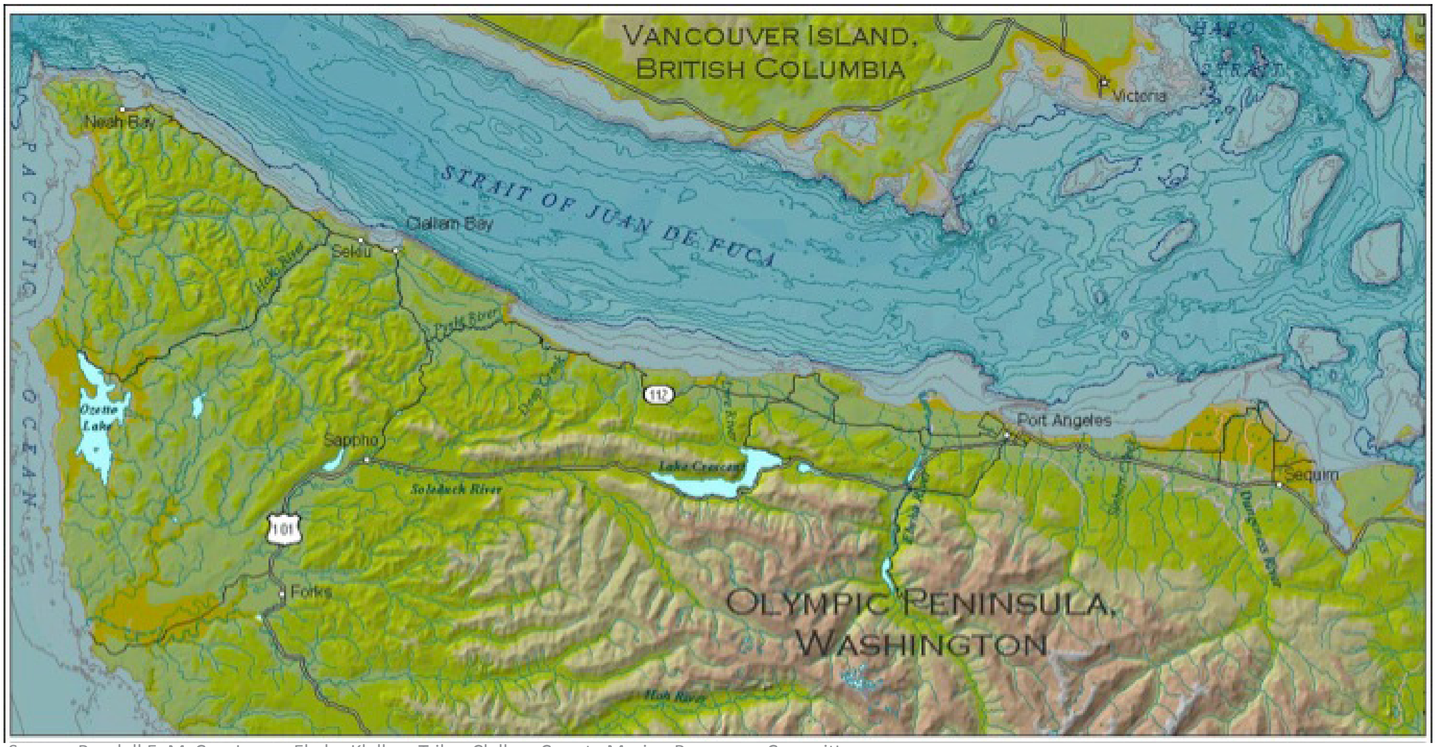
Part I. Clallam County

Geography

Clallam County is located on the Olympic Peninsula, bordered by the Strait of Juan de Fuca to the north and the Pacific Ocean on the west. It is south of the San Juan Islands and its tip at Cape Flattery is the most northwest corner of the contiguous United States.

The county's 254 miles of marine shoreline ranges almost the entire length of the Strait of Juan de Fuca to Discovery Bay and the North Pacific Coast. With a population of approximately 71,000 residents, Clallam County is predominantly rural. Its western border is marked by the Olympic Coast National Marine Sanctuary and the Olympic National Park to the south.[3] Of the 2,670 square miles in Clallam County, 1,739 square miles is land while 931 square miles is considered shorelines of the state.[4]

Figure 3. Map of Clallam County (Cities and Rivers)



Source: Randall E. McCoy, Lower Elwha Klallam Tribe, Clallam County Marine Resources Committee

Within Clallam County the Strait of Juan de Fuca shoreline is comprised of bluff beaches, barrier beaches (also known as spits), rocky platforms, stream deltas, inlets and embankments associated with protected lagoons and salt marshes. These shoreline features are constantly changing and fluctuating in response to geographic and oceanographic natural processes such as sediment erosion, deposition and landslides.[5]


Cape Flattery-Neah Bay Clallam County

History

Clallam County takes its name from the Klallam or S'Klallam ("strong people"), the indigenous tribe who occupied the largest portion of what today is inland Clallam County.[6] The Makah and the Quileute people occupied the coastal areas on the most north and western portions of the county. The Lower Elwha Klallam Tribe lived along the Elwha River and Ediz Hook in Port Angeles, with the Jamestown S'Klallam Tribe occupying nearshore areas in the eastern area of the county known as Dungeness.[7]

Clallam County, one of the first regions of Washington State to be explored by Europeans in 1778, quickly became a prime resource for the fur trade.[8] Despite its early European exploration and rich natural marine and forest resources, the region became a strong economic force in the early 1900's when the Elwha River dam introduced hydroelectric power. The result was an explosion of the lumber industry, which maintained its position as the primary employer in the region for the following 25 years. In Clallam County, World War I demanded spruce resources, which were vital to building the first airplanes. Around 1920, as spruce timber demand developed, pulp production took off in Port Angeles, fulfilling the growing market for the newsprint industry and the other uses of cellulose products.[9] While a railroad was completed


Dungeness drift cell: Dungeness Spit and Shoreline

in 1915, transport remained dominated by water travel until the opening of the Olympic Loop Highway in 1931, now known as Highway 101, allowing the first convenient automobile access to the region.[10]

While the timber and agriculture industries continued to grow after World War II, income created by the fishing industry also became significant. Commercial and sport fishing activities generated revenue for the local economy to today although declines of fish populations due largely to inadequate planning and regulation of both fisheries management and land development, affect this revenue.

Declines in fish population forced the State government to take a deeper look into commercial fishing practices and rights. The Boldt decision, in 1974, addressed this issue by granting tribes 50% of annual catch.[11] Not all tribes in the region were recognized as treaty tribes, and the Boldt decision gave fishing rights only to tribes recognized under the treaty.[12]

Seven federally listed tribes include portions of Clallam County as part of their Usual and Accustomed area; these are Point No Point/Port Gamble S'Klallam, Jamestown S'Klallam, Lower Elwha Klallam, Makah, Quileute, Hoh, and Quinault. They all contribute significantly to the community, economy and ecological fabric of the county.

By the 1980s, logging activities had declined as the main source of income, although still remain a vital force in the economy. The decline of logging allowed other industries such as agriculture and the growing service industry to emerge as strong components of Clallam County's economy.[13]

Jamestown S'Klallam Tribe: Tribal Center

Today's Economy in Clallam County

Recently, Clallam County has become a destination for retirees. As of 2010, the 65 or older population claimed the highest age group percentage.[14] The county's natural setting provides magnificent views of sparsely populated countryside and many community engagement activities. Sequim is popular due to its mild climate. The deep-water port in Port Angeles contributes to the regional economy by supporting the service and tourism industries.[15]

Currently, Clallam County has a number of restoration and infrastructure projects underway, which employ residents and stimulate the county's economy. One of these projects is the Elwha River dam removal. Both the removal of the Glines Canyon and Elwha dams began in 2011. This project has attracted many researchers to the area and enabled other environmentally related projects to add to the area's tourist attractions. The Elwha River will soon flow freely for the first time in 100 years, benefiting surrounding ecosystems and the local salmon runs.[16]

Lavender Fields- Sequim, Clallam County


Dungeness Spit-Recreation Area

Dungeness Crab and Seafood Festival

Tourism

Clallam County has a multitude of stunning landscapes and provides year-round outdoor recreation opportunities for both tourists and locals. The coastline of the Strait of Juan de Fuca and the Pacific Ocean offers a variety of activities for visitors, ranging from clam digging to kayaking, sailing and whale watching. In 2010, the National Park Service estimated that visitors to the Olympic National Park spent $103 million. This value was determined through estimates on how much visitors spend when they visit the park. The result - an average of $92 per day (excluding park fees) is spent by day and overnight visitors.[17] Olympic National Forest, Olympic National Park and the Dungeness Recreation Area provide millions acres of recreation lands to hike, camp, scuba dive, rock climb, go boating, ride horses, canoe, go beachcombing, view wildlife, snowshoe and many more activities.[18]

The Clallam County Parks, Fair and Facilities Department and other organizations host outdoor festivals during the summer months that draw visitors by the thousands. Some of the most popular festivals are Clallam County Fair, Dungeness Crab and Seafood Festival, Blues Festival, Rodeos, rallies, and more.[19] The city of Forks was the setting for the popular vampire Twilight saga, and has since become a vacation destination for fans. Visitors also enjoy exploring historical sites and the rich cultural heritage of the region.

Due to its unique geographical location and 200-mile marine coastline, the maritime and fishing industries are important players in Clallam County's economy.[20] Despite lagging demand for wood and food, forestry and agriculture remains a significant industry.[21]

Service-Sector

The service sector has experienced growth in recent decades. In 2010, educational services provided the highest employment. Health care and social assistance employ 21.6% of the work force, followed by retail trade at 12.2%. The public administration sector was ranked at 4th place with respect to local employment. Other leading employers in the county are currently government and service industries, partly due to the growing leisure and tourism activities. The county also houses two prisons, a hospital and a school district, which are all major employers.[22]

Academic institutions and non-profits in Clallam County contribute to the education of residents and visiting students. Local citizens founded Peninsula College in 1961, which provides local educational opportunities. Today the college enrolls 6,000 part and fulltime students.[23] Clallam County is also home to the Pacific Northwest National Laboratory (PNNL), one of the first institutions to develop processes that turn agriculture wastes into methane fuel. Currently PNNL has about 4,700 employees and its business revenue is more than $1.1 billion. The Marine Sciences Laboratory is located in Sequim, is working on technologies that include arsenic speciation, mercury analysis, sulfide analysis, radiochemistry, chemical repository and mycoremediation.[24]

Natural Resources Management

Efforts to protect and restore waterways and lands within Clallam County's borders are often lead by a countywide consortium of groups including representatives from local cities, the county, Tribes, concerned citizens and non-profit organizations. These groups are working on an array of land conservation and management issues including watershed planning, salmon recovery, groundwater management and water quality, natural resource planning and monitoring, shoreline management, critical area designation, forest practice regulation and land use planning.[25]

There are many organizations, agencies, coalitions, and non-profits that participate in land and shoreline management in Clallam County. Many of the Tribes in this county are also active in the protection of the shoreline and land management. State agencies such as the departments of Fish and Wildlife, Natural Resources and Ecology have ongoing research throughout the county and its shoreline, as do local city and county governments.

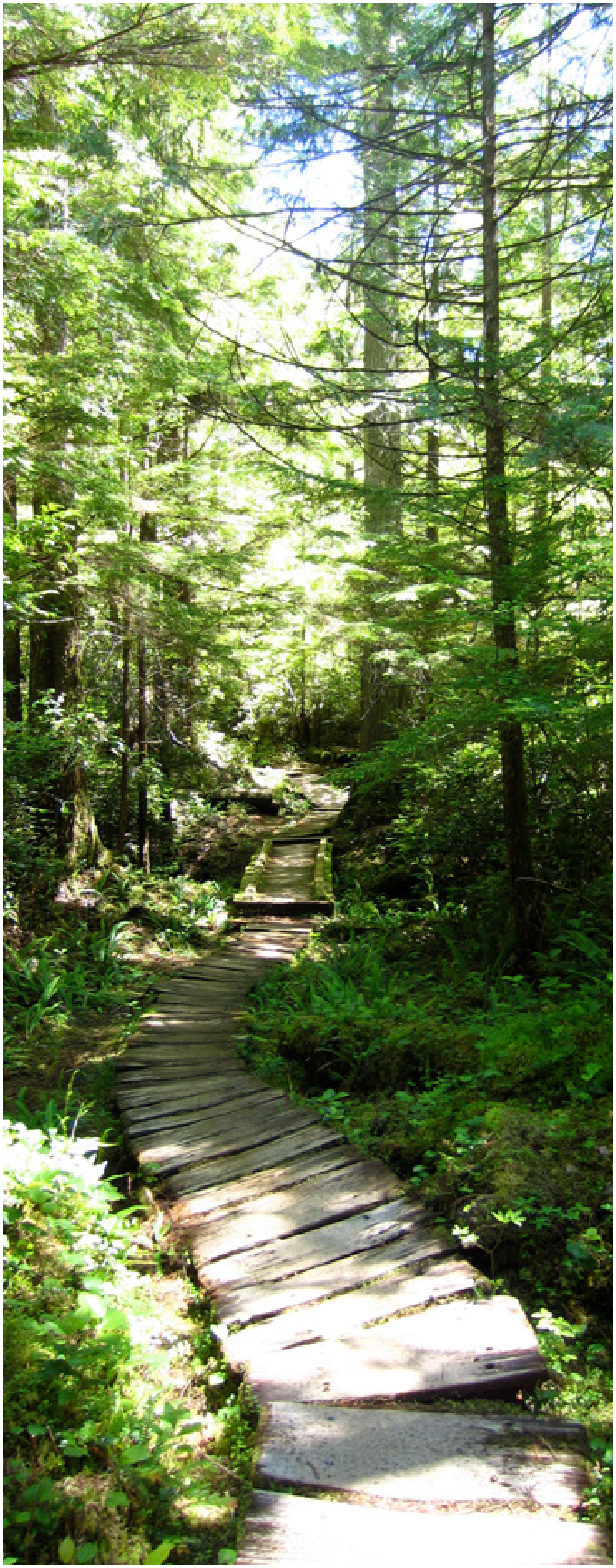
Research Group Monitoring

Biodiversity

The county borders a large portion of the Olympic National Park, the Strait of Juan de Fuca; it also includes the Elwha, Dungeness, and Sol Duc watersheds, all internationally recognized areas due to their rare geological and climatic conditions, which results in immense biodiversity.[26] The landscape of wetlands, estuaries, forests (including old growth), agricultural lands, numerous rivers, lakes and streams and a magnificently unique shoreline support unparalleled biodiversity of plants, mammals, birds, reptiles, fish, invertebrates and micro biota.[27]

Thirty-eight years after being added to the U.S. National Park System, Olympic National Park was accepted as a United Nations Educational, Scientific and Cultural Organization Biosphere Reserve in June 1976 in recognition of its biological importance to the world. Established as a World Heritage site in 1981 added to its recognition of global importance, specifically for its 'outstanding and significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals.[28]

The Olympic National Park contains several species of giant conifers, including Douglas fir, western red cedar, western hemlock and sitka spruce. The Olympics also has many glacier-clad peaks, alpine meadows, and extensive old growth forests.[29,30] The Olympic range is one of the best examples of a protected temperate rainforest in the Pacific Northwest.[31] The many river systems that begin along the snowcapped Olympic peaks provide ideal habitat for salmon. About 100 km of the Park includes the Pacific Coast, creating the longest undeveloped coast in the United States.



Ozette Triangle Trail

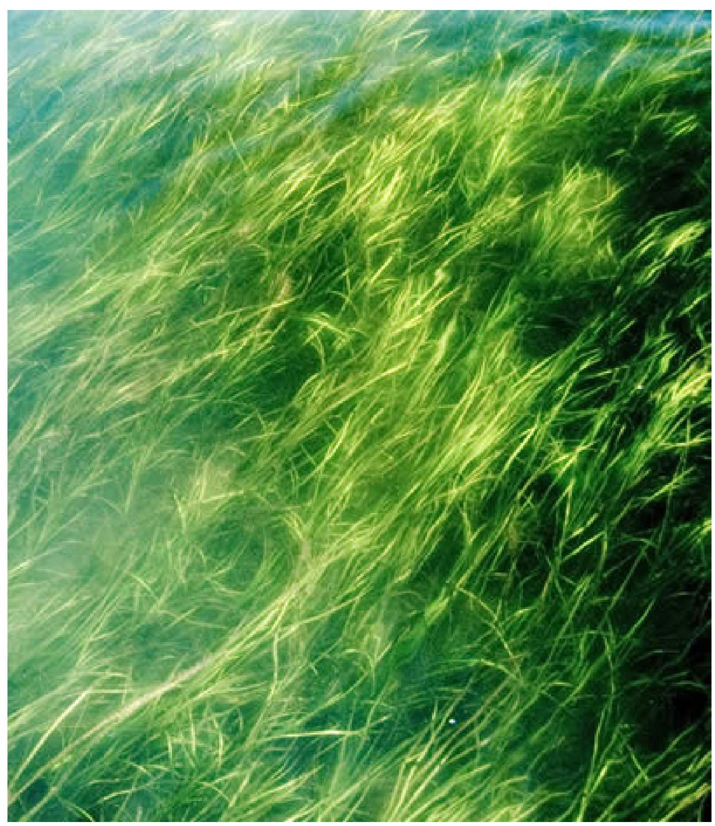
Olympic National Park- Sandy Point Beach

Coastal Abundance

The county's miles of shoreline support a complex and rich marine ecosystem. The Strait of Juan de Fuca is approximately 102 miles in length and 10-18 miles wide. It is the access route to the Pacific Ocean from the Puget Sound and the Strait of Georgia and serves as an international boundary between the US and Canada.[32] The Strait of Juan de Fuca also links Pacific coastal waters with the marine and estuarine waters of interior western Washington and Canada. The Strait supports approximately 100 shoreline kilometers of vegetated habitat.[33] This area serves as the migratory path for a multitude of bird species, fish and marine mammals.

Overstory and understory kelp forests and eelgrass beds are the dominant aquatic species along the Clallam County nearshore that support for diverse nearshore ecosystem. At least five of the fish species are federally listed as threatened —including Chinook, Hood Canal Summer Chum, Lake Ozette Sockeye salmon, Winter Steelhead, and Bull trout— due largely to the decline of their natural habitat. The forage fish species, eulachon, is also listed. Vegetation within the nearshore zone is crucial habitat for both migrating and resident species.[34]

Freshwater Bay



Eelgrass beds

Salmon and Trout

The numerous rivers and streams found throughout Clallam County —Bogachiel, Dungeness, Elwha, Pysht, Lyre, Jimmycomelately, Morse, Sol Duc and Salt Creek, to name a few— have historically allowed for some of the most productive Pacific salmon runs in the world. Chinook, coho, chum, sockeye, and pink salmon, cutthroat, bull trout, and steelhead are dependent on the region.[35] There are numerous reports of historical runs of 100-pound salmon returning to the Elwha River prior to the construction of the dams at the turn of the century.[36]

Salmon and Trout, and the forage fish on which they depend, are culturally and economically significant to the community, particularly to the Tribes in the area. They are also an important food source, sought for commercial, recreational, and subsistence harvest. In addition, sport fishers support the local economy when they come to Clallam County for the salmon runs.

The Strait of Juan de Fuca nearshore zone provides a major migration corridor for Puget Sound salmon, as well as salmon from the Klamath and Columbia River regions. Nearby pocket estuaries and salt marshes are important breeding, rearing and feeding areas for juvenile salmon as they gain strength and size before their journey out to sea.[37]

Salmon stocks have significantly declined in the region, in large part due land and marine management practices including overharvest, legacy impacts from logging, water quality impacts from septic and storm water runoff, diking, damming and the installation of bulkheads and rock walls on the coastline. Several local stocks of salmon and trout are federally recognized as threatened and or endangered, including, steelhead, chum, sockeye, bull trout and Chinook.[38]

Forage Fish

Numerous forage fish use Clallam County shorelines for spawning, feeding, and migration. Juvenile and adult herring transit the shoreline, and historically have spawned on eelgrass along Dungeness, Discovery, and Sequim Bays. Surf smelt and sand lance both migrate along Clallam County shorelines, and adults spawn along many of the beaches. Eulachon, an important forage fish species for coastal tribes that are federally listed, have been documented in the Elwha River.

Makah-Eagle and salmon print

Clallam's Nearshore

The nearshore zone ranges from the riparian forested land throughout the photic zone where sunlight allows the growth of marine vegetation. It is commonly described as “the area of tidal influence” in lower rivers and extends offshore to a depth of 30 m MLLW (Mean Lower Low Water). This zone could be further categorized into the intertidal zone and subtidal zone, which are normally defined by differences in wave characteristics.[39,40] Figure 4 demonstrates the area defined as the nearshore.

From the dynamic nearshore interactions between the land and the water rise various types of landforms. In Puget Sound, several major geomorphic forms are identified, including rocky shores, beaches, deltas, estuaries and lagoons.[41,42] They are all outcomes of coastal physical processes that have occurred for thousands of years. Clallam County's shoreline, specifically the northern part of Washington State on the west coast to the middle of Discovery Bay has a length of approximately 254 miles. This section is under continuous seasonal impacts originating in the Pacific Ocean continuing along the Strait of Juan de Fuca.[43,44]

Figure 4. Nearshore diagram

Source: http://www.kingcounty.gov/environment/watersheds/central-puget-sound/nearshore-environments/eroding-bluff.aspx (Retrieved July, 2013)

Economic Benefits of Nearshore Ecosystems

Natural systems can be valued as economic assets, providing valuable goods and services (see Part III). Like built systems, including roads, buildings and farms, natural systems (ecosystems) provide essential goods and services for economic development and financial security at local, regional and national levels.

Nearshore ecosystems provide a particularly valuable suite of ecosystem services. Different types of nearshore ecosystems support a variety of natural infrastructure and processes. Eelgrass, for example, provides bank stabilization, water purification, food provisioning, habitat for fish and Dungeness crab, and nursery areas for juvenile crab and fish species. Salt marshes, herbaceous wetlands, forested wetlands, coniferous forests, and deciduous forests contain different infrastructures and maintain diverse ecosystem functions, producing varied goods and services that are critical to the regional and national economy. Part II of this report provides explicit examples of each of the services outlined in Table 2.

Table 2. Nearshore Ecosystem Services that Support the Clallam County Economy

1.	Water regulation
2.	Water supply
3.	Climate stability
4.	Air quality
5.	Food production
6.	Soil retention
7.	Soil formation
8.	Waste treatment
9.	Habitat and nursery
10.	Aesthetic information
11.	Recreation and tourism
12.	Scientific and educational values
13.	Cultural and artistic inspiration

Sandy Point beach-Clallam County

Fishing dock-Quileute Nation

Feeder bluff on the Clallam County Coast

Feeder Bluffs-a critical component to drift cells and Clallam County shorelines

Much of Clallam County's shoreline is outlined by steep bluffs that range from fifty to several hundred feet high. These surfaces are composed of many layers of sand, silt, gravel and clay. As these bluffs naturally erode, they provide the building materials to *feed* beaches.

Feeder bluffs, also known as coastal bluffs, are the primary source of beach sediment along the shore, and their natural erosion is essential for nourishing and maintaining beaches and associated nearshore habitats. Critical feeder bluff habitats include coastal forests, spawning beaches for forage fish (i.e. surf smelt), eelgrass beds and salt marshes.[45] Beaches and associated habitats such as salt

Feeder bluff (aerial photo) and sediment from Elwha River marshes serve as the linkage between rivers and marine environments for migratory species such as salmon, and are important for surf smelt, herring and other forage fish. These beaches are home for most of the regions' shellfish, as well as for the feeding, roosting, and nesting grounds for numerous marine and shorebirds.

Coasts in Decline

Development on top of bluffs and in close proximity to the waterfront can increase the likelihood of landslides. Land clearing and grading changes the natural drainage patterns and increases water run-off from these affected bluffs. Subsequent actions taken to stabilize bluffs through the construction of bulkheads and seawalls hinder sediment transport, reduce habitat and intensify the erosion process on nearby beaches and adjacent shorelines/bluffs.

Whidbey Island Landslide, 2012

Historically, coastal bluffs provided approximately 85 percent of the sediment to the Elwha drift cell.[46] However, 68 percent of feeder bluffs within the Elwha drift cell are now armored with bulkheads. Ediz Hook, along the Strait of Juan de Fuca side is almost all armored.[47] This has caused a significant loss in sediment transfer for nearby beaches and spits. This process, known as sediment starvation, results in smaller beaches and estuaries, less habitat for fish and birds and a greater risk of storm surge damage for shoreline residents.

According to Restore America's Estuaries, a national nonprofit dedicated to working to preserve the nation's estuaries, coastal and estuarine habitat has been declining for decades with national losses of nearly 60,000 acres each year from 1998 to 2004.[48] These coastal habitat losses impact local and regional economies, impede commercial fishing, tourism and recreation, and disrupt key green ecosystem services including water and waste treatment.

Extensive shoreline modification in Clallam County

Physical Processes Defined

To understand the diverse landforms that constitute Clallam County's shoreline, it is necessary to have a basic grasp of the various physical processes that create such forms. The following explanations focus on long-term and short-term coastal processes that are relevant to nearshore landforms, and also their implications for sediment transportation.

Long-term

— **Sea Level.** Sea level changes could result in erosion of the shoreline. There are global and local causes of a relative sea level change. On a global scale, the sea level has been rising due to an increasing amount of water in the oceans caused by the melting of the glaciers. Locally, sea level changes occur because of land movement and consolidation, the molecular expansion of warming water and subsidence due to groundwater pumping.[49]

— **Beach Profile.** Beach profile can be defined as the vertical cross-section of water depth and land elevation.[50] Since there are close correlations between beach profile and sediment, wave, and tide characteristics, a specific equilibrium beach profile reflects specific sediment, wave, and tide types that are present.[51] Understanding this relationship helps explain current shoreline geomorphology and also aids the prediction of future changes.

Short-term

— **Waves.** In general, waves are generated by the wind blowing across the ocean surface. It is an important force for sediment transportation because waves carry energy. However, waves in the open ocean only create circular motions, which does not contribute to horizontal movement of sediment. Within the coastal zone, an area where the water is shallower, other forces exist. In simple terms, waves do not always approach the shoreline in a parallel way, and usually the energy is concentrated at the headlands rather than at the bays.[52] Due to changes in wave behavior, transportation and deposition of sediment occur only in certain areas along the Clallam County coastline.

— **Tides.** The gravitational forces of the moon and the sun drive tides. Tidal currents play an important role in driving sediment transportation particularly in the Strait of Juan de Fuca and in areas with large tidal ranges.[53]

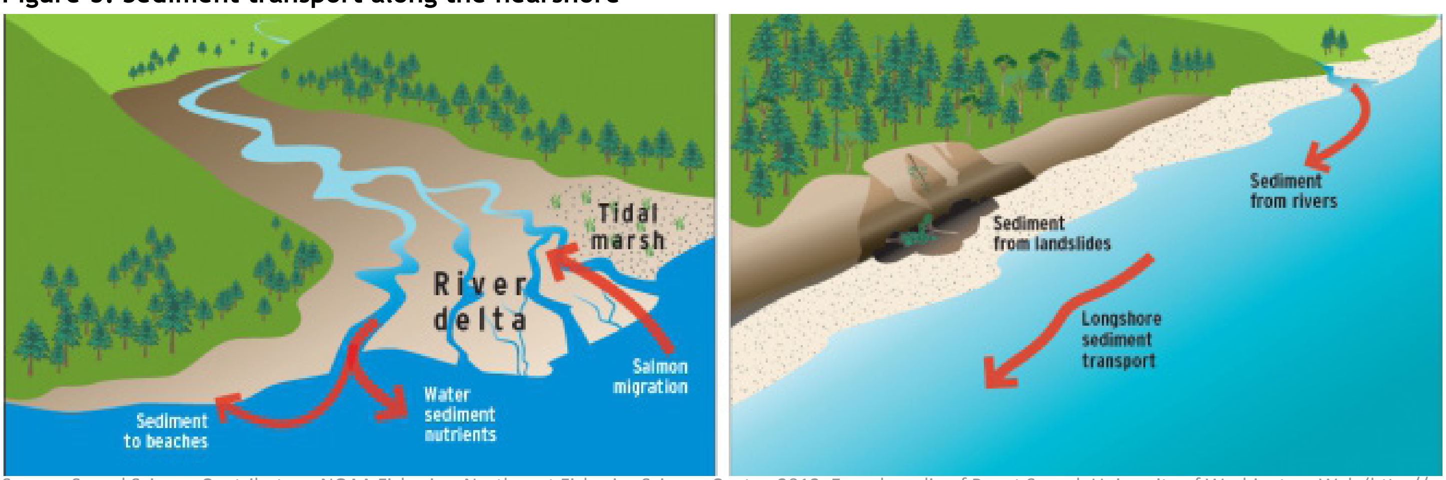
— **Currents.** Currents describe the motion of water. They respond to the rise and the fall of tides. They are also driven by wind and thermohaline circulation, which is the result of density differences in water determined by temperature and salinity.[54] The following sections discuss how the motion of water has impacts on sediment transportation and its consequences on nearshore landforms.

Sediment Transport. Previous sections focused on physical processes that dominate the nearshore zone. Some key outcomes of these dynamic processes are erosion, deposition, and transportation. Following are several key phenomena that are ubiquitous on Clallam County's shoreline.

— **Sediment Transport.** Coastal sediment transport is categorized as littoral transport and cross-shore transport depending on whether the transport occurs parallel or perpendicular to the shoreline. Drift cells, which are made up of three components, define these: a sediment source, a sediment transit zone, and a sediment deposition zone.[55] Within a drift cell, the different types of transport are due to dynamic physical processes happening in the nearshore zone. However, sediment transport is a complex process to understand because its driving forces are diverse and intertwined. In general terms, the magnitude of longshore transport is determined by wave height, particle grain size, and wave incidence angle whereas cross-shore transport is more complex because the net effect is determined by onshore and offshore transports that are caused by various kinds of waves and currents.[56]

— **Shoreline Modification.** Currently feeder bluffs are under intense development pressure due to the ocean views they provide and their abundant presence relative to other shoreline geological structures. Property owners in Puget Sound take expensive measures along their shorelines in order to slow bluff erosion and landslides. One erosion protection technique consists of armoring the shoreline, which blocks the vital connection between beaches and their sediment supply. As shore modifications (bulkheads, armoring and seawalls) block the flow of sediments, the highly valuable shoreline habitat can disappear due to a lack of sediment supply and armoring structures then increase erosion. Subsequently, tidal beaches experience a decrease in spawning habitat, sea grasses, and other key ecological attributes. Currently the average drift cell in Puget Sound is close to 35% armored, fragmenting the shoreline and destroying nearshore ecosystems.[57]

Figure 5. Sediment transport along the nearshore



Source: Sound Science Contributors, NOAA Fisheries, Northwest Fisheries Science Center. 2012. Encyclopedia of Puget Sound. University of Washington. Web (http://www.eopugetsound.org/articles/shoreline-formation-puget-sound (Retrieved February 2013)

Bluff Erosion. Bluff erosion occurs naturally when sediments detach from the bluff due to wind or wave contact and extreme weather such as heavy precipitation or storm surge. Feeder bluff systems create nearshore environments that create specific habitats for several important species, and for this reason bluff erosion is a vital component of the nearshore ecosystem.

Bluff erosion in Clallam County

Comparison of the Elwha and Dungeness Drift Cells

Drift cells are sections of coastline that have a source that releases sediments, a zone of net directional sediment transport, and a sink where sediments accumulate.[58] The Elwha and Dungeness drift cells are located along the nearshore environment of the respective Elwha and Dungeness rivers.

The Elwha and Dungeness drift cells provide an excellent depiction of how bluff erosion and sediment transport play essential roles in maintaining nearshore environments and how they are being impacted by external factors. The Elwha drift cell provides a nearshore environment that is in the process of partial restoration. Adaptive and restoration management analysis of these drift cells can optimize sediment delivery restoration and achieve full ecosystem restoration of this important region. The Dungeness study area provides an opportunity to assess the ecosystem services that a fully functioning nearshore environment provides as well as the economic values that are derived from such ecosystems.

Figure 6. Elwha and Dungeness Drift Cells

Source: Washington State Department of Ecology, Coastal Monitoring & Analysis Program

Historically, feeder bluffs were estimated to contribute over 85% of sediment to the Elwha littoral system, while 15% originated from inland flows, such as rivers.

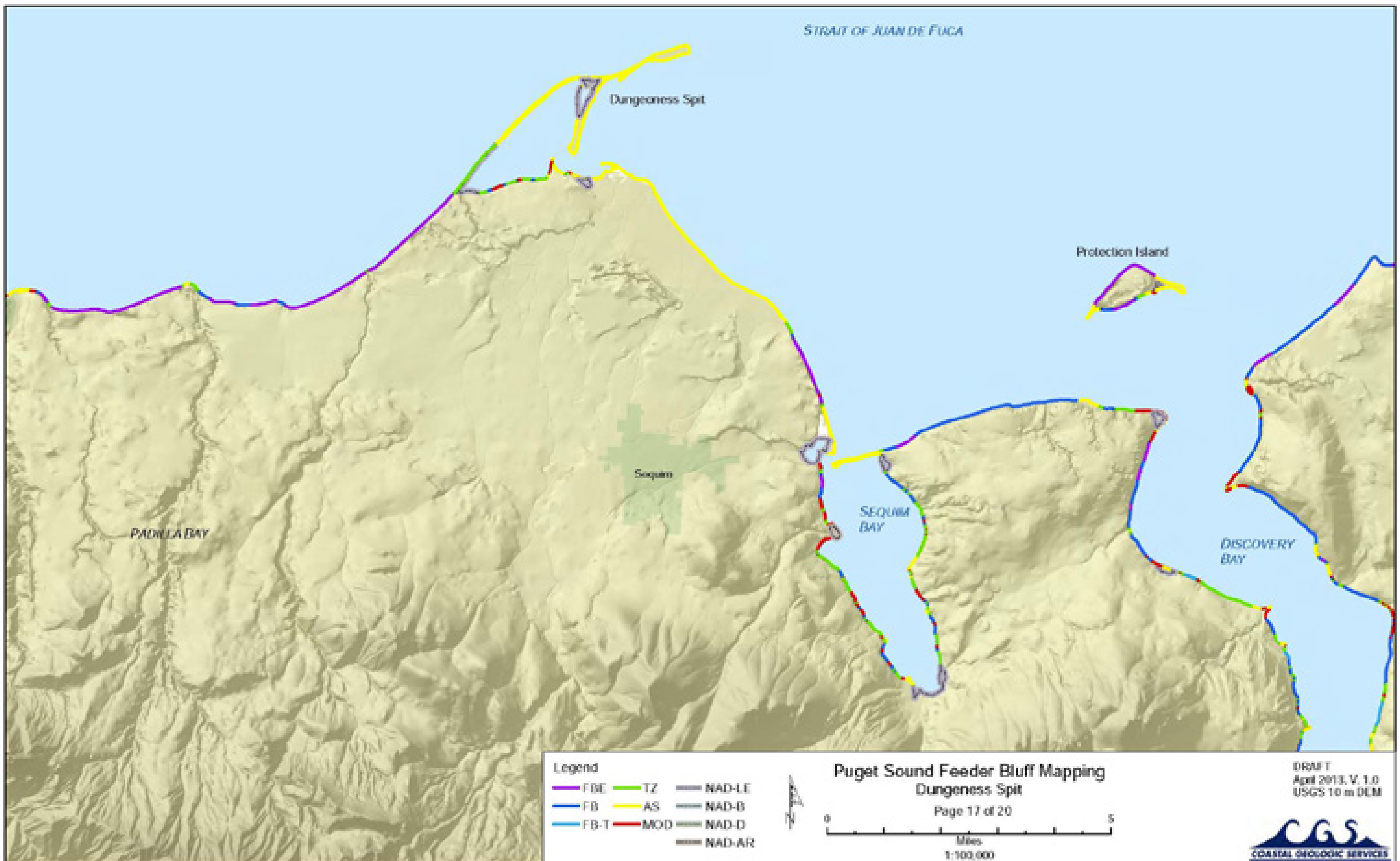
The Elwha Drift Cell

Historically, feeder bluffs were estimated to contribute over 85% of sediment to the Elwha littoral system, while 15% originated from inland flows, such as rivers. Since the Elwha River had two dams for over 100 years, minimal sediment was provided from this source to the shoreline. In addition to the dams, extensive shoreline armoring has significantly decreased the amount of sediment available to the drift cell. Both of these factors resulted in a significant reduction in sediment flow to the Elwha drift cell. Both dams have recently been removed, and according to the National Park Service, 13 million cubic meters of sediment from the river is anticipated to be delivered to the sediment-starved nearshore within five years of the completion of both removals.[59]

The Dungeness Drift Cell

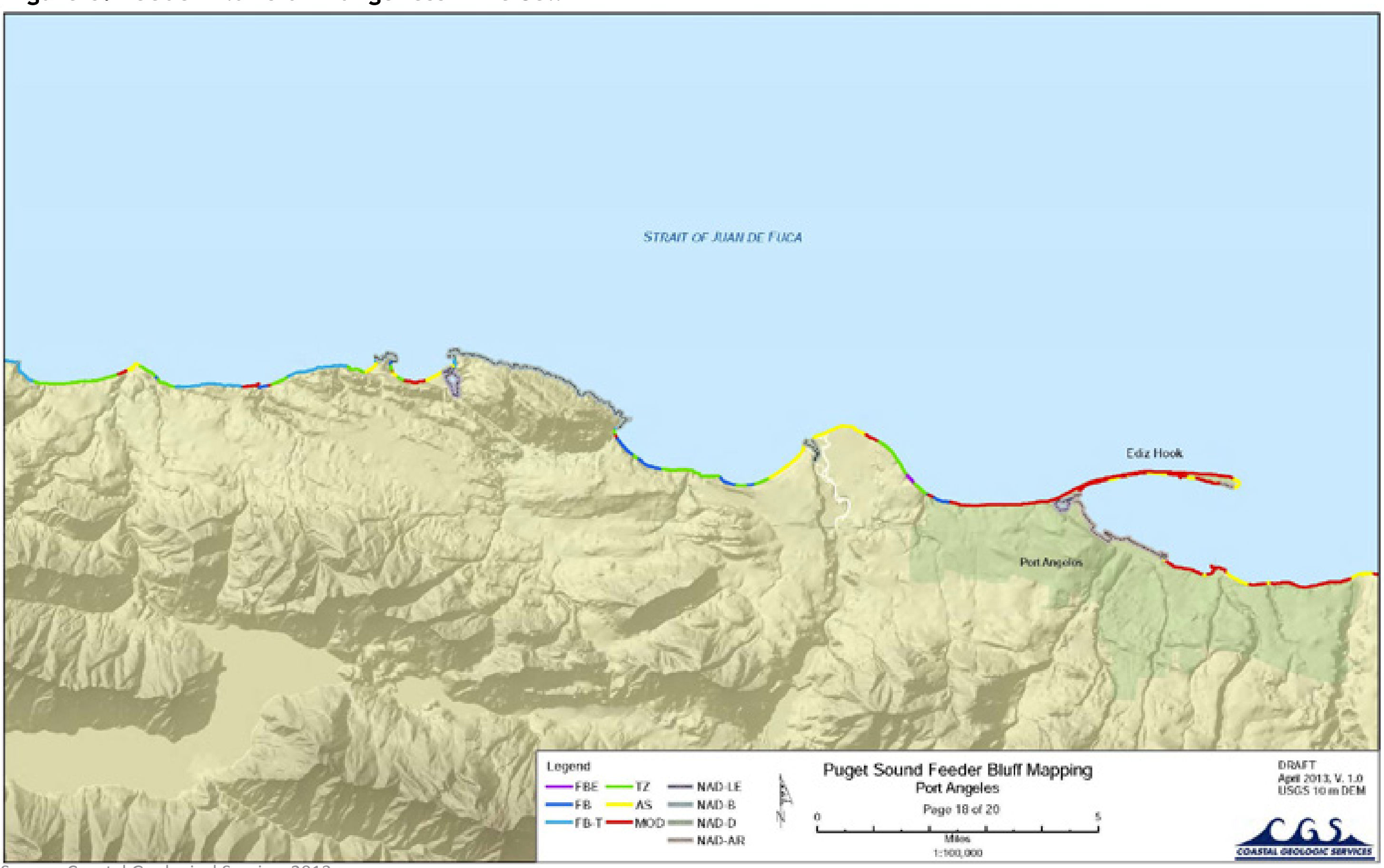
In contrast, the Dungeness drift cell has been a relatively fully functioning drift cell system in terms of the production of sediment from the bluffs supporting the nearshore shoreline and nearshore habitats. Dungeness Bay provides approximately 5,200 acres of critical spit and estuary habitat for a large variety of waterfowl, shorebirds, wading birds, marine and freshwater mammals, crustaceans, shellfish, forage fish, salmon and char. Dungeness Bay was created by the fragile 5-mile long Dungeness Spit, which is entirely the product of enormous sediment recruitment, originating primarily from the 8.8 mile-long drift cell to the west.

Figure 7. Feeder Bluffs on the Elwha Drift Cell



Source: Coastal Geological Service, 2013

Figure 8. Feeder Bluffs on Dungeness Drift Cell



Source: Coastal Geological Service, 2013

Nearshore Biodiversity

The nearshore region is rich in a wide variety of both terrestrial and aquatic plants and animals as a result of unique habitats created by the presence of land, fresh and salt water. The Strait of Juan de Fuca provides migration corridors for many species, including salmon, marine mammals, and migratory birds, which makes the nearshore ecosystem extremely vital in terms of biodiversity conservation. There are many *state-defined priority species* (species that are considered high priority for management and conservation) present in the Strait of Juan de Fuca.[60]

Several key habitat types are discussed in detail to demonstrate the importance of the nearshore zone in reference to its biodiversity.

Beaches and Bluffs

Bluffs are critical to the nearshore zone because they provide habitat for animal species such as forage fish, juvenile salmon, and shellfish. These areas are also home to eelgrass and kelp beds and marine riparian vegetation that provide extremely important habitats for other species.

Kelp and eelgrass beds

Kelp and eelgrass are dominant vegetated habitats along the Clallam County shoreline. Overstory and understory kelp beds are dominant (due in part to sediment starvation along the shoreline).[61,62] Eelgrass beds are also abundant globally.[63] Certain estuarine habitats, such as eelgrass, are threatened nearshore zones. For example, to a global scale, mangroves, sea grasses and salt marshes are endangered and disappearing quickly at rates 2 to 15 times faster than forests.[64]

Kelp and eelgrass are common marine plants in the nearshore zone. Kelp beds do not have roots that carry nutrients from the substrate to the plants; instead, they directly absorb nutrients from the water. This explains why they live in environments with high energy because continuous water movements can renew needed nutrients. Kelp plants utilize a root-like structure, also known as a 'holdfast', to anchor to hard substrate of the ocean. Brown kelp, which make up the majority of overstory and understory habitat, also require high ambient light levels to grow and are therefore confined to shallower areas of the nearshore zone.[65] Detached kelp also provides an important habitat offshore.[66]

Unlike kelp, eelgrass has fully functional root systems called rhizomes that allow them to grow in fine-grained substrates. Eelgrass is similar to kelp in that it also needs abundant sunlight in the summer to store nutrients, which are needed to survive the winter.[67] Eelgrass provides feeding grounds for waterfowl, gunnels, nudibranch, pipefish, marine mammals, and a number of other species. Live eelgrass helps control erosion, while dead blades provide detritus and nutrients for organisms at the bottom of the food chain. Macroalgae, diatoms, and copepods that would have flowed freely through the marine forest can attach themselves to the blades to be consumed by other organisms. By accounting for a significant part of the nearshore food web, they support local economies as well. The Port Townsend Marine Science Center states, "Fish and shellfish which depend on eelgrass for all or part of their life cycle account for a multimillion dollar industry in Washington."[68] Yet, dredging, docks, and other structures have destroyed eelgrass beds. Their conservation is vital to the ecology, landscape, and economy of the nearshore environment.

Chinook Salmon in the Elwha River after dam removal

Kelp beds in Clallam County

Marine riparian vegetation and large woody debris

Marine riparian vegetation, which is composed of a variety of plant species, such as Douglas-fir, Western hemlock, as well as understory including red huckleberry and trailing blackberry, serves as a connection between aquatic and terrestrial habitats. This unique community is critical to the nearshore zone because the vegetation provides abundant organic matter that feeds species high up in the food chain, as well as insects and marine invertebrates that are important food sources for other species. The vegetation also enables solid mass soil formation that is less vulnerable to erosion, and thus protects water quality by filtering or cycling nutrients and pollutants and reducing soil run off.[69]

The presence of large woody debris (LWD) is vital to the nearshore ecosystem habitat.[70] In the Pacific Northwest the placement of large logs on the beach create pools, provide shade and reduce gravel or sand movement, all three factors are essential for spawning habitat. Numerous fish species (salmon, forage fish) spawn in beaches that are rich with LWD. The presence of LWD can lead to increased populations of juvenile Coho during the summer and winter, and Steelhead and Cutthroat during winter.[71] Higher densities of juvenile fish species and creation of more spawning habitat also cause an increase in ecosystem health-an ecosystem able to sustain a strong economy.

Large Woody Debris, Clallam County

Nearshore Policy

On April 16, 2013, the White House released its final implementation plan for the National Ocean Policy describing coastal land management and stewardship practices. Among these practices, the plan identifies coastal habitat restoration as a top national priority that will produce economic and public safety benefits in the short, medium, and long term for coastal communities.

The Shoreline Master Program (SMP), a statewide regulatory document derived from the Shoreline Management Act (GMA), addresses the national effort of conserving shorelines. One of the main tools used for informing the SMP is the shoreline inventory as it identifies critical habitat along the nearshore. The inventory also establishes a baseline against which to measure shoreline quality or alterations.[72]

The Elwha River

The Elwha River is home to the Lower Elwha Klallam Tribe, which is part of the larger Klallam community. The Tribe has strong historical, cultural and economic connections with the Elwha watershed; this ecosystem provides food and resources for tribal community members. However, with the construction of two dams in the early 1900s, the salmon runs decreased dramatically and the Tribe lost their subsistence resources, as well as cultural and spiritual sites. Salmon, a keystone species of the Pacific Northwest bioregion, provides vital food and nutrient sources to humans and other species such as bears, eagles, and marine animals. It is estimated that only 1% of pre-dam salmon population was left downstream of the Elwha Dam. Since construction of the dams, the Tribe has been dedicated to advocating for river and salmon restoration projects.[73] The Tribe also operates a local hatchery to maintain the salmon populations.[74] With the dam removals, the local community expects to experience a growth in salmon populations and an overall recovery throughout the riverine and coastal ecosystems. Parts III and IV of this report quantifies the economic benefits of these improvements.

The Elwha Nearshore Consortium is a group of citizens, scientists and managers first convened in 1994 to understand and promote the nearshore restoration associated with the Elwha dam removals: including the implications of coastal sediment deposition, and restoration priorities of the Elwha nearshore.[75]

Geological Setting

The Elwha River Delta lies between Freshwater Bay and Ediz Hook, extending northward into the Strait of Juan de Fuca. Its sediment is supplied by eroding bluffs and the Elwha River Watershed, which is a 72km long river draining from the Olympic Mountains into the Pacific Ocean. The formation of the Olympic Mountains, the convergence of the oceanic Juan de Fuca plate and the continental North American plate, glacial processes and sea-level changes have shaped the region, resulting in the development of the Elwha River delta and coastal bluffs. Evidence of these processes is the exposed feeder bluff, which became a source of sediments.[76]

Modern natural processes continue shaping the delta today. At the delta, wave climate is mediated by processes in the Strait of Juan de Fuca and Pacific Ocean. Waves are generated by local winds and swells from the Pacific, with a typical height of 0.5 m and occasional height over 1-2 m. The tidal range (the difference between mean higher high water and mean lower low water) is about 2.15m at Port Angeles and 2.43 m at Neah Bay.[77] Additionally, discharge of the Elwha River has one peak in winter due to substantial rainfall and another in late spring and early summer because of snowpack melt.[78] Altogether, modern processes including waves, tides, and river discharge largely define the features of the delta.

Figure 9. Elwha River Watershed

Source: http://www.elwhabiodiversity.org/elwha/

Dam Constructions and Removal

The construction of the Elwha Dam began in 1910 in order to harness the power of nature and gain economic benefits, in the form of power to fuel a growing regional economy. The Elwha Dam was 108ft high and was not initially secured to the bedrock. After the bottom section of the dam failed, a reconstruction occurred and eventually the dam became operational in 1913 with a fish hatchery installed in 1915 in compliance with a Washington State law requiring fish passage devices.[79] Due to increasing demand for electricity, the Glines Canyon Dam was built eight miles upstream of the Elwha Dam, which was much higher at a height of 210ft, compared to the Elwha Dam, at 108ft.

In 1992 the initiative to remove the dams along the Elwha resulted in the Elwha River Ecosystem and Fisheries Act. Even though the Act did not mandate removal of dams it did stipulate the full restoration of fisheries and ecosystems, therefore the only way to accomplish this was decided in an environmental impact statement (EIS) in 1995.[80] Both dams were taken down beginning in 2010. By March 2012, the Elwha dam was fully removed and the Glines Canyon dam will be completely gone by the summer of 2013. It is a slow process because the enormous quantity of sediment trapped behind the dams could cause significant disturbance to ecosystems, and engineers are trying to avoid this impact by building alternative passages for water and sediment flows.

Biophysical Impacts of the Dams

Both physical and biological processes of the Elwha ecosystem were significantly altered by the construction of the two dams. Upstream migration of salmon was blocked by the dams.[81] Side channel habitat was lost or degraded when the sand and gravel that are critical components of salmon spawning habitats were trapped behind the two dams.[82] About 34 million cubic yards of sediment are trapped in Lake Mills, which is the reservoir behind the Glines Canyon dam, and Lake Aldwell, behind the Elwha dam.[83] Other ecological consequences of the dams include rising temperature of reservoir water, which impairs fish spawning, geomorphic changes due to lack of sediment supply such as erosion of river beds and altered river flow patterns.

Biophysical Impacts of Dams Removal

Dam removal plays an important role in restoration of nearshore ecosystems and overall shoreline processes. Removal is delivering millions cubic meters of sand, gravel and fine sediment to Clallam County beaches. The delivery of sediments is expected over several years, giving species the opportunity to regain lost habitat.[84]
It is expected from previous environmental impact statements that fine sediments trapped by two dams will be the first to be flushed downstream; this would return original rocky habitats into sandy ones.[85] Such changes can be beneficial to some species creating new habitat and restoring important spawning areas. A critical process is how sediments that have been trapped for decades will affect landforms on the shoreline. Changes that have already occurred include beaches with finer sediments and the rapid formation and disappearance of gravel bars.[86] Although removing the dams is the first step to ecosystem restoration, additional actions will be necessary to realize entirely the potential associated with the removal project's goals.[87]

Elwha Dam before removal

Elwha Dam, 2012

Glines Canyon Dam before removal

Glines Canyon Dam, 2012

Elwha River sediment flow into the Strait of Juan de Fuca

Elwha River sediment flow into the Strait of Juan de Fuca

Elwha River sediment flow into the Strait of Juan de Fuca

Elwha River sediment flow into the Strait of Juan de Fuca

Part II. Ecosystem Services In Clallam County

Ecosystems provide a wide variety of valuable public benefits at a low cost over long periods of time.[88] It would be impractical, and in some cases impossible, to replace these economically valuable natural systems with more costly and less efficient capital substitutes. When ecosystems are valued as assets and brought to the center of economic decision-making, their cost-effective services are less likely to be lost.

Ecosystem Goods and Services

There is a difference between ecosystem goods and services, and acknowledging these distinctions enable their separate valuation as independent assets. Ecosystem goods are tangible, quantifiable items or flows, like, timber, drinking water, fish, crops and wildlife. Many goods are considered exclusive, meaning they can be held under property rights that can exclude the use or ownership of that good to others. These excludable goods can be valued; therefore they are tradable and marketable. The flow of these goods can produce economic returns.

Ecosystem services are valuable benefits that are not as obvious as ecosystem goods. Gretchen C. Daily defines ecosystem services as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life".[89] Unlike ecosystem goods, ecosystem services are not tangible items one can weigh or hold. Flood protection, waste treatment, climate stability and water filtration are only a few of the services provided. Services are harder to value than goods because many times they are not traded in financial markets. Paradoxically, ecosystem services are critical to both our quality of life and for economic production.[90]

In general, ecosystem services are non-exclusive, meaning that if someone enjoys a service this does not prevent another from doing so as well. When one person enjoys the view of the Strait of San Juan de Fuca (aesthetic value), she/he does not exclude others from doing the same.

Ecosystem Service Markets
In an ecosystem service market, beneficiaries of an ecosystem service pay those who offer to provide the ecosystem service. The utility of ecosystem service markets will become apparent in coming years as new markets develop for habitat, climate control, temperature and water quality. A number of factors make ecosystem service markets more challenging than markets for goods. Unlike goods, a flow of services is often measured overtime. Quantifying the amount of flood protection provided by a given forest and the value of that flood protection is much more difficult than calculating the potential for timber harvest. Regardless of the difficulty in measuring service flows, this value is usually higher than the production of goods of that same ecosystem.[91]

It is increasingly recognized that the trade and overall utilization of these goods and services form an essential part of our economy. Not only do natural services produce goods, but also provide "…actual life-support functions, such as cleansing, recycling, and renewal, and they confer many intangible aesthetic and cultural benefits as well".[92]

Resiliency
Resilience implies the potential of a system to return to a previous state after a disturbance. A system is assumed to be fragile when resilience is low. When natural functioning systems are replaced or modified they become less resilient; for example, wetlands that are converted to open water by clearing of vegetation produce fewer ecosystem services and provide less economic value.[93] Without resilience, an entire economic system can collapse and revert to a less productive one.

Given the ecosystem services that are applicable for specific land cover types, an ecosystem service valuation (ESV) represents the economic value of these services.


Marine Life

Ecosystem Services Produced in Clallam County

Following are detailed explanations and examples of ecosystem services valued in this report. In Clallam County a total of 15 ecosystem services were identified. In Part III, the total economic value of ecosystem services will be examine in greater detail.

Aesthetic Information, and Recreation and Tourism
Aesthetic value, as an ecosystem service, refers to the value of human appreciation of natural land and seascapes. Recreational value is the value of activities that take place in these naturally aesthetic sceneries. The existence of a national park and several designated scenic areas in Clallam County attests to the social importance of these services. There is substantial evidence demonstrating the economic value of environmental aesthetics and recreational activities through analysis of data on tourism, housing prices, wages, and relocation decisions. Degraded landscapes are frequently associated with economic decline and stagnation.[94]

Illustrative Example
Activities such as sailing, rafting, skiing, kayaking, camping, hunting, hiking, and bird watching provide a great source of income for Clallam County businesses throughout the year. Not only are the county's beautiful forests and rivers an aesthetic wonder, but the shoreline and beaches are also a great place for recreational activities such as hiking, fishing, surfing, tide pool exploration, and clamming. Olympic National Park and Olympic National Forest attract millions of visitors year round.[95] Clallam County operates over fifteen county parks, totaling approximately 735 acres, where residents and visitors enjoy interacting in unique natural surroundings.

The parks and facilities are an annual revenue stream and job provider for Clallam County. The county Parks and Facilities tourism report declared $1,808,254 in revenue for the year of 2013 and have comparable numbers for the prior years.[96]


Sea Kayaking in Clallam County

Habitat and Nursery

Habitat is the biophysical space and process in which wild species meet their needs. Healthy ecosystems provide physical structure, adequate food availability, appropriate chemical and temperature regimes and protection from predators. Habitat may provide refugium and nursery functions. Biodiversity provides the structure and complexity of ecosystems lending resiliency and producing provisioning, regulating, cultural and supporting ecosystem services. In addition to the physical structure provided to species, food/web relationships are important components of habitats that support all species.[97]

Illustrative Example

Preserving and restoring the ecosystem health of Clallam County's many watersheds helps maintain and recover salmon populations. Since 1999, the Washington State Salmon Recovery Funding Board and the Puget Sound Partnership have invested about $27 million, which supported prioritized projects across the North Olympic Peninsula. These efforts are primarily geared towards restoring and protecting salmon habitat.[98]

Two locally-based lead entity consortiums which were established by state statute, work to determine restoration priorities. They include the North Pacific Coast Lead Entity which extends from Cape Flattery in Neah Bay south along the Pacific Coast to Ruby Beach; and the North Olympic Peninsula Lead Entity for Salmon, which begins on the county's eastern edge in Blyn, and extends west along the Strait of Juan de Fuca to Cape Flattery.

This prioritization is also guided by[99] ecosystem restoration and salmon recovery actions from lead entity strategies, the Elwha and Dungeness chapters of the Puget Sound Chinook Recovery Plan, the Eastern Strait of Juan de Fuca-Hood Canal Summer Chum Recovery Plan, Lake Ozette Recovery Plan, draft WRIA 19 Salmon Recovery Plan and the Washington Coast Sustainable Salmon Partnership Sustainability Plan.

These plans often include a comprehensive set of actions related to salmon recovery including needed habitat restoration as well as harvest and hatchery management, water diversions, and forest management. Key lead entity partners include Tribes, county and city governments, non-profit groups and citizens. Other important partners include regional recovery organizations including the Puget Sound Partnership and Hood Canal Coordinating Council, as well as the Washington Coast Sustainable Salmon Partnership.

Examples of this work include: the restoration of Jimmycomelately Estuary in Blyn; removal of fish-blocking culverts in Salt Creek, acquisition of property needed to set back a levee currently constraining the Dungeness River, floodplain reconnection at Morse Creek, removing floodplain constrictions along the Pysht and Big rivers and creating access to off-channel rearing habitat in the Sol Duc and Calawah rivers.

The largest restoration project currently underway in North America is the removal of two large, aging dams on the Elwha River just west of Port Angeles. Removal of the two large dams is a key part of the Elwha Chapter of the Puget Sound Chinook Recovery Plan. This project is lead by Olympic National Park in partnership with the Elwha Klallam Tribe. The North Olympic Peninsula Lead Entity for Salmon has allocated funding for re-vegetating the newly exposed floodplains, and building of large engineered logjams to maximize restoration efforts.

Chinook salmon, Oncorhynchus tshawytscha

Marine life in Sequim, WA

Water Regulation

This category includes regulation of water flows, particularly water runoff, flooding, and aquifer recharge through the ground and along terrestrial surfaces to accommodate animal and plant species in the ecosystem. Ecosystems absorb water during rain and release it in dry times multiple ways, one of which is permeable soil. Porous soils play a critical role in water flow regulation because it allows aquifer recharge. Other regulation methods include retaining water through river floodplains and wetland forests when water runoff peaks and the risk of flooding is high.[100] In addition, forest cover and riparian vegetation contribute to modulating the flow of water from upper portions of the watershed to streams and rivers in the lower watershed. When forested basins are heavily harvested, the remaining vegetation and litter layer on the forest floor absorbs less water. The elimination of vegetative cover reduces water absorption, increasing the flow of water onto land and bodies of water, therefore, enabling further land erosion, soil degradation and larger quantities of unfiltered stormwater runoff.[101]

Illustrative Example

Lack of natural water regulation in developed lands can be costly and problematic to local landowners. In Clallam County, drainage plans are used as a method for the control of stormwater runoff on individual properties. These plans are required to control increases in rainwater runoff resulting from development of the land. Every Clallam resident is responsible for damage caused by stormwater runoff due to their development. One standard method is to route all roof runoff into downspout drywells.[102] Alternatively, maintaining a minimum of 65% to 70% of the natural pervious land cover[103] can eliminate the need for mitigation by the county and property owner, saving the time and money required to build infrastructure to mitigate this water flow.

Soil Retention

Soil retention refers to the ability of soil to retain water through soil particles. Soil retention capacity varies with the size of soil particles. For example, water molecules attach to clay better than to sand. In other words, water transmission is easier through sandy soil than clay soil. Soil retention can be improved through stormwater management; avoiding or limiting development in areas with a high risk of erosion due to slope, erodability of soil, and other factors; and the protection of endemic land covers and mitigating previous harmful activities.

Erosion and flooding have already caused hundreds of feet of cracked pavement and bank slumping on Highway 112 leading to an increase in maintenance costs and unsafe driving conditions.[104] Every year the monetary value to fix and maintain the roads in the country increases, and $32,797,143 was budgeted in 2013 for road expenditures.[105]

Shoreline development has occurred over many years. Natural factors like wind and storm surges accelerate the erosive impacts on developed lands, due to the lack of protective biological cover.[106] Structures that are built with a sufficient distance from the bluff, and that retain a healthy riparian buffer, can avoid these impacts, while allowing the feeder bluff to continue providing ecosystem services.

Illustrative Example

Bluff erosion, though a natural process that maintains diverse coastal habitats, could pose dangers to landowners and structures close to the bluff edges.[107] The Department of Ecology in Washington State provides guidance for landowners to achieve slope stabilization and erosion control by encouraging the use of vegetative buffer areas. Once landowners select their site characteristics, they can identify appropriate protection measures and suitable vegetative site-specific treatments.[108]

Collecting a water sample at Port Williams in Sequim, WA.

Bluff in Clallam County

Food Provisioning

Providing food for human populations is one of the most important ecosystem functions. Agricultural lands are our primary source of food; farms are considered modified ecosystems, and food is considered an ecosystem good with labor and built capital inputs. Agricultural value is measured by the total market value of crops produced; however, market value is only a small portion of the total value agricultural lands provided through pollination, carbon sequestration, aesthetic value, and other services.

Illustrative Example

In Clallam County there are over 900 acres of agricultural land. Farms ususally average 49 acres, although many are smaller.[109] According to the 2007 census data, 76% of farms in Clallam County make less than $10,000 per year.[110] Agricultural lands depend on ecosystem services provided by natural ecosystems including pollination, pest control, nutrient regulation, and soil formation. On the other hand, agricultural ecosystems provide services as well, such as soil and water regulation, carbon sequestration and other cultural services.[111]

Johnston Farm, Port Angeles, Washington

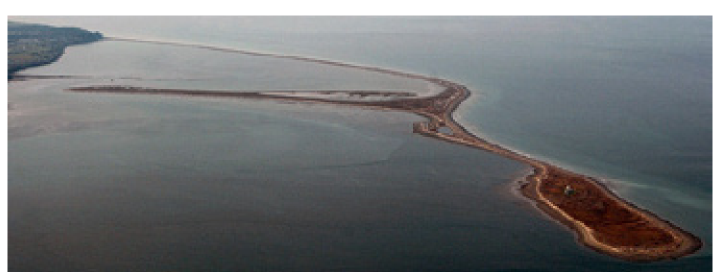
Disturbance regulation

Estuaries and bays, coastal wetlands, headlands, sand, cobble and gravel beaches, mudflats, eelgrass and seagrass beds, rock reefs, and kelp forests provide protection from storms, storm surges, tsunamis and other disturbances. These ecosystems are able to absorb and store large amounts of rainwater or water runoff during a storm, in addition to providing a buffer against coastal waves. Estuaries, bays, and wetlands are particularly important for absorbing floodwaters.[112]

Today, changes in land use combined with the potential for higher frequency storm events due to climate change make this service one of the most important for economic development in the county. In order to have productive lands, protected built capital, and high value, productive ecosystems, damage reduction strategies must be effective and efficient. Given that significant infrastructure can be damaged during large storm events, tourism and recreation can be harmed as well. One of the most significant factors in an ecosystem's ability to prevent flood damage is the absorption capacity of the landscape. This is determined by land cover type (forest vs. pavement), soil quality, and other hydrological and geological dynamics within the watershed. The retention of forest cover and restoration of floodplains and wetlands provide this tangible and valuable ecosystem service. Most notably, it reduces property damage, lost work time, injury, and loss of life caused by floods. With sea level rise the slope of rivers is being reduced creating greater flood threats, particularly at high tide.[113]

Illustrative Example

With climate change increasing the chances of extreme weather events, higher ocean waves and more intense water and winds may reduce beaches, accelerate bluff erosion, and damage the coastal infrastructure. The Oregon and Washington shorelines are vulnerable to extreme storm waves, which have increased as much as eight feet since the mid-1980s and come ashore with 65% more force.[114] As of 2013, Clallam County spends $18,830 annually on flood preventive controls and dikes, but more money will be needed for preventative flooding measures as extreme weather patterns become more frequent.[115]



Dungeness Spit

Port Angeles Landfill:
An assessment of ecosystem services

History of the Area

The landfill, owned by the City of Port Angeles, is located just three miles from downtown. From the early 1950s until 1979, a private contractor owned the land. The northwestern part was at fist mined for gravel and sand. After these activities ceased the mine began to be filled with solid waste. The surrounding areas were also developed as support facilities to sustain the function of the landfill. In 1983 the land, now owned by the Port Angeles Works and Utilities Department, was capped with 2ft to 4ft of soil in order to continue landfilling. Solid waste was placed at a depth of 50 to 60ft, with no bottom liner, and expanded out to about eight acres adjacent to the Strait of Juan de Fuca. In 1990 this area was closed in compliance with WAC 173-304. Due to strong wind and wave action a section of cell West 304 eroded and exposed waste that fell onto the beach. Cells 1, 2 and 3 were constructed in the middle portion of the property with bottom-lined areas in 1990, 1993 and 1999 respectively. After the last cell was developed and filled the landfill was closed and the final cover was constructed in 2007.

Aerial view of Port Angeles Landfill

Trash on beach due to bluff failure at Port Angeles Landfill

Since 2001 the Clallam County Department of Health and Human Services modified the Landfill Operating Permit to require the City of Port Angeles to produce a plan for stabilization of the bluff and site clean-up. The City hired a consulting agency, Parametrix, to conduct geotechnical testing that resulted in slope instability in the lower portion of the landfill due to bluff erosion. From this testing, Parametrix suggested seven possible alternatives to alleviate the risk. The alternatives proposed were: no action, semi-annual clean up of eroded waste, clean up of existing waste and cover the eroded waste, revetment wall at slope toe with slope laid back, revetment wall at toe with soil removal, regrade entire bluff slope and gunnite cover or completely remove the landfill.

In 2003 the City of Port Angeles applied for the construction of a rock and sheet pile bulkhead, which was denied by the Department of Fish and wildlife given the negative impact this would have on fish life. After a few years of back and forth the City built a retention wall with certain water quality standards, material and construction specifics and beach nourishment projects if necessary. In 2006 the Glacier Construction Services was awarded $2,071,098.17 for the construction of the wall.[116] The work had state permits but not federal permits.

The construction encountered many problems, the main two were related to the cutting back of the slope and the soil conditions, two issues that were not addressed thoroughly in the initial geotechnical report. These concerns plus a number of other weather related adversities temporarily suspended the construction. In the summer of 2007 the project was continued and finished by December of that same year.

Associated Costs

Altogether, the costs associated to the landfill slope stabilization project added up to $6.9 million. The consulting cost $1.3 million, city staff costs $83,000, engineer estimate $2.5 million, final construction cost $2.7 million plus $200,000 for drilling subcontractor and $6,000 for settlement costs.[117]

To sum it up, the 450ft long seawall and slope stabilization was a $6 million plus project, which was installed with incomplete permitting in 2006. There has already been evidence of increased erosion at the ends and base of the seawall indicating continuing erosion.[118]

Today a continuing stabilization project is underway, the Port Angeles Landfill Self-Stabilization, is planned to prevent trash from the east part of cell 304 to fall into the Strait. This project is intended to begin in summer of 2014 worth a total budget of $19 million. DoE has already approved $3.9 million of financial assistance for the completion of the slope stabilization in this area. The working plan is to remove a portion of the trash from cell 304 east to another cell onsite (cell 305). However, due to limited funding the entire east cell cannot be removed[i], therefore about 250,000 cubic yards will be relocated. The feet estimated is a conservative sum given the assumption of the bluff eroding at a rate of 5ft per year. This plan addresses the erosion problem for about 25 years. 10% of the total $19 million budget will be allocated to enhance the existing seawall on the west portion of cell 304.[119]

Port Angeles Landfill Seawall during construction, 2007

Completed seawall-Port Angeles Landfill

[i] The estimated cost of removing the entire 304 cell is about $100 million dollars. The estimated cost of removing the east side of cell 304 completely is about $40 million dollars.


Active bluff on east cell 304 and beginning of seawall at west cell 304


Current site conditions east end cell 304


Aerial view of Clallam County coastline - Elwha Mouth to Ediz Hook

Economic Assessment

A rapid assessment of ecosystem services (ES) present in the landfill area, can illustrate the value that a healthy functioning nearshore and its economic contribution. Through the Benefit Transfer Methodology we are able to identify and value the services produced. The land cover types valued in this case study are riparian buffers, intertidal areas and feeder bluffs.

Table 3 provides the ecosystem services we were able to value for this case study. Even though these and more ecosystems services could be present in the area they were not valued given lack of available information or differences in ecosystem types. For riparian buffer and intertidal areas the values are presented in acres per year, while the feeder bluff value is in foot per year.

The values for riparian buffer and intertidal areas are provided by several ecosystem services as shown in Table 3. Healthy and functioning riparian buffers and intertidal areas contribute between $240,000 to $1 million annually to the regional economy. By providing habitat, contributing to the water supply and regulating gas and climate. The feeder bluffs in the landfill area contribute about $7,000 to $14,000 a year. This range varies depending on whether the shoreline is armored or not. The feeder bluff numbers are valued using estimated avoided cost on nourishment projects to sustain bluffs and counteract erosion.

Table 3. ES Identified for land covers in the Port Angeles Landfill Area

	Feeder Bluffs	Intertidal Areas	Riparian Buffer
Moderation of Extreme Events	X		X
Food Provisioning		X	
Climate Stability		X	
Habitat and Nursery		X	X
Soil Formation		X	
Water Supply			X
Recreation and Tourism			X
Aesthetic Information		X	

Present and valued in this study	X
Present but not valued in this study	
Not present for this land cover type	

Aerial view of Port Angeles landfill with sediment

Table 6 demonstrates the difference in dollar value of maintaining a shoreline without armoring. In the high range, an uninterrupted feeder bluff can contribute more than $18.00 per foot. The City of Port Angeles in now spending up to $1 million on annual nourishment on the 2 miles of Ediz Hook and more than $2,000 a year in maintaining the seawall.[120] About $8 million were spent on stabilizing the slope and building the seawall for 450ft along the landfill area. These extraordinary expenses can be avoided by allowing the free flow of sediment feeder bluffs already provide to the shoreline. Costly projects such as armoring not only destroy habitat, but also interrupt the natural nourishment nature bestows.[121]

Table 4. $ Values of ES produced by riparian buffer and intertidal area in Port Angeles landfill site.

	Acres	$Low/acre	$High/acre	Low total	High total
Riparian Buffer	84.3	$2,500	$5,049	$210,726	$425,602
Intertidal	20.8	$1,572	$30,100	$32,691	$626,079
Total	***105.1***			***$243,417***	***$1,051,681***

Table 5. $ Values of ES produced by feeder bluffs (average) in Port Angeles landfill site.

	Feet	$Low/ft	$High/ft	Low total	High total
Feeder Bluff	1200	$6.21	$12.42	$7,452	$14,904

Table 6. $ Values of ES produced by feeder bluffs armored and unarmored in Port Angeles landfill site.

	Feet	$Low/ft	$High/ft	Low total	High total
Feeder Bluff Armored	450	$2.97	$5.94	$1,336.50	$2,673.00
Feeder Bluff Unarmored	750	$9.45	$18.90	$7,087.50	$14,175.00

Climate Stability, and Air Quality

Marine ecosystems play a critical role in natural carbon sequestration and storage. They help to regulate the gaseous portion of nutrient cycles that effect atmospheric composition, air quality and climate stability. Both carbon sequestration and storage enable higher climate stability by removing greenhouse gases from the atmosphere. During the sequestration of carbon dioxide, marine algae and seaweeds use photosynthesis to convert carbon dioxide into biomass, organic matter used to fuel the plant. This sequestration contributes to the "flow" of carbon. Storage of greenhouse gases contributes to the build-up of carbon "stocks." Just as living plants sequester and store carbon dioxide, non-living biomass, organic matter, sediments and rocks can store carbon stocks without consuming it[ii]. Because the mass of stored carbon is so great with respect to its host, large amounts of carbon are expelled from decaying organic matter. Thus, dying species of terrestrial and marine plants are replaced with healthy ones, which sequester and store carbon for the next generation.

Illustrative Example

Blue carbon refers to the large quantity of carbon that is being stored and sequestrated in wetland and marine vegetation and soils. It is ranked as one of the most productive carbon sinks on the planet due to its high efficiency compared with terrestrial habitats.[122]

Up-close Kelp

Nutrient Cycling (Soil Formation)

There are 22 elements essential to the growth and maintenance of living organisms. While some of these elements are needed only by a small number of organisms, or in small amounts under specific circumstances, all living things depend on the nutrient cycles of carbon, nitrogen, phosphorous, and sulfur in relatively large quantities. These are the cycles that human actions have most affected. Silicon and iron are also important elements in ocean nutrient cycles because they affect phytoplankton community composition and productivity. Living organisms facilitate the movement of nutrients between and within ecosystems turn them from biologically unavailable forms, such as rocks or atmospheric gases, into forms that can be used by other forms of life. Without functioning nutrient cycles, life on the planet would cease to exist. As plants die, they contribute to the pool of organic matter that feeds the microbial, fungal and micro-invertebrate communities in soils. These communities facilitate the transformation of nutrients from one form to another. Larger animals play a crucial role in nutrient cycles by moving nutrients from one place to another in the form of excrement, and through the decomposition of their bodies after death. Forests also play a significant role in global nutrient cycles; they hold large volumes of basic nutrients and keep them within the system, buffering global flows.

Deforestation has played a large part in altering global carbon and nitrogen cycles.[123] These ecosystems trap and retain nutrients that would otherwise run off into streams and rivers, and eventually end up in the ocean. A combination of increased use of fertilizers and the loss of the buffering capacity of these ecosystems has led to fresh water, estuarine, and ocean systems suffering nutrient overloads which lead to large blooms of phytoplankton. Loss of commercially, recreationally, and culturally important fish species has resulted. The number of marine dead zones in the world has doubled every decade since the advent of synthetic nitrogen fertilizers.[124] The presence of these dead zones is a clear indication that global nutrient cycles have been severely altered by human actions.

[ii]The biomass of the average tree is approximately 50 percent carbon by weight (NSFA 2002). Northeast State Foresters Association (NSFA). (2002). Carbon Sequestration and Its Impacts on Forest Management in the Northeast. www.nefainfo.org/publications/carbonsequestration.pdf

Many other ecosystem services depend on nutrient cycling. Given that ecosystem productivity would cease without it, production is impaired when these cycles become significantly altered. Nutrient cycling is a precursor to ecosystem and economic productivity. This fundamental role cannot be fully substituted by human-made solutions, and operates at multiple, overlapping scales; therefore, it is difficult to arrive at an accurate economic value for these services, and it is often undervalued.[125] Given that nutrient cycling is critical to the operation of life on the planet, it is important that biological science informs policy that will protect this critical service. Yet, because it is so fundamental, economic techniques for valuing nutrient cycling at the appropriate scale are limited. The value of nutrient cycling is not included in the value of final goods and services for which nutrient cycling is an essential input process. For this reason, valuing nutrient cycling is not double counting.

Illustrative Example

Deforestation, the burning of fossil fuels and industrialization has increased the amount of CO2 in the world's oceans, causing ocean acidification. The Strait of Juan de Fuca's waters have not been spared from this trend, and the commercial oyster industry has been negatively affected.[126] Healthy riparian ecosystems produce photosynthesis, cycle nutrients and pollutants, improve water quality and help mitigate acidification.

The nitrogen cycle directly contributes to aquatic eutrophication (excess of nutrients), and the use of fertilizers and untreated human sewage are common factors that increase levels of N in our oceans. The low levels of oxygen in upwelled waters exacerbate CO2 impacts on organisms and on entire ecosystems.[127]

Pollination

Pollination supports wild and cultivated plants and plays a critical role in ecosystem productivity. Many plant species, and the animals that rely on them for food, would go extinct without animal and insect mediated pollination. Pollination services are also crucial for crop productivity for many types of cultivated foods, enhancing the basic productivity and economic value of agriculture.[128] The loss of forestlands and native shrubby riparian areas in suburbanizing rural areas reduces the ability of wild pollinators to perform this service.

Illustrative Example

Clallam County farmland produces a variety of products such as vegetable seeds, hay, and is famous for its commercial lavender.[129] Through pollination, lavender abundantly grows throughout Sequim bringing in over 5,000 tourists from all over the country to attend the annual Lavender Festival.[130]

Nurse log with fern, Olympic National Forest

Sequim Washington, Lavender farm

Energy and Raw Materials

Raw materials include biological materials used for medicines, fuel, art and building. The sea has provided basic provisioning materials to coastal communities throughout the world for centuries. The skins of marine mammals were used for clothing, gas deposits for energy production, and the timber of mangroves and coastal forests for shelter. Raw marine materials are utilized for non-essential goods as well including shells in ornamental items.

Illustrative Example

Timber is a key industry in Clallam County, with 285,842 acres in commercial timber holdings. Over 50% of those holdings are located in watersheds that drain to the Pacific Ocean.[131] Within this region of the county, timber is the biggest industry, occupying 31.6% of the land.

Science and Education

The number of educational and research institutions devoted to studying marine and terrestrial environments demonstrates the scientific and educational importance of ecosystems within Clallam County. Government, academia, and non-profits are devoted to formally studying ecosystems and their response in Clallam County.

Illustrative Example

Many governments and non-governmental organizations indirectly protect the economy and community through environmental science, restoration and conservation actions, public outreach and landowner support and education. Organizations include: the Coastal Watershed Institute, Feiro Marine Life Center, North Olympic Land Trust, Beach Watchers, Marine Resource Committees and many others.

Timber Industry

City Pier Marine Life Workshop, Port Angeles

Soil Formation

Climate, living organisms, topography, and time exert significant influences on soil formation. Soil quality and abundance is critical for human survival, yet human actions can also affect nature's ability to provide high-quality soils.[132]

Illustrative Example

The fertile land of Dungeness Valley, where large-scale commercial farming takes place, requires extensive irrigation due to low average rainfall.[133] The snowpack and snowmelt play a large role in the soil conditions within the mountains as well as the coastal drainages. Due to climate change, the snowpack months have been reduced and there is an earlier snowmelt due to the increase in temperatures during the summer months. With these environmental changes, the soil dries out more frequently leaving less moisture for vegetation.[134] With dryer soil, a larger demand for irrigation arises and the agriculture dependency on the water supply increases.

Waste Treatment

Microorganisms in sediments and mudflats of estuaries, bays, and nearshore areas break down human and other animal wastes. They can also detoxify petroleum products. The physical destruction of habitat, alteration of food webs, and overload of nutrients and waste products disrupts disease regulation and waste treatment services, increasing the economic costs of damage from waste materials. Changes to ecosystems can also create breeding sites for disease vectors where they were previously non-existent.[135]

Illustrative Example

The increase in water temperature is affecting the overall riparian and river interaction. In some cases, riparian buffers have receded creating larger open areas with increased sunlight. This affects the microclimate and the aquatic micro fauna.[136] In Clallam County many bodies of water have periods of being labeled "impaired" by the state due to high levels of fecal coliform and low amounts of dissolved oxygen, where both large and small bodies of water are impacted.[137]

Soil Profile

Washington Conservation Corps crew removing beached creosote-contaminated wood at 3 Crabs Beach, Clallam County

Water Supply

Watersheds produce water, including surface water and groundwater for rural and metropolitan areas. The hydrological cycle is affected by structural elements of a watershed such as forests and wetlands. Geologic and climatic such as evapotranspiration also play a significant role. According to the United Nation Environment Programme, over 60% of the world's population gets their drinking water from forested watersheds. This rainfall figure is misleading because water resources are not distributed evenly over time, geography, or throughout the population. Increasing loss of forest cover around the world has decreased water supply due to lower groundwater recharge and lower flow reliability.

Illustrative Example

All Clallam County watersheds are experiencing climate change impacts. Reduced snowpack and rainfall is expected to decrease Clallam County's ability to meet the growing need for municipal water demands, hydropower, and irrigation for agriculture.[138] Climate change has reduced the seasonal water flow from semi-annual peaks to just once a year.[139] Another concern for the water supply is that of sea level rise. Rising sea levels result in infiltration of salt water into fresh water aquifers, altering their quality and making them unusable without desalination.[140] A preventative method called the Shallow Aquifer Recharge method projects an estimated initial cost of $ 9 million, and a continuing operational cost around $40,000.[141] Investments in wetland conservation for disturbance prevention and sustainable forest management for water supply and filtration are expected to help elevate these costs.

Elwha River

Ecosystem Service Diversity and Trade-offs

Ecosystems are complex systems. Complex systems are characterized by strong (usually non-linear) interactions between the parts, and complicated feedback loops that make it difficult to distinguish cause from effect, with significant time and space lags, discontinuities, thresholds, and limits.[142]

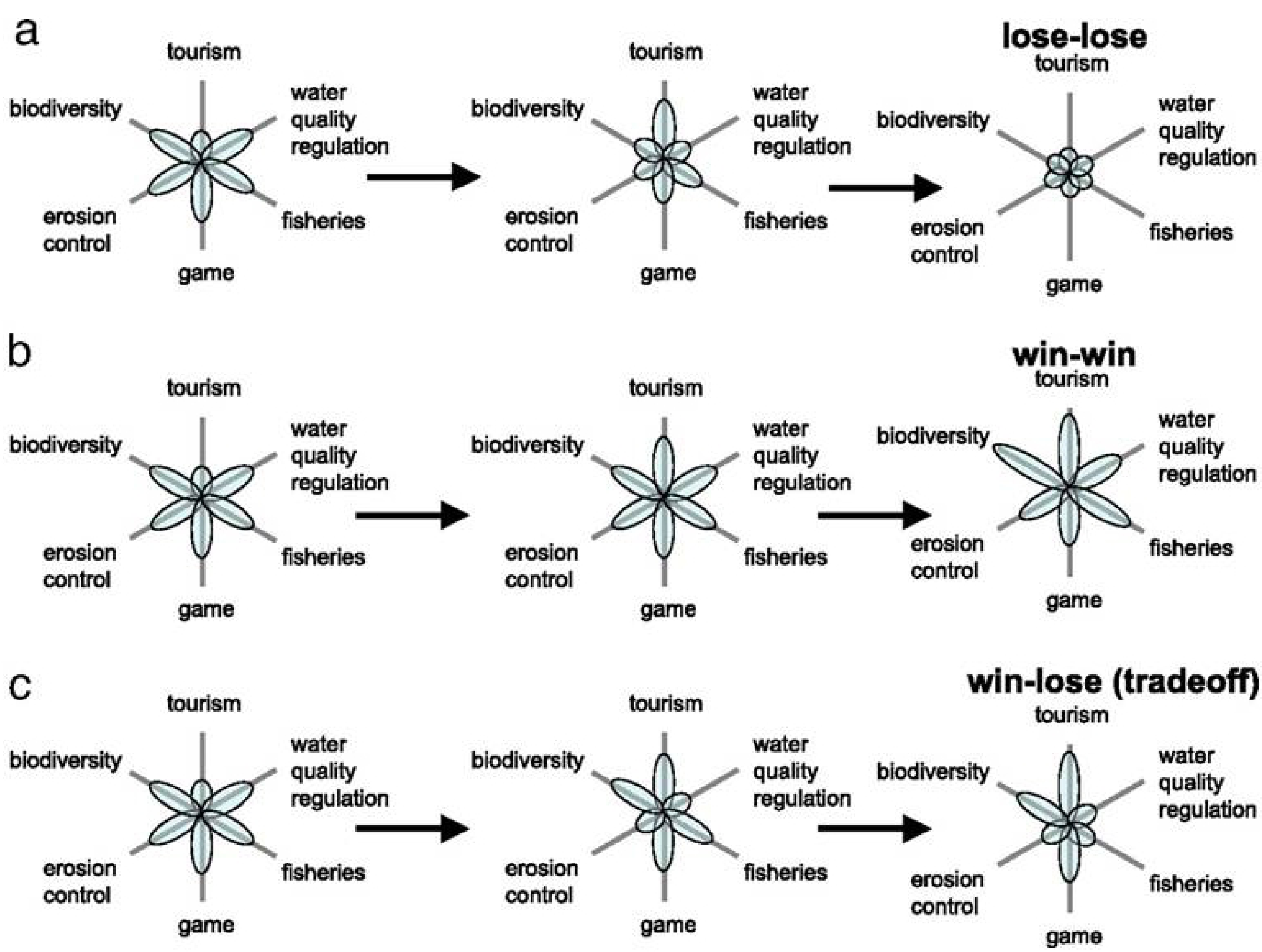
Understanding the relationship of ecosystem services present in different landscapes is an emerging area of ecosystem service analysis. Scientists are exploring the intersection between ecosystem services that are commonly wrapped together across different spatial landscapes and temporal scales.[143] It is vital to understand how social or ecological conditions impact ecosystem services categorization, and the nature of their classification. Doing this might indicate further research in this area.

Balancing Trade-offs

Ecosystem service management tradeoffs arise when the provisioning of one service is enhanced at the cost of reducing the provisioning of another service.[144] A key conservation management challenge is stewarding interdependent ecosystem services across connected landscapes. Actions to enhance the supply of some ecosystem services, mainly provisioning services such as food and timber, have led to declines in many other ecosystem services, including regulating and cultural services such as water regulation and soil regulation.[145] The Millennium Ecosystem Assessment described the need to address these challenges through better management of tradeoffs. Capturing synergies that exist between ecosystem services at different spatial and temporal scales will result in far better outcomes for communities.[146,147]

The concept of ecosystem service trade-offs can be illustrated graphically using "Tradeoff Flowers". The following figure graphically depicts hypothetical examples of combinations of ecosystem goods and services that are produced under different management scenarios. Hypothetical scenario A depicts a region that began with a pristine environment and abundant ecosystem services. An exclusive focus on promoting tourism may have led to development at the expense of the environment, and eventually degraded the asset that attracted tourists originally, creating a "lose-lose" situation for both the measured human economy and ecosystem services.

Figure 10. Tradeoff Flowers Depicting Alternative Suites of Ecosystem Services under Different Scenarios



Source: Tallis H. et al., 2008. PNAS 105:9457-9464

Part III. Valuation of Clallam County

To estimate the value of ecosystem services produced in Clallam County, Earth Economics first identified the services that are present on the landscape. Working with Clallam County, Department of Ecology, Coastal Watershed Institute, Department of Natural Resources, Peninsula College and Friends of Dungeness Refuge, this baseline valuation was completed using Geographical information Systems (GIS) land cover acreage data provided by Clallam County.

Land Cover

The spatial distribution of ecosystem goods and services produced in a region can be mapped across the landscape. Each land cover type from cultivated crops to forests provides an array of unique services. For example, forestlands notably provide water supply, pollination, biological control and disturbance regulation.

In order to analyze the value of ecosystem services present in Clallam County, multi-layered GIS data was utilized to differentiate distinct land cover types. Data was obtained from the National Land Cover Database (NLCD). The NLCD 2006 is a 16-class land cover classification scheme that has been applied across all 50 United States and Puerto Rico at a spatial resolution of 30 meters.[148,149]

Table 8 presents a breakdown of the ecosystems by land cover type and habitat for the nearshore study area, which includes a 200 feet buffer back from the shoreline. Open water covers 42% of the study area; total forestland (predominantly evergreen forest) covers 18%; 17% of the area is wetland; barren land including rock, sand and clay covers 11%. Four percent of the nearshore study area is developed (1,066 acres).

Using data from the wetland database, we were able to further define the marine wetland and water classes. The area reported is breakdown of the open water and wetlands land cover classes reported above. The area does not include additional acreage, but provides detail on the area for coastal wetlands (2,121 acres), which covers 8% of the study area.

Table 7. Land Cover Types by area for the entire Clallam County (NLCD 2006)

Land Cover Type	Area (acres)	Percent of total land cover
Open Water	594,355	35%
Forest	857,691	50%
Barren Land (Rock/Sand/Clay)	14,344	0.8%
Woody Wetlands	21,110	1.2%
Emergent Herbaceous Wetlands	5,889	0.3%
Developed	37,949	2.2%
Shrub/Scrub	123,248	7.2%
Grassland/Herbaceous	34,231	2%
Pasture/Hay	21,677	1.3%
Cultivated Crops	608	0.03%
Total	**1,711,102**	**100%**

Table 8. Land Cover Types by Area for the Nearshore Study Area (NLCD 2006)

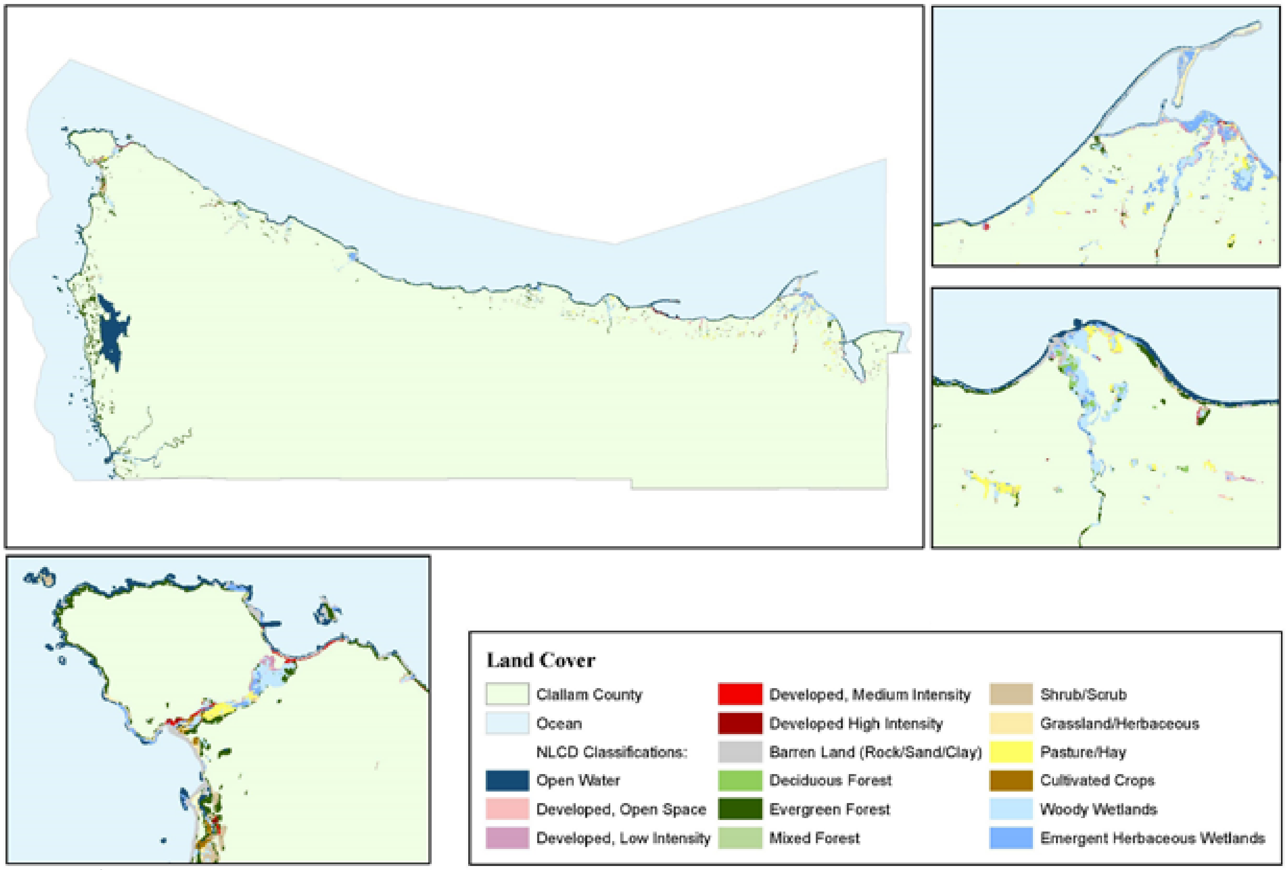
Land Cover Type	Area (acres)	Percent of total land cover
Open Water	11,696	42%
Forest	4,985	18%
Barren Land (Rock/Sand/Clay)	3,026	11%
Woody Wetlands	2,702	10%
Emergent Herbaceous Wetlands	1,978	7%
Developed	1,066	4%
Shrub/Scrub	796	3%
Grassland/Herbaceous	722	3%
Pasture/Hay	726	3%
Cultivated Crops	86	0.03%
Total	**27,783**	**100%**

Secondary values for the entire count were calculated using the benefit transfer valuation method. Fifteen ecosystem services were valued over 12 land cover types: cultivated crops, forests, fresh water, grasslands, marine, marine wetlands, pasture, riparian buffer, sea grasses/algae beds, shoreline, shrub and wetlands. A description of each of the land covers is provided in Table 5, referenced with NLCD categorization descriptions.

Table 9. Marine Ecosystem Types by Area for the Nearshore Study Area

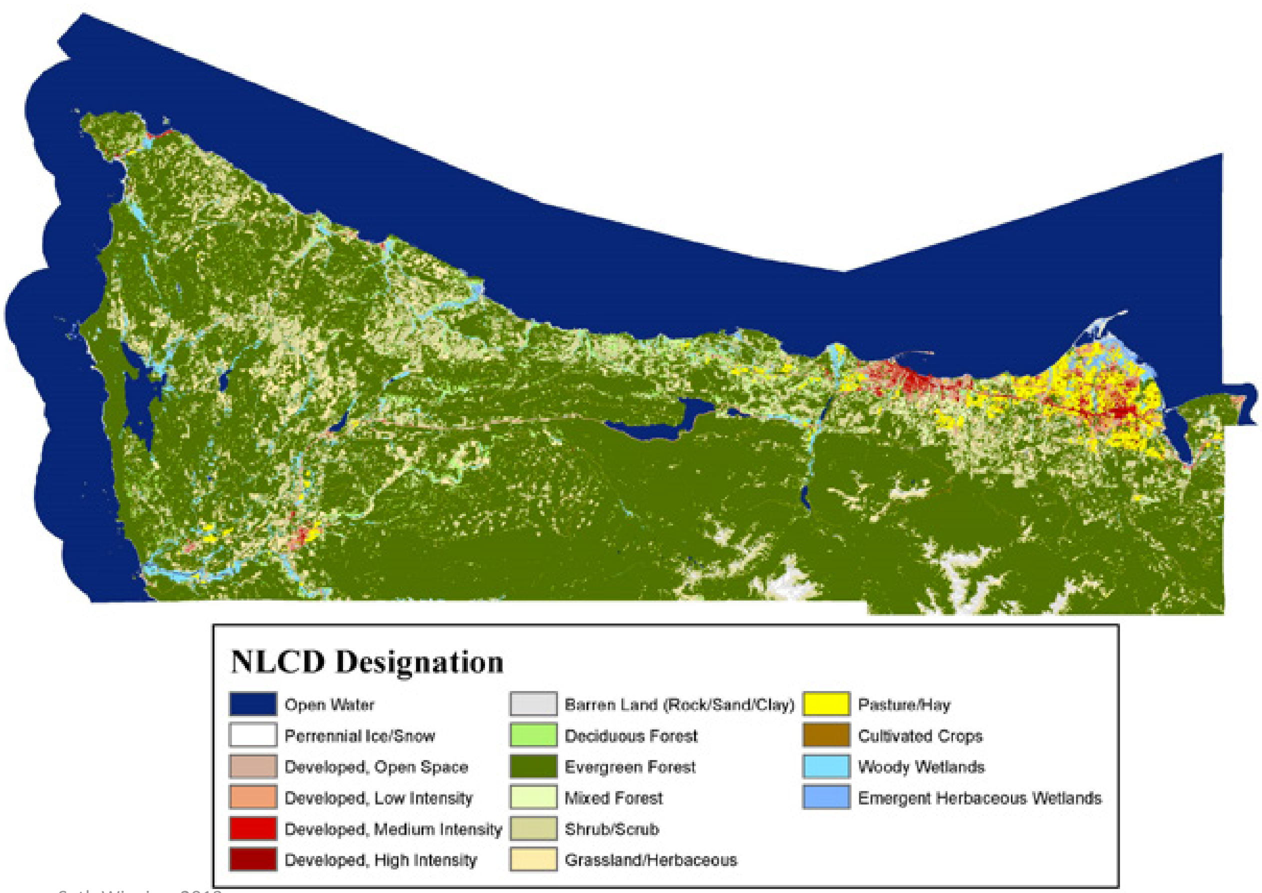
Land Cover Type	Area (acres)	Percent of total marine cover
Estuarine and Marine Deepwater	374	1.3%
Estuarine and Marine Wetland	2,121	8%
Beach estimate	3,915	14%

Figure 11. A visual illustration of the nearshore land cover and ecosystem types along the shoreline of Clallam County



Source: Seth Wiggins, 2013

Figure 12. Clallam County divided into all land cover types-only 12 of which are valued



Source: Seth Wiggins, 2013

Primary Values for Nearshore Ecosystems

The following results are a preliminary estimation for a few of the economic values of the ecosystem services provided by the nearshore ecosystems in Clallam County. The values provided are preliminary because of the limited information and site-specific bio-physical data available for primary valuation. The list of ecosystem services that are valued in this study is provided in Table 10. Direct use values refer to benefits obtained from the direct use of ecosystem goods and services. Direct use values include extractive ecosystem goods that are generally consumed such as food and raw materials, as well as non-extractive ecosystem goods and services such as recreational benefits. Indirect use values are generally public services that usually do not have market prices associated with them. Indirect use values include regulating services such as water quality and climate stability. In addition, there are option values and non-use values. Option values, which refer to the future use value of an ecosystem service, are mostly excluded from ecosystem valuation assessments because of the difficulty of assessing the potential future use of an ecosystem component (potential medicinal use of plant). Non-use values refer to the values that individuals place on the knowledge that biodiversity and ecosystems will be maintained (existence value), as well as that other people will have an opportunity to experience them in the future (bequest value).

Feeder Bluff Values

Feeder Bluff-Supportive Value

Clallam County's shoreline features evolve and change in response to sediment erosion and deposition caused by bluff erosion, retreat and landslides. As mentioned above, bluff erosion and landslides provide sediment to the county's shoreline beaches in large quantities.

Although erosion processes can be costly for built infrastructure along the coast that are close to the bluff edge, properly functioning drift cells create and maintain the nearshore habitats that are necessary for salmon, shellfish and other fish. For example, forage fish (sand lance and surf smelt) depend on beaches with mixed sand and pea gravel for spawning. Littoral drift of eroded sediment from feeder bluffs is thus directly linked to the maintenance of forage fish spawning habitat and their reproductive success along the county's coast. Forage fish are key species that support salmon populations. In addition, the transfer of sediment to beaches allows eelgrass beds to thrive in the low tide terraces. Eelgrass beds are important habitat for migrating salmon and critical spawning beds for herring.

Table 10. List of Ecosystem Services with Value Estimates for Study Area

Ecosystem Services Assigned Value	Land Cover Types	Type of value
Bluff sediment transfer	Feeder bluff	Indirect
Habitat	Coastal nursery	Indirect
Carbon storage	Forest, freshwater wetland, saltwater wetland	Indirect
Carbon sequestration	Saltwater wetland	Indirect
Recreational fishing	Shoreline and associated waters	Direct
Commercial fishing	Shoreline associated waters	Direct

Valuation Method

In order to monetarily value sediment transfer provided by feeder bluffs, we used preliminary average annual bluff sediment volume (yd^3/yr) rates, between 2001 and 2012, for the Dungeness and Elwha drift cells provided by Department of Natural Resources Engineering Geologist, Dave Parks. The original data estimated for Dungeness sediment contribution rate of 3.0 ($yd^3/ft/yr$), for Elwha, 2.1 ($yd^3/ft/yr$). Converting this data to tons, the current estimated average rate of sediment transfer is 0.81 tons/foot/year in the Dungeness drift cell and 0.567 tons/foot/year in the Elwha drift cell.[150] It should be noted that the data shows that the average rate of sediment transfer is lower in the armored portions of the Elwha drift cell (0.297 tons/foot/year compared to the unarmored portions (0.945 tons/foot/year).

The monetary value for sediment transfer within the drift cells was based on the cost of beach nourishment for Ediz Hook. The estimate from the county set the cost of beach nourishment between $500,000 to $1 million for 50,000 tons of beach material.[151] Based on this cost the value of the natural sediment transfer provided by feeder bluffs was estimated between $10-$20 per ton of beach sediment.

Results

Using this $10-$20 range, we estimated the value of sediment transfer was $8.10 to $16.20/foot/year for the Dungeness drift cell, and $5.67 to $11.34/foot/year on average for the Elwha drift cell. The armored portions of Elwha had an estimated value of $2.97 to $5.94/foot/year, whereas the unarmored portions had an estimated value of $9.45 to $18.90/foot/year.

The sediment transfer value along the Dungeness drift cell is **$253,449 to $506,898 per year.** For the Elwha drift cell (armored and unarmored) the economic value is **$99,360 to $198,720.**

We can also estimate the different values of sediment transfer in the Elwha drift cell of armored and unarmored portions. Armored portions contribute annually approximately **$28,215 to $56,430, while unarmored portions contribute $61,425 to $122,850.** E ven though the length of armored shoreline in Elwha drift cell is larger (9,500 ft) than unarmored shoreline (6,500ft), the economic contribution of unarmored feeder bluff in this area is noticeably higher.

Feeder Bluff-Structural Value

The value of the feeder bluffs was calculated using the amount of sediment feeder bluffs deposit along the shoreline. However, the calculation of the feeder bluff's total value would be incomplete without consideration of their structural value. Although the structural value explained below will not be included in the feeder bluff calculation these values are still important to mention because they represent the avoided cost of damages or destruction to the actual shoreline and to the properties and infrastructures built on that shoreline. These damages may be caused by natural disasters, storm surges, climate change, or other factors.

Ediz Hook is a three-mile spit that extends into the Strait of Juan de Fuca west of Port Angeles. Located at the base of Ediz Hook, Nippon Paper is a leading manufacturer of paper and pulp products and an important member of the business community of Port Angeles. The total assessed value of Nippon Paper in 2012 was $21,379,561 based on Clallam County Assessor & Treasurer's assessment.[152] The assessed value of the mill was not the sole amount taken into account; the positive impact for the Port Angeles community was also measured. Employing 210 fulltime personnel, Nippon Paper operates with an annual payroll of $24 million in addition to benefits. Moreover, the majority of Nippon Paper's approximately $65 million in annual purchases directly benefits Clallam County companies. This annual expenditure translates to $260 million in economic value to the local area using the Washington Input Output model.[153] Undergoing the construction of a new $85 million dollar cogeneration plant,[154] the mill is dependent on the calm waters of the harbor for their continued growth. Built directly on the shoreline of Ediz Hook, Nippon Paper profits from the sheltering the spit provides.

The US Coast Guard has also been a direct beneficiary of Ediz Hook since the commission of their air station on the spit in 1935. Built on the end of Ediz Hook, the US Coast Guard air-sea rescue station utilizes its strategic position to carry out over 400 search and rescue missions yearly, saving on average 75 lives and $2 million in property per year and assisting over 500 individuals.[155] The rescue station employs over 300 people.[156] Recognizing that the net deficit of sediment to wave action was around 180,000 cubic yards per year if left to natural forces,[157] the Army Corps has expended funds to protect the hook. Authorized to place 100,000 cubic feet of sediment on the hook every five years to prevent sediment loss, the Army Corps has experienced a lack of funding to re-nourish the beach.[158] Averaging $100,000 in maintenance expenditures yearly, the Army Corps engaged in re-nourishment projects of about 30,000 cubic yards in 1985, 1991, and 1997.[159] The most recent contract in 2011 was billed for $636,000 in order to place 50,000 tons of cobble and gravel on 52,000 linear feet of beach.[160] All of these maintenance expenses have been a costly effort to replace the natural sediment flow halted by the construction of the Elwha and Glines Canyon Dam and shoreline armoring. The removal of the dams is expected to increase sediment flow by 50,000 cubic yards per year and reduce spit maintenance costs by at least $28,000.[161]

Ediz Hook's most valuable contribution is the large, natural protected deep-water port that the narrow sand spit protects from storms and ocean swells. The Port Angeles Harbor, which is deep enough to allow anchorage for ocean- bound ships, offers ferry service that links the city to Victoria, British Columbia, and the rest of Canada. The businesses that utilize the Port hire over 1,600 people and have business revenue of over $160 million. Indirectly, the benefits to the greater Clallam County area are 3,500 jobs and $90 million in revenue.[162]

Feeder Bluff Value Related to Landslide Occurrence

Shorelines are constantly changing ecosystems. In a process similar to rivers facilitating the flow of water, shorelines regularly transfer sediment along beaches. The deposition of sediments also helps stabilize slopes by widening the beach at the base of bluffs and limiting erosion from wave run-up. This process helps to regulate the rate of land sliding. Landslides pose a risk to humans and ecosystems, not to mention the economic resources spent on mitigation of natural disasters. If shoreline nourishment were constant at an average rate, the shoreline would be less prone to natural disasters such as landslides and less tax dollars would be spent on ameliorate damages.

> In 1998, the Aldercrest-Banyon landslide alone damaged or destroyed 138 homes and accounted for $30-40 million in losses.

Therefore landslides and feeder bluffs are integrally linked. A landslide is a natural geological phenomenon that occurs as a result of ground movement, such as rockfalls, deep failure of slopes and shallow debris avalanches and/or flows. These ground movements can occur in offshore, coastal and onshore environments and contributing factors, such as gravity, affect the original slope stability.[163] Typically, pre-conditional factors build up specific sub-surface conditions that make the area prone to failure, but the actual landslide often requires a trigger before the flow begins. Landslides are complex, often manifesting themselves in numerous different ways, from small shallow slumps and rock topples to deep-seated landslides. Understanding landslide behavior allows scientists to develop landslide mitigation techniques and determine future hazards for roads, houses and infrastructure.[164]

> During the first two weeks of March 2009, 1,500 landslides damaged or destroyed an estimated 200 homes and buried sections of 150 highways, compelling FEMA to hand out over $7 million in assistance.[168]

Population growth has expanded development into once sparsely populated rural forests and agricultural lands. Coupled with more frequent and intense storm events, mapping and understanding landslides can greatly reduce impacts to infrastructure, loss of life, and property. Although we do not have an exact estimate of the precise damage landslides have caused in Washington, rough estimates from other large storm systems and earthquakes total to billions of dollars. Therefore, the potential damage from landslides is tens to hundreds of billions of dollars.[165] Nationally, landslides account over $2 billion of loss annually and result in an estimated 25 to 50 deaths per year. The direct costs include the repair of roads and property. The associated indirect costs, such as loss of property value and tax revenue, and environmental effects, such as degradation of water quality, can greatly exceed direct costs. To pay for these direct costs, the Washington Department of Transportation routinely budgets $15 million a year for highway cleanup after landslides.[166]

> In 2013, a landslide on Whidbey Island affected more than 30 homes. The amount of earth that fell into the Sound was the equivalent of 40,000 dump-truck loads of earth. The official damages report has yet to become public, but the majority of the homes affected were not insured against landslide damage. The additional insurance to cover a $300,000 home against a landslide costs about $1,000 annually, depending on the slope of the land and/or proximity to a cliff.[169]

Landslides in Washington State occur frequently during intense rain events. Earthquakes can also trigger landslides; the 1949, 1965 and 2001 earthquakes caused numerous landslides throughout the Puget Sound basin. Other potential landslide events in Washington State can be caused by diminished vegetation, rain-on-snow events and human development on hazardous slopes. Washington's population growth, largely from in-migration, is causing increasing pressures to develop in landslide-prone areas, so knowledge about these hazards has never been more important.[167]

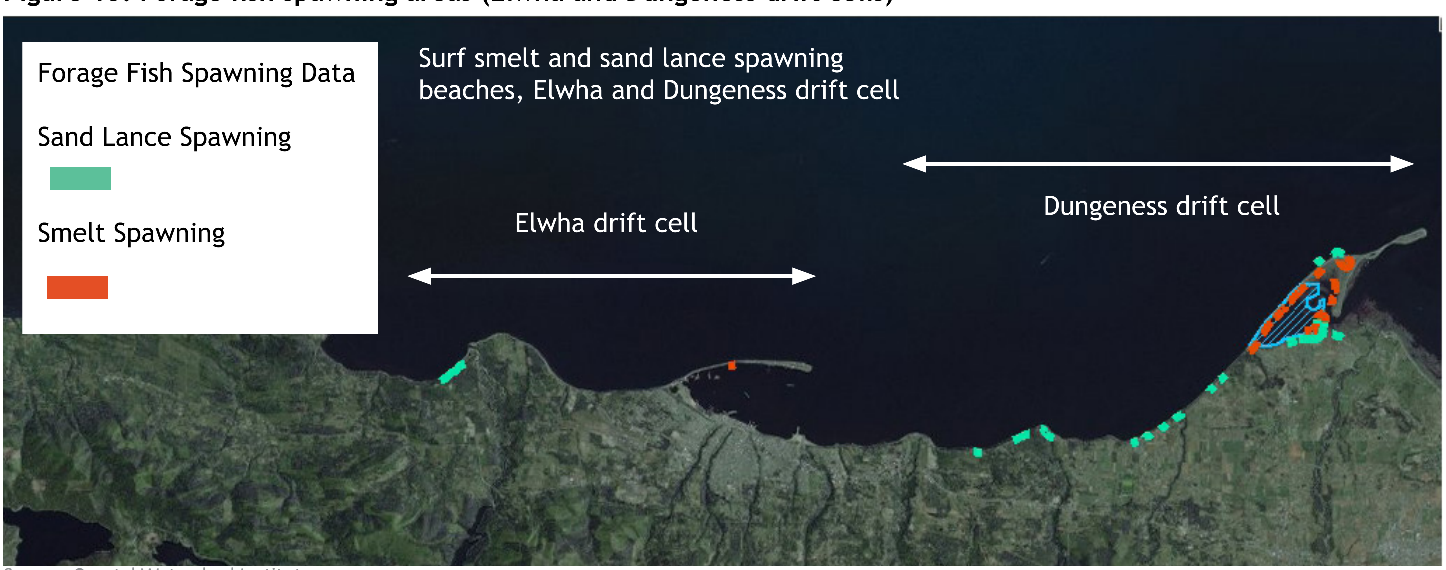
Forage Fish Supportive Value

We have derived values to estimate the value of supportive forage fish, which are dependent on the fine-sediment rich beaches of the region, as well as the associated coastal habitat values. Forage fish inhabit the shoreline where feeder bluffs provide fine sediment.[170]

Forage fish are small to medium sized species, including anchovies, pacific herring, menhaden, surf smelt, sand lance and sardines. These species, among many others, are food for marine predators and other commercially important larger fish species. The species represented by this valuation were surf smelt (hypomesus pretiousus) and sand lance (Ammodytes hexapterus). These are two intertidal sand spawning forage fish that our partners at the Coastal Watershed Institute monitor, although there are other species. In Clallam County about 48% of the forage fish found in intertidal sand is sand lance, while the other 52% is surf smelt divided into about 5 different species: euchalon, longfin, caplin, night and rainbow. Herring is also a common forage fish species that spawn on eelgrass beds.

A global study undertaken by the Lenfest Ocean Program estimated the value that forage fish provide to other fisheries.[171] The total global supportive value was reportedly $11.3 billion per year in 2006. The estimate of supportive fish value is considered an underestimate given its exclusion of predators with no commercial value, but an important part of the food chain, such as: catch, seabirds and marine mammals. This value also excludes the economic value of recreational fisheries, ecotourism, and ecosystem services such as water filtration.[172] In order to adopt this monetary value ($11.3 billion per year) across ecosystem types, the study provided average values for different ecopath models separated into different latitudes. Each ecopath model needed to represent a marine or estuarine ecosystem and have all fish data available. The latitude groupings consisted of three categories: tropical-subtropical (< 30° N – < 30° S), temperate (≥30° N – 58° N and ≥30° S – 58° S), and high latitude (>58° N and > 58° S).[173] For more information on these values please refer to the Lenfest Report.[174]

Figure 13. Forage fish spawning areas (Elwha and Dungeness drift cells)



Source: Coastal Watershed Institute

Valuation Method

For this valuation we used the average supportive value for high-latitudes, $631/km^2/year (2006$). To estimate the supportive value of forage fish, we converted this value to dollars per acre ($631/km^2/year/247.105 = $2.55/acre/year), and then inflated this value to 2012$ ($2.90/acre/year).

Results

In Clallam County herring usually spawn on certain areas with eelgrass. However, herring and many other species of forage fish depend extensively on kelp beds for migrating. Therefore, using available land cover data for Clallam County nearshore area, there are 6,677 acres of kelp and 215.7 acres of eelgrass (Dungeness and Elwha drift cell only).[175] We applied the forage fish supportive value from Lenfest Ocean Program ($2.90/acre/year) to the total acreage of eelgrass and kelp present in Clallam County. The total supportive value of herring is an estimated **$20,000 per year.**

Surf smelt and sand lance are two common forage fish species found in the Clallam County nearshore. Although unlike herring, both sand lance and surf smelt spawn in intertidal sands. In total for spawning areas of both sand lance and surf smelt there are 28.02 acres present in Clallam County (about 4.8% of the total shoreline). At this time, it is impossible to provide a complete economic ecosystem service value to the functions forage fish provide to the entire ecosystem, due to the lack of methodology and economic data available to conduct the valuation process.

However, important research on abundance and spawning areas of forage fish has been conducted in Clallam County spearheaded by the Coastal Watershed Institute. Given the essential component forage fish represent for the entire nearshore, research on important spawning areas is vital for the fish survival and the overall health of the nearshore. Table 11 presents the area per specific location along the Clallam County shoreline where spawning grounds for surf smelt and sand lance have been documented.

A fundamental part of this project is the focus on two drift cells within the county shoreline: Elwha (Freshwater Bay) and Dungeness. Documenting the abundance of forage fish species and habitat creation at these locations is vital given the increasing development pressure at both these locations. Table 11 summarizes the results of the extensive research on forage fish populations. Figure 13 is the visual representation where spawning sites along the Elwha and Dungeness drift cells were documented.

Table 11. Spawning areas for surf smelt and sand lance along the Clallam County shoreline

	Location				
Spawning areas (ft²)	Elwha - Freshwater Bay	Dungeness Drift cell	Sequim Bay	Western Strait	Total
Surf smelt (ft²)	66,700	404,040	8,000	186,000	664,740
Sand lance (ft²)	20,000	240,000	324,000	40,000	624,000
				Total Spawning Area in Clallam County (ft²)	***1,228,740***

The results provided in table 12 indicate that Dungeness Bluffs are consistently used for spawning by surf smelt. In the 2013 study, spawn density was highest in June but early state eggs were found in September, indicating that spawning along Clallam County shorelines possibly extend into October. These results affirm similar results from surveys taken in 2008 and Parks et al (2013). In all cases the results conclude that not only bluff sediment volume is a critical element to include in proper feeder bluff management, but also the feed rate, composition, and timing of sediment deposition. These data also show that, as the Elwha dam removal project proceeds, surf smelt continue to use the Freshwater Bay shoreline of the Elwha drift cell for spawning, and this reach continues to be the only area in the Elwha drift cell that can support surf smelt spawning. As the dam removal project proceeds and sediment flows continue, forage fish spawning habitat should increase, however this increase is likely to be temporary if additional efforts to enable more sediment capture along the shoreline are not taken immediately.

Economic values of benefits regarding the abundance of forage fish spawning areas created by sediment or the impact of further degradation of Elwha bluffs shoreline in the face of this restoration event cannot be quantified at this time. This is due in part to the lack of economic methodologies to relate biological process with economic benefits and the lack of time to develop these and more related primary data.

In summary, these results affirm that surf smelt spawning along Clallam County shorelines, and specifically protection of spawning habitat along Dungeness Bluffs and Freshwater Bay, and restoration actions along Elwha Bluffs reaches, are important factors to include in future ecosystem valuation of the nearshore- a top priority for further development.

Table 12. 2013 Elwha and Dungeness Surf smelt spawn survey summary of total number of eggs and (percent relative composition) by development stage by reach. Data provided by Shaffer and Harris, Coastal Watershed Institute.

Date	Site	Total # of eggs	1 cell to morula	Blastula	Gastrula	1/2 - 1 coil	1 coil	1 - 1 1/2 coil	> 1 1/2 coil	Late eyed	Dead	Est. # broods (average)
Jul	D bluffs	410	0	19 (5)	5 (1)	178 (43)	28 (7)	25 (6)	11 (3)	0	144 (35)	2
Aug		117	0	3 (3)	0	16 (14)	22 (19)	24 (21)	9 (8)	1 (1)	42 (36)	2
Sep		69	0	9 (13)	0	7 (10)	4 (6)	2 (3)	1 (1)	0	46 (67)	1
Jul	D Spit	3	0	0	0	0	0	0	0	0	3 (100)	1
Aug		1	0	0	0	0	0	0	0	0	1 (100)	0
Jul	FW Bay	2	0	0	0	0	0	0	1 (50)	0	1 (50)	1
Aug		7	0	1 (14)	2 (29)	2 (29)	0	2 (29)	0	0	0	1
Sep		12	0	0	0	0	9 (75)	0	0	0	3 (25)	1

* Site abbreviation: D Bluffs (Dungeness Bluffs), D Spit (Dungeness Spit) and FW Bay (Fresh Water Bay-Elwha)

Coastal Nursery Habitat Values

Habitat ecosystem services highlight the important role that ecosystems play in providing habitat for all species, especially migratory species, and in maintaining the viability of gene pools. Habitats provide the necessary conditions, such as space, cover, food and water, to sustain life. Humans derive value from the habitat services provided by ecosystems including the existence values associated with wildlife, food provisioning services and outdoor activities such as wildlife viewing and bird watching.

The shores along Clallam County's coastline provide critical nearshore habitat functions and values for the region's fish and wildlife. Coastal bluffs are the primary source of beach sediment, which is essential for maintaining beaches and associated nearshore habitats. Critical habitats dependent on these functioning coastal systems include coastal forests, spawning beaches for forage fish (i.e. surf smelt and sand lance), migratory corridors including kelp, eelgrass beds and salt marshes. All of these habitats support the local salmon populations as well.

Valuation Method

The estimates for habitat are transfer values from a global meta-analysis and literature review of 320 ecosystem service valuation studies. A 2012 study by de Groot et al. reported an annual average value of $10,648 per hectare for nursery habitat provided by saltwater wetlands per year, and $194 per hectare for coastal systems (includes estuaries, continental shelf area and seagrasses; 2007$).[176]

Results

To estimate the value of the study area, we converted these values to dollars per acre. The value for nursery habitat provided by salt wetlands ($4,774/acre/year) was applied to the saltwater wetland area (2,121 acres in Clallam County) for a total value of **$10.1 million per year.** The value for nursery habitat provided by coastal systems ($86.97/acre/year) was applied to the area of nearshore estuaries and marine deep-water area (374 acres), the kelp and eelgrass area (6,893 acres; eelgrass area is only for Dungeness and Elwha drift cell area) and the estimated nearshore beach area (3,915 acres), for a total value of **$972,419 per year.**

Climate Stability and Carbon

Coastal habitats store large amounts of carbon in their vegetation, sediments and soils. This stored carbon is often referred to as coastal blue carbon. If these habitats are converted or disturbed, the carbon can be released into the atmosphere in the form of greenhouse gases.

Blue carbon sequestration and storage involve three components:

- Annual sequestration rate, which is the yearly flux of organic matter transferred into soils;
- The total carbon stock stored in soils as a result of prior sequestration, which is a function of the soil carbon density;
- The depth of the organic soils beneath these ecosystems.

The economic value of carbon can be estimated based on several different valuation methods including the avoided costs of the predicted impacts of climate change (i.e. damages avoided due to avoiding the release of carbon from a forest), the replacement cost, or the market price of carbon trading. Typically, policymakers use an estimated social cost of carbon (SCC) or shadow price of carbon to assess the economic benefits of climate change mitigation and other related policy options from an avoided cost perspective.[177] Avoided costs reflect the actual damages avoided in terms of the predicted impacts of climate change due to rising concentrations of carbon dioxide in the atmosphere. There are also government-set carbon prices that take the form of a cap and trade program or carbon tax. The carbon tax or offset price is sometimes set as a marginal abatement cost representing the cost to abate one ton of CO_2 towards achieving an emission reduction target.

Valuation Method

In order to estimate the value of carbon for this study, an average value was calculated based on the U.S. EPA estimates of SCC. The federal government conducted an inter-agency consultation to develop a SCC estimate to be used in cost-benefit analyses of U.S. federal regulations. The SCC values adopted by the US government study ranged from $5 to $65 per ton of CO_2 (2007 U.S. dollars) based on different climate modeling scenarios. The central SCC for 2010 was reported as $21.40 per ton of carbon dioxide in 2007 U.S. dollars.

Results

To estimate the value of carbon, we converted the value to dollar per ton of carbon ($21.40*3.67=$78.54/tC), and inflated this value to 2012 US dollars ($86.97/tC). This average dollar value per ton of carbon, $86.97/ton of carbon was multiplied by the average tons of carbon per hectare of ecosystem for each land cover type that sequesters and stores carbon. Given that the stored carbon is measured at a fixed point in time, we considered the carbon storage value as a carbon annuity similar to a carbon annuity account (CAA). A CAA is an account where the full carbon price is made directly into an annuity account, and as long as the carbon sink (natural feature which absorbs carbon) remains in place, the carbon provides an annual earning/value from the annuity account.[178] This value was calculated using an annuity coefficient based on an interest rate of 3% over 50 years, to estimate the annual value of the carbon storage.[iii]

Saltwater Wetland Carbon

Salt marshes are intertidal wetland ecosystems found on sheltered coastlines that occur from the sub-arctic to the tropics, though they are most prominent in temperate zones. Salt marshes are key ecosystems within nearshore and estuarine environments. Salt marshes provide important nursery habitat for fish and crustaceans. They also release slow decomposing organic matter, which is a food and energy source for both marine and terrestrial creatures. Salt marshes provide other ecosystem services such as coastal protection due to their ability to dissipate wave action, reducing flooding and erosion.

As intertidal ecosystems, salt marshes accumulate sediments (i.e. sediment accretion), which make them adaptable to sea level rise. As they accumulate sediments, the total amount of stored carbon increases. The saline environment of salt marshes inhibits the creation of methane (CH4), making their net annual carbon sequestration rates greater than freshwater wetlands.

The peaty organic soils underlying salt marshes can range in depth from less than a half a meter to over seven meters. According to the Nicholas Institute's "State of the Science on Coastal Blue Carbon", estimates for carbon stored in the top meter of salt marsh soil on the west coast is on average, 863 tCO_2e[iv]/hectare (range of 330 to 1,588 tCO_2e/hectare). We converted this average soil carbon content to tons of carbon per hectare (235.4 tC/ha) by dividing 863 by 3.67 (1 tC = 3.67 tCO2), and then converted to tons of carbon per acre (235.4 tC/ha/2.47 = 95.3 tC/acre).[v]

[iii] Given that stored carbon is measured at a fixed point in time, we considered the carbon storage annual value as a carbon annuity similar to a carbon annuity account (CAA). A CAA is an account where the full carbon price is made directly into an annuity account, and as long as the sink remains in place, the carbon provides an annual earning/value from the annuity account. This value was calculated using an annuity of 3% over 50 years, which is an average discount rate and term of annuity. Three percent is the average rate used for carbon values by U.S. EPA analysis. http://www.epa.gov/climatechange/EPAactivities/economics/scc.html

[iv] Tons of CO_2 equivalent: Measure that describes the global warming effect specific greenhouse gas has, using as a reference the equivalent concentration of CO_2.

[v] Based on six observations from study areas along the California coast. Sifleet, S., Pendleton, L. and Murray, B.C. 2011. State of the Science on Coastal Blue Carbon: A Summary for Policy Makers. Nicholas Institute for Environmental Policy Solutions. Report NI R 11-06. Duke University.

In addition, the global measurements of annual carbon sequestration rates for salt marshes range from 0.6 to 68.6 tons of CO_2/hectare/year (0.2 to 27.8 tCO_2/acre/year), based on 122 observations from North America and Western Europe.[179] Measurements for the annual carbon sequestration rate for salt marshes on the U.S. west coast provide a range of 1.4 to 14.1 tons of CO2e/ha/year (average of 6.33 tCO_2e/ha/year), or 0.6 to 5.7 tCO_2/acre/year (average of 2.6 tCO_2/acre/year)[vi]. The carbon stored in the biomass of salt wetland sites reportedly ranges from 5.1 to 18.3 tons of CO_2 per hectare (average of 11.7 tCO_2/ha), or 2.1 to 7.4 tons of CO2 per acre (average of 4.7 tCO_2/acre).

Valuation Method

To estimate the value of the carbon stored by salt marshes, the average carbon value of $86.97 per ton of carbon (see Carbon Valuation Section) was multiplied by the amount of carbon stored per acre (235.4 tC/ha/2.47=95.3 tC/acre) for an estimated $8,287 per acre.

We converted the U.S west coast average annual carbon sequestration rate to tons of carbon per hectare (6.33 tCO_2e/ha/year/3.67=1.7 tC/ha/year; 1 tC = 3.67 tCO2), and then to tons of carbon per acre (1.7tC/ha/year/2.47= 0.7tC/acre/year), to estimate the value of carbon sequestration by salt marshes in the study area. The average carbon value of $86.97 per ton of carbon (see Carbon Valuation above) was multiplied by 0.7 tC/acre/year to estimate the value of annual carbon sequestration by salt marshes as $60.79/acre/year.

In addition, the carbon stored in the biomass (i.e. plants) of salt wetland sites is an average of 1.3 tC/acre. The value of this carbon per acre is $112.35/acre, based on our carbon value (SCC of $86.97/tC; see Carbon Valuation Section).

Results

The total area of coastal salt marsh in the Clallam County study area is 2,121 acres (estuarine and marine wetland). In sum, based on our data, the average soil carbon stored per acre is 95.3 tons of carbon and the annual value is $322/acre/year for carbon stored.

As a result, we estimate that 202,072 tons of carbon is stored in the upper one-meter of soil-sediment in the study area's salt wetlands, which is worth **$17.6 million today.** Annualized over 50 years, this stored carbon is worth **$683,031 each year.**

The yearly carbon sequestration rate is estimated to be 0.7 tC/acre/year, which is worth $60.79/acre/year. Thus, an additional 1,482 tons of carbon are sequestered each year by the study area's salt wetlands, worth **$128,905 each year.**

Lastly, the carbon stored in the biomass (i.e. plants) of salt wetland sites is an average of 1.3 tC/acre. The value of this carbon per acre is $112.35/acre, Given that the study area's salt wetlands cover 2,121 acres, we estimate that they store 2,740 tons of carbon, which is worth a total of **$238,260 today**. Annualized over 50 years, this stored carbon is worth $9,260 each year.

The combined total value of carbon stored in soils, carbon stored in the wetland plant biomass and annual carbon sequestered is $387 per acre per year, and the total value for the study area's salt wetlands is **$821,195 each year.**

[vi] Average of 5 studies along west coast of California

Seagrass Carbon

Seagrasses are flowering plants that grow in shallow marine and estuarine habitats with mostly soft substrates and wave-sheltered conditions. They provide a wide range of ecosystem services including raw materials, food, coastal protection, erosion control, water purification, carbon sequestration, fish habitat, as well as tourism and recreational values.

Eelgrass (Zostera marina) is a marine flowering plant that is often used as an indicator of estuarine ecosystem health. Eelgrass beds provide essential nearshore habitat for many marine species; however there has been a declining trend for eelgrass in the greater Puget Sound. In 2009, there were an estimated 54,363.2 acres +/- 8,895.8 acres (22,000 (+/- 3,600) hectares) throughout Puget Sound.

Eelgrass beds provide complex habitat that supports a diverse web of species including fish, invertebrates and waterfowl. They provide spawning grounds for Pacific herring, out-migrating corridors for juvenile salmon, and feeding and foraging habitats for waterbirds (i.e. black brant, great blue heron). They also produce oxygen, dampen wave energy, absorb nutrients and promote organic matter mineralization and sedimentation.[180]

Global estimates for carbon stored by seagrasses range from 880 to 6,000 tons of carbon per hectare (average 3,440 tC/ha), or 356 to 2,429 tons of carbon per acre (average 1,392.7 tC/acre) for soils. For biomass, from 0 to 13 tC/ha (average 6.5 tC/ha), or 0 to 5.3 tons of carbon per acre (average 2.6 tC/acre). The combined average total for carbon stored in biomass and soils is an estimated 3,447 tC/ha or 1,395.3 tC/acre.

Valuation Method

To estimate the value of carbon stored by seagrasses we converted this average to tons per acre (3,447/2.47= 1,395 tC/acre). The total area for eelgrass was reported for the Elwha and Dungeness nearshore area as a total of 215.7 acres (87.3 hectares). We applied the average ton of carbon per acre to this area to estimate a total of 300,905 tons of carbon stored.

Results

The value of seagrasses for storing carbon in Clallam County is worth **$26.2 million.**

Annualized over 50 years, the value of carbon stored is **$1 million per year.**[vii]

[vii] Given that the stored carbon is measured at a fixed point in time, we considered the carbon storage value as a carbon annuity similar to a carbon annuity account (CAA). A CAA is an account where the full carbon price converted into an annuity account, and as long as the sink remains in place, the carbon provides an annual earning/value from the annuity account. This value was calculated using an annuity of 3% over 50 years, which is an average discount rate and term of annuity. Three percent is the average rate used for carbon values by U.S. EPA analysis. http://www.epa.gov/climatechange/EPAactivities/economics/scc.html
Calculation: ($8,287/acre*0.03887)

Forest Carbon

Carbon benefits include both the storage of carbon and the annual sequestration of carbon. Forest carbon storage refers to the total amount of carbon contained in an ecosystem biomass and soils at a given time. Carbon sequestration refers to the process that removes carbon from the atmosphere and accumulates it as storage. Trees remove carbon dioxide (CO_2) from the atmosphere and convert it into organic compounds, such as cellulose and lignin – the main components of wood. About half of each kilogram of wood is carbon and every kilogram of carbon that is in a tree represents about 3.7 kilograms of CO_2 removed from the atmosphere. As a result forests have the ability to reduce the build-up of atmospheric greenhouse gases and contribute to efforts to reduce global climate change. Carbon storage is reported as a weight in terms of tons of carbon per hectare, and carbon sequestration is reported as a rate of accumulated tons of carbon per hectare per year.

Forests store enormous amounts of carbon in standing trees and in the soil because of their cumulative years of growth.[181] Over half of the global carbon stored in land-based ecosystems is currently stored in forests. According to USDA data, 41.4 billion metric tons of carbon is currently stored in the nation's forests, and an additional 192 million metric tons of carbon are sequestered each year. The additional carbon sequestered annually offsets roughly 11 percent of the country's industrial greenhouse gas emissions. This is the equivalent of removing almost 135 million passenger vehicles from the nation's highways.[182]

Valuation Method

The average carbon stored per acre of forest in Washington State has been estimated at 92.9 tons per acre.[183] The new estimates are based on 2010 data from annual forest inventories that assess carbon storage state by state across the country's federal, state and private forests.
To estimate the value of forest carbon storage ($8,080/acre), the average of 92.9 tons per acre were multiplied by the average U.S. SCC $86.97/ton of carbon (see Carbon Valuation Section). The annuity coefficient applied to the full carbon value was based on 3% earnings over 50 years to estimate the annual value of the carbon storage.[viii]

Results

The value of Clallam County's forests for storing carbon is an estimated $314/acre/year.

The total forest cover in the nearshore study area is 4,985 hectares. Based on the above data and calculations, the total value for carbon stored by forests is **$40.3 million.** The annual value for carbon stored by forests in the study area is **$1.6 million per year.**

[viii] Given that the stored carbon is measured at a fixed point in time, we considered the carbon storage value as a carbon annuity similar to a carbon annuity account (CAA). A CAA is an account where the full carbon price is made directly into an annuity account, and as long as the sink remains in place, the carbon provides an annual earning/value from the annuity account. This value was calculated using an annuity of 3% over 50 years, which is an average discount rate and term of annuity. Three percent is the average rate used for carbon values by U.S. EPA analysis. http://www.epa.gov/climatechange/EPAactivities/economics/scc.html
Calculation: ($8,080/acre*0.03887)

Fresh Wetland Carbon

Wetlands are integral to landscape functions including the carbon cycle, water and nutrient availability, water purification, habitat provision, tourism and recreation. Wetlands store significant amounts of carbon in their rich organic soils and peat. Wetlands globally cover about six to nine percent of the Earth's surface and contain about 35 percent of global terrestrial carbon. In the Clallam nearshore study area, freshwater wetlands cover a total of 2,559 acres.

Valuation Method

Carbon storage by wetlands is estimated based on results from a natural capital value study undertaken on the southwest coast of British Columbia's Lower Mainland watersheds (an area directly north of the Clallam County study area).[184] This study extracted data from the 1996 Canada's Soil Organic Carbon Database for wetland cover types for the study area.[185] The wetlands stored an average of 339.7 tons of carbon per hectare (ranging from 168.7 to 642.3 tC/ha).

We converted the average carbon stored per hectare to tons stored per acre (339.7/2.47= 137.5 tC/acre), to estimate the value of carbon sequestration by wetlands in the study area.

The total area of freshwater wetland in the Clallam County study area is 2,559 acres, according to the NLCD data (total woody wetlands and emergent wetlands minus the area of estuarine and marine wetland).

Results

It is an estimated that 351,974 tons of carbon is stored in the soils of the study area's freshwater wetlands, which is worth **$30.6 million today** ($11,961/acre).

Annualized over 50 years, this stored carbon is worth **$1.2 million each year** ($465/acre/year).

Groundfish, Salmon and Shellfish Commercial Fisheries

Washington State's commercial fishery is the largest U.S. fishery in terms of revenue on the Pacific Coast. NOAA reported that the State had the highest landings revenue in the region with $331 million in 2011, which included $232.7 million for shellfish (70% of the total value). The shellfish total value includes $90.5 million for clams, $83.6 million for crabs, $4.7 million for mussels, and $42.8 million for oysters.[186] An economic analysis for the Washington Department of Fish and Wildlife reported the value of ex-vessel commercial fish landings for Clallam County at $3.1 million, in 2006.[187] Fourty-seven percent of this value was from groundfish catch, ($1,456,700) 20 percent from salmon catch ($603,500) and 34 percent from shellfish ($1,036,100). In addition, the total value includes the value of fish landed at ports in Clallam County from nearshore and deepwater areas. As a result, we focused our value on the values of coastal pelagic species and shellfish. Note that these values are on the low end as they exclude aquaculture and tribal fisheries data, and are based on 2006 data. For example, if we estimated Clallam County's shellfish catch value based on the statistic that five percent of Washington's landed value for commercial fisheries is from the Clallam County nearshore, the estimated landed value for shellfish would be $11.64 million in 2011.[188] This is based on the NOAA reported landed revenue for shellfish in Washington State $232.7 million for 2011. However, we have only used the former value for shellfish in our calculations ($1,036,100; 2006).

In addition, we include the economic impact of the fisheries. The NOAA reported that the economic impacts of Washington's seafood industry (excluding imports) totaled $1.8 billion in sales and $992.7 million in value added, in 2011. This includes $660.3 million in sales by harvesters, $283.5 million in sales by processors and dealers, $127.9 million in wholesalers and dealers, and $700.9 million in sales by retailers. The seafood industry supports a total of 27,022 jobs across these sectors.[189] We used the same statistics that were reported in the preceding paragraph to estimate the economic impact for the shellfish catch for Clallam County. Twelve percent (i.e., the reported percent for shellfish as total value of Washington state's fishery) of the total sales (excluding harvester sales), and value added ($221.5 million, $124.1 million, respectively) for the state was estimated as the value for all shellfish catch, and 5 percent of this value ($6.95 million, $6.2 million, respectively) was estimated for Clallam County.

Valuation Method

In order to estimate the value of coastal commercial fishing for nearshore coastal areas in Clallam County, we used the estimated landed value of shellfish catch $1,179,972 ($1,036,100 inflated to 2012$). In addition, we estimated the economic impact of the shellfish catch for Clallam County at $7.09 million in sales (excludes harvesters sales), and $6.33 million in value added (inflated to 2012$). To estimate the average current value per foot of Clallam County's nearshore shoreline, we estimated the total of $14.6 million, and then ascribed the value to the total shoreline of the county (1,341,120 linear ft).

Results

Using this calculation ($14.6 million/1,341,120 linear ft), the county's nearshore habitats are worth, on average, an annual **$10.88 per shoreline linear foot** in terms of commercial shellfish fisheries landed value, sales and value added.

Salt Water Recreational Fishing

There are several studies that report on the value of recreational fishing for Washington State, including reports by the WDFW and the USFWS. According to an economic analysis commissioned by the Washington Department of Fish and Wildlife, the total net economic value for saltwater recreational fishing within Washington State was $81.8 million in 2006.[190] In addition, the 2006 USFWS survey for saltwater recreational fishing and crabbing reported a total of $120.2 million per year in spending plus $164.3 in individual income, which supported 4,649 jobs for Washington State.[191] A subsequent study reported marine recreational fishing spending for coastal areas only at $44.2 million, which contributed $19.2 million in personal income and supported 586 for the year 2006.[192]

Valuation Method

In order to estimate the value of saltwater coastal recreational fishing for nearshore coastal areas, we used the total economic impact of $63.4 million.[193] To estimate the current value per foot of Clallam County's nearshore shoreline, we inflated the value to 2012 dollars (total value of $72.2 million), and then applied the values to the total shoreline of the state (17,952,000 linear ft).[194]

Results

The total value of saltwater coastal recreational fishing in WA State is therefore estimated to be worth, on average, $4.02 per ft of coast ($72.2 million/17,952,000 linear ft). As a result, we estimated that Clallam County's shoreline and associated nearshore (1,341,120 linear ft) is worth, on average, an annual **$5.4 million** in terms of saltwater recreational fishing.

Summary of Nearshore Values

The values presented in this assessment for the nearshore zone along Clallam County's coast include some of the ecosystem goods and services that are provided by the nearshore ecosystems and habitats. However, valuation for the ecosystem goods and services was limited by the information and data available at the time of the study. These values range from $2.90 per acre per year for forage fish supportive value to $57,480 per mile per year for saltwater commercial fishing (Table 13).

Table 13. Summary Table of Nearshore Ecosystem Service Values, 2012 US$

Clallam County Nearshore Ecosystem Service (200 foot shoreline buffer)	Annual Value (2012 U.S. dollars)	Total Annual Value $/year (2012 U.S. dollars)
Carbon storage - coastal forest	$314/acre/year	$1.6 million
Carbon storage - salt wetlands (1 meter soil depth plus biomass)	$326/acre/year	$138,165
Carbon sequestration - salt wetland	$60.79/acre/year	$683,031
Carbon storage - coastal freshwater wetland	$465/acre/year	$1.2 million
Carbon storage - seagrass (Dungeness & Elwha eelgrass area only)	$4,716/acre/year	$1.0 million
Nursery Habitat - salt wetland	$4,774/acre/year	$10.1 million
Nursery Habitat - estuary/beach/kelp/eelgrass	$87/acre/year	$972,419
Forage Fish Supportive Value (kelp & seagrass area)	$2.90/acre/year	$20,000
Feeder Bluff Sediment Transfer	$8.10-$16.20/foot/year (Dungeness drift cell)	$253,449 - $506,898 (Dungeness drift cell)
	$6.21-$12.42/foot/year (Elwha drift cell)	$99,360 - $198,720 (Elwha drift cell)
	$2.97-$5.94/foot/year (Elwha armored bluffs)	$28,215 to $56,430 (Elwha armored bluffs)
	$9.45-$18.90/foot/year (Elwha unarmored bluffs)	$61,425 to $122,850 (Elwha unarmored bluffs)
Commercial Fisheries (shellfish)	$10.88/foot/year	$14.6 million (shellfish landed value, sales and value added)
Saltwater Recreational Fishing	$4.02/foot/year	$5.4 million (Clallam County total)

Benefit Transfer Valuation - Secondary Values

The following sections include secondary values that were not calculated with primary data. The Benefit Transfer Methodology (BTM) uses values from preexisting peer-reviewed studies researched elsewhere and applies these values to the study area. For this report, the BTM was used to select studies from the Ecosystem Valuation Toolkit database and applied to the entire Clallam County.[195] By assessing the number of acres of each land cover type, a total minimum and maximum per-acre dollar value for 15 ecosystem services was determined. Values were summed across all land cover types resulting in a total annual flow of value for Clallam County.

Benefit Transfer Method

BTM is a widely accepted economic methodology in which the estimated economic value of an ecological good or service is determined by examining previous valuation studies of similar goods or services in other comparable locations. The studies used for the BTM can be from all over the world as long as they are from similar vegetation types and provide services that are present in the study location. BTM limitations are described in detail in Appendix F.

Table 14. Valuation Methods

Avoided Cost (AC)	Value of costs avoided that would have been incurred in the absence of particular ecosystem services. Example: Hurricane protection provided by barrier islands avoids property damages along the coast.
Replacement Cost (RC)	Cost of replacing ecosystem services with man-made systems. Example: Natural water filtration replaced with costly man-made filtration plant.
Factor Income (FI)	The enhancement of income by ecosystem service provision. Example: Water quality improvements increase commercial fisheries catch and incomes of fishermen.
Travel Cost (TC)	Cost of travel required to consume or enjoy ecosystem services. Travel costs can reflect the implied value of the service. Example: Recreation areas attract tourists whose value placed on that area must be at least what they were willing to pay to travel to it.
Hedonic Pricing (HP)	The reflection of service demand in the differential prices people will pay for associated goods. Example: Housing prices along the coastline tend to exceed the prices of inland homes.
Contingent Valuation (CV)	Value for service demand elicited by posing hypothetical scenarios that involve some valuation of land use alternatives. Example: People would be willing to pay for increased preservation of beaches and shoreline.
Group Valuation (GV)	Discourse-based contingent valuation, which is arrived at by bringing together a group of stakeholders to discuss values to depict society's willingness to pay. Example: Government, citizen's groups, businesses come together to determine the value of an area and the services it provides.

The “transfer” refers to the application of derived values and other information from the original study site to a new but sufficiently similar site, like a house or business comparable.[196,197] As the “bedrock of practical policy analysis”,[198] BTM has gained popularity in the last several decades as decision-makers have sought timely and cost-effective methods for valuing ecosystem services and natural capital.[199]

Earth Economics maintains a continually expanding database of published ecosystem service valuation studies for use in benefit transfer studies called SERVES (see http://esvaluation.org). The valuation techniques used to derive the values in the database studies were primarily developed within the disciplines of environmental and natural resource economics. As Table 8 indicates, these techniques include direct market pricing, replacement cost, avoided cost, factor income method, travel cost, hedonic pricing and contingent valuation.

Due to limitations in the range of primary valuation studies conducted on ecosystem services, not all ecosystem services that were identified on each land cover could be assigned a known value from the database. For example, the land cover class “Fresh water” has only been valued for four ecosystem services: air quality and climate stability, aesthetic and recreational value, habitat and biodiversity, and water supply. Yet, areas with fresh water also provide food, raw material, nutrient cycling, and a number of other important benefits. Table 9 provides a matrix that summarizes the suite of ecosystem services identified on each land cover in Clallam County, compared with those actually valued in this study.

A total of 15 ecosystem services were identified in Clallam County across 12 land covers. Valuation was possible for between 2 and 12 services on a given land cover, depending on the available studies. Table 9 suggests that because a large number of ecosystem services (for most land covers) have yet to be valued in a primary study, our valuation provides a significant underestimate of the true value. As further primary studies are added to the database, the known value of ecosystem services in Clallam County will rise.

The large range in values provided represents a baseline appraisal of Clallam County’s natural capital, similar to a house or business appraisal. This appraisal replaces the former estimate of zero that has been the default value of ecosystem services. As further studies are added to the Earth Economics database, and as spatial mapping of ecosystem services is completed, this range in values will narrow. Only a limited range of the known ecosystem services on each land cover were valued in this study, thus the low end of the range provided can be considered an underestimated value. Ecosystem services may also be treated like economic assets, as they provide a stream of benefits over time, similar to bridges, roads or other built infrastructure. Valued as such, a discount rate may be applied to these services, allowing for calculation of the present value (or asset value) of these systems.

Table 15. Ecosystem Services present in Clallam County

	Cultivated Crops	Forest	Fresh Water	Grassland	Marine	Marine Wetlands	Pasture	Riparian Buffer	Seagrass/ Algae beds	Shoreline	Shrub	Wetland
Aesthetic Information	X	X	X	X		X				X	X	X
Air Quality		X									X	
Climate Stability	X	X		X	X	X			X	X	X	X
Energy and Raw Materials					X	X			X			
Food		X			X	X						X
Habitat & Nursery		X	X		X	X			X		X	X
Moderation of Extreme Events	X	X	X	X	X	X		X				X
Pollination	X	X		X			X				X	
Recreation and Tourism	X	X	X	X		X	X			X	X	X
Science & Education		X										
Soil Formation	X	X			X		X	X	X			
Soil Retention	X			X								
Waste Treatment		X		X		X		X				X
Water Regulation		X										
Water Supply	X	X	X		X	X		X				X

Ecosystem Service produced and valued in this study	X
Ecosystem service produced but not valued in this study	
Ecosystem service not produced by land cover type	

Annual Flow of Value of Clallam County

The ecosystem service values for Clallam County were converted to 2011 US Dollars, and presented in units per acre per year, representing the annual flow of values generated by a single ecosystem. Combining all the available ecosystem services for one land cover yield a total value in dollars. For example, one peer reviewed scientific paper valued climate stability in cultivated crops at $10.61 and $123.45[200] per acre per year, depending on the crops valued, creating a range of values where the minimum is $10.61 and the maximum is $123.45. Both of these values are the two extremes of values found in other studies valuing air quality and climate stability in cultivated crops. This range of values is then combined with other values of ecosystem services produced by cultivated crops in order to produce a total worth of that land cover type in Clallam County. Tables 16 through 19 summarize the values, using the unit dollars per acre per year ($/acre/year) of ecosystem services present in each land cover type in Clallam County. Appendix D provides a reference table where each value can be found with its corresponding source.

The combined ecosystem service values for each land cover were summed and the total worth of that land cover type per acre per year is provided in Table 20. These values are placed next to the total acres of each land cover type and then multiplied by the high and low per acre/year values. The table presents the estimated total annual value for all lands within Clallam County.

This initial appraisal offers baseline values for the benefits provided by nature in Clallam County annually. Based on a total of 15 ecosystem services over 12 land cover types, Clallam County's ecosystem services contribute roughly $18 billion to $52 billion a year to the local and regional economy.

Table 16. Min and max $/acre/year value for cultivated crops, forests, and fresh water

	Cultivated Crops		Forests		Fresh Water	
	Min ($/acre/year)	Max ($/acre/year)	Min ($/acre/year)	Max ($/acre/year)	Min ($/acre/year)	Max ($/acre/year)
Aesthetic Information	$33.68	$85.86	$4.17	$17,237.97	$79.33	$90.97
Air Quality			$15.87	$692.77		
Climate Stability	$10.61	$123.45	$12.59	$1,100.28		
Energy and Raw Materials						
Food			$17.15	$50.15		
Habitat and Nursery			$1.25	$3,016.00	$136.78	$2,975.27
Moderation of Extreme Events	$13.66	$194.72	$1.79	$657.28	$842,933.84	$842,933.84
Pollination	$2.67	$1,888.32	$69.98	$411.65		
Recreation and Tourism	$2.13	$4.93	$0.21	$2,569.72	$1.71	$21,893.37
Science and Education			$40.97	$452.27		
Soil Formation	$2.49	$23.03	$6.14	$6.14		
Soil Retention	$2.30	$127.17				
Waste Treatment			$32.52	$277.54		
Water Regulation			$0.08	$10.68		
Water Supply	$11.02	$44.73	$10.72	$1,826.01	$2.57	$14,464.89
Total	***$78.57***	***$2,492.22***	***$213.45***	***$28,308.46***	***$843,154.23***	***$882,358.35***

Table 17. Min and max $/acre/year value for grasslands, marine and marine wetlands

	Grasslands		Marine		Marine Wetlands	
	Min ($/acre/year)	Max ($/acre/year)	Min ($/acre/year)	Max ($/acre/year)	Min ($/acre/year)	Max ($/acre/year)
Aesthetic Information	$0.01	$1,206.32			$366.58	$366.58
Air Quality						
Climate Stability	$10.57	$162.61	$22.22	$22.22	$34.73	$378.06
Energy and Raw Materials			$0.05	$0.05	$5.07	$47.31
Food			$8.96	$724.32	$67.79	$16,463.98
Habitat and Nursery			$2.40	$19.32	$0.76	$1,409.26
Moderation of Extreme Events	$23.80	$4,007.01	$3.07	$3.07	$269.97	$106,639.46
Pollination	$411.65	$411.65				
Recreation and Tourism	$4.46	$15,178.07			$10.17	$636.68
Science and Education						
Soil Formation			$38.14	$106.88		
Soil Retention	$37.95	$26,941.07				
Waste Treatment	$6,525.01	$21,171.89			$150.22	$29,015.16
Water Regulation						
Water Supply			$13.12	$110.47	$46.13	$123.01
Total	*$7,013.43*	*$69,078.62*	*$87.97*	*$986.33*	*$951.42*	*$155,079.49*

Table 18. Min and max $/acre/year value for pastures, riparian buffer, seagrass/algae beds

	Pastures		Riparian Buffer		Seagrass/algae beds	
	Min ($/acre/year)	Max ($/acre/year)	Min ($/acre/year)	Max ($/acre/year)	Min ($/acre/year)	Max ($/acre/year)
Aesthetic Information						
Air Quality						
Climate Stability					$1.92	$273.83
Energy and Raw Materials					$1.23	$1.23
Food						
Habitat and Nursery					$1,571.92	$10,864.67
Moderation of Extreme Events			$23.80	$303.56		
Pollination	$2.68	$411.65				
Recreation and Tourism	$0.05	$30.69				
Science and Education						
Soil Formation	$6.91	$6.91	$37.95	$26,941.07	$6,142.36	$17,198.60
Soil Retention						
Waste Treatment			$21,171.89	$21,171.89		
Water Regulation						
Water Supply			$16.56	$561.67		
Total	*$9.64*	*$449.25*	*$21,250.19*	*$48,978.20*	*$7,717.42*	*$28,338.33*

Table 19. Min and max $/acre/year value for shoreline, shrub and wetlands

	Shoreline		Shrub		Wetlands	
	Min ($/acre/year)	Max ($/acre/year)	Min ($/acre/year)	Max ($/acre/year)	Min ($/acre/year)	Max ($/acre/year)
Aesthetic Information	$259.38	$684.97	$13.09	$13.09	$38.62	$5,142.12
Air Quality			$6.89	$69.24		
Climate Stability	$110.67	$110.67	$6.30	$7.94	$4.83	$840.12
Energy and Raw Materials						
Food					$67.79	$9,668.76
Habitat and Nursery			$0.63	$555.96	$2.18	$53,546.42
Moderation of Extreme Events					$18.93	$9,491.02
Pollination			$1.35	$6.75		
Recreation and Tourism	$2,869.56	$50,592.13	$0.27	$1,300.20	$1.72	$12,494.14
Science and Education						
Soil Formation						
Soil Retention						
Waste Treatment					$201.63	$5,496.05
Water Regulation						
Water Supply					$0.44	$22,434.51
Total	*$3,239.61*	*$51,387.78*	*$28.53*	*$1,953.20*	*$336.14*	*$119,113.14*

Table 20. Total annual value in ecosystem services per acre and total annual values multiplied by acres present in Clallam County of each land cover type

	Acres	$Low/acre	$High/acre	$ Total Low	$ Total High
Cultivated Crops	608	$79	$2,492	$47,751	$1,514,721
Forests	857,691	$213	$28,308	$183,076,996	$24,279,911,819
Fresh Water	19,145	$843,154	$882,358	$16,142,187,756	$16,892,750,557
Grasslands	34,231	$7,013	$69,079	$240,079,598	$2,364,659,288
Marine	594,355	$88	$986	$52,286,141	$586,228,432
Marine Wetlands	2,494	$951	$155,079	$2,373,079	$386,808,698
Pasture	21,677	$10	$449	$208,988	$9,738,194
Riparian Buffer	81,931	$21,250	$48,978	$1,741,045,003	$4,012,821,914
Seagrass/algae beds	6,893	$7,717	$28,338	$53,194,021	$195,328,271
Shoreline	3,914	$3,240	$51,388	$12,679,834	$201,131,754
Shrub	123,248	$29	$1,953	$3,515,829	$240,727,460
Wetlands	26,999	$336	$119,113	$9,075,512	$3,215,952,325
Total	*1,773,186*			*$18,439,770,506*	*$52,387,573,433*

Asset Value of Clallam County

An ecosystem produces a flow of valuable services over time, much like traditional capital assets. As long as the natural infrastructure of the present ecosystems is not degraded or depleted, this flow of value will likely continue into the future. This analogy can be extended by calculating the net present value of the future flows of ecosystem services, just as the asset value of a capital asset (infrastructure) can be calculated as the net present value of its future benefits. However, this calculation is no more than an economic exercise, because ecosystems are not bought and sold in this manner; its usefulness is to demonstrate their long-term economic worth.

Calculating the net present value of an asset requires the use of a discount rate. The net present value of Clallam County was calculated using two discount rates: 0% and 4%. Using a 0% discount rate assumes the regenerating nature of natural capital and if maintained, people in the future will benefit from the same amount and quality of services as we currently enjoy. The 4% discount rate was established by the Army Corps of Engineers for use in large projects, and discounts the value of benefits by 4% every year into the future. Discounting can be adjusted for different types of assets and is designed to control for the following:

— Pure time preference of money. This is the rate at which people value what they can have now, compared with putting off consumption or income until later.

— Opportunity cost of investment. A dollar in one year's time has a present value of less than a dollar today, because a dollar today can be invested for a return in one year.

— Depreciation. Built assets such as cars and levees tend to deteriorate and lose value due to wear and tear.

Using a discount rate implies several assumptions. For example, discounting assumes that the benefits humans enjoy in the present are more valuable than the benefits future generations will experience. There are valid arguments that natural capital assets should apply lower, and possibly negative, discount rates than built capital assets because they tend to appreciate rather than depreciate over time. Both natural and built capital assets are important to maintain a high quality of life, but each operates on a different time scale. For these reasons, a zero discount rate, or nominal rate, best reflects the asset value of Clallam County.

Calculations of the present value of the flow of ecosystem services demonstrate that intact natural systems provide enormous economic value to society in the short and long term. The present generation receives a relatively small amount of the total value provided by these services. If a complete conservation of ecosystems is achieved in the present – meaning no further decline of ecological functions – future generations will reap huge economic benefits from healthy functioning ecosystems. For Clallam County the net present value analysis over a 100-year period is demonstrated in table 21.

More detailed information on the primary studies used in this benefit transfer is listed in Appendices D and E, and study limitations are outlined in Appendix F.

Table 21. Net present value with discount rates

Discount Rate	Low Estimate	High Estimate
0% (100 years)	$1.8 trillion	$5.2 trillion
4% (100 years)	$451 billion	$1.2 trillion

Economic Consequences of Lost Nearshore Services

Although the complexity of ecosystems is widely recognized, the deterioration of natural cycles and processes has possibly led to a deeper appreciation and interest of the intrinsic value of the services ecosystems provide. The further an ecosystem is disrupted, the more human effort it takes to replace the service once provided. The lack of knowledge of biological systems and environmental science, as well as the denial of our dependence on healthy functioning ecosystems, has augmented a general depreciation and destruction of ecosystems. The destruction of these ecosystems has had a tremendous impact on both our ecology and economy. Understanding the reciprocity between social needs and natural processes is where the utility of ecological economics commences.

When ecosystem services are lost, people pay. When natural flood protection is degraded, levees must be constructed. If salmon productivity is compromised, new hatcheries must be designed. When natural filtration systems are destroyed, expensive water treatment plants become necessary. Real costs are incurred to replace services that were previously free. These capital-intensive services are often either less efficient or unable to replace the original natural services. In addition, one expensive infrastructure system may damage another. Such is the case of costly storm water systems that actually increase peak flows and flooding, requiring further flood protection expenditures. There are many Puget Sound examples of polluted stormwater and levees that narrowed floodways and damaged salmon populations.

Benefits of Restoration

In restoration and conservation, the potential return on investment merits careful consideration. The rate of return on a particular restoration investment depends on the physical and economic characteristics of the restoration work. Currently, the number of trees planted or miles of shoreline restored is tracked, but the economic impact of that work is not typically calculated. For example, the Thea Foss Waterway clean-up in Tacoma, Washington provided a 2:1 return: over $300 million in new investment. This return on investment is expected to support over 1,036 jobs and return about $134 million in additional tax revenue to the state over the next 20 years.

The expected dollar value benefits of ecosystem services provided by restoration investments can be estimated the same way benefits from built capital are estimated. The great differences between minimum and maximum values reported in peer-reviewed studies can be attributed to a great variation in the health of the study site, study date, methodology used and the age of the study. Generally, higher values can be associated with healthier functioning ecosystems.

When we compare restoration costs to the high value range, the return on investment is extraordinary. In the table below, the restoration costs of salt marshes and estuaries are compared to the annual ecosystem service value of these land types in their pristine condition.

Restoration Impact on Jobs: Shellfish Example

Healthy riparian areas directly support the Washington State economy by providing beneficial ecological functions for downstream shellfish beds. Proper salinity levels and limited pollution from storm water runoff and septic systems are key to sustaining healthy conditions for beds of Manila clams and other commercial mollusks found in Clallam County's mudflats and estuaries. Bacterial and pollutant contamination has devastated the industry, which has led to the closing of thousands of acres of beds and eliminating nearly half of the industry's jobs in Washington State since 2000.[201]

Restoring watersheds will reverse the decline of harvestable shellfish beds. The Puget Sound Action Agenda sets a 2020 goal to restore 10,800 acres of shellfish bed to harvestable quality. This will add jobs and economic value to the Puget Sound Basin.[202]

Table 22. Costs of restoration and benefits of ecosystem services for marine wetlands and open water estuaries in Puget Sound.

Land Type	Restoration Cost	Ecosystem Service/ Economic Benefit[ix]	Note
Marine Wetlands	$900 per acre (minor project) to $9,000 per acre (major project)	Up to $122,098.87 per acre, per year	— Minor project example: Removal of invasive plant species. — Major project example: Large-scale sediment installation. — This figure does not include septic system upgrades. Salt marshes serve as storm buffers by acting as a sponge for large storm surges and heavy rainfall.
Open Water Estuary	$8,000 per acre (minor project) to $250,000 per acre (major project)	Up to $1,863.11 per acre, per year	— Minor project example: Removal of invasive plant or animal species. — Major project example: Removal of contaminants and restoration from an oil spill. Estuaries provide a safe haven and spawning grounds for a diverse list of animals including birds and fish.

Source: Harrison-Cox, J., Batker, D. Christin, Z., Rapp, J. 2012. Puget Sound: Washington State's Best Investment. Earth Economics.

Table 23. Jobs associated with shellfish fishing in Puget Sound.[203]

	2011 Current Status	Note
Jobs currently supported by shellfish fishing in Puget Sound	311 jobs per year	This figure does not include jobs associated with shellfish farms due to data availability difficulties.
Jobs currently supported elsewhere in the Washington State economy by shellfish fishing	467 jobs per year	This figure includes jobs associated with production of shellfish like truck drivers who deliver harvested shellfish to workers who process them for food.
	Restoration of Shellfish Beds	**Note**
Short term jobs created from restoration of 10,800 acres of shellfish beds by 2020	1,469 jobs total	This figure includes planning, construction, planting, and monitoring jobs created by shellfish bed restoration projects.
Annual Increase in shellfish fishing jobs after restoration	22 jobs per year	These jobs will be permanently created from the increased acres of shellfish beds.
Jobs supported elsewhere in economy from post-restoration creation of shellfish fishing jobs	25 jobs per year	Similar to above.

Source: Harrison-Cox, J., Batker, D. Christin, Z., Rapp, J. 2012. Puget Sound: Washington State's Best Investment. Earth Economics.

[ix] Table referenced from: Harrison-Cox, J., Batker, D. Christin, Z., Rapp, J. 2012. Puget Sound: Washington State's Best Investment. Earth Economics.

Part IV. Applying Valuation Findings to Policy and Investment Decisions

The short- and long-term economic sustainability of Clallam County relies on environmental sustainability and healthy nearshore ecosystems.[204] When ecosystems are lost or degraded, there are real costs in terms of lost property value, shellfish harvest, flood protection and storm buffering. When natural systems are compromised, their services are lost, including flood protection, storm buffering, shellfish production and other benefits. "Lose an ecosystem service, gain a tax district," because these services are needed, taxing districts are created to replace what nature once provided for free. Flood districts, water districts, shellfish districts and stormwater districts are created when natural systems are compromised. Investments that protect and restore natural systems are wise taxpayer investments. Increasingly, federal, state and local governments are implementing policies that protect natural capital. This section explores how ecosystem service valuation can inform the implementation of local and state policy in Clallam County.

The Shoreline Master Program and No Net Loss

Shoreline protection planning is mandated by the Washington State's Shoreline Management Act (SMA) for each county and their local government (RCW 90.58.020).

> As with many other local land use policies required by the state, SMP provides an opportunity for the public to participate and discuss the needs of various communities that are directly involved with shoreline ecosystems. These state requirements are intended to protect the long-term economic value and viability of private property, as well as public resource assets within local government jurisdictions, and for the citizens of the State of Washington in the present and future.

The SMA objectives propose to protect shorelines, provide public access and allow development of water-dependent uses. These activities must be carefully guided as natural shorelines have high economic values that contribute significantly to the local and regional economy. Shorelines produce a number of ecosystem services including aesthetic and recreational, disturbance regulation, food provision, air quality, climate stability, habitat and biodiversity and nutrient cycling. Conserving shorelines generates and maintains jobs, lowers cost for public health while preserving a high quality of life, higher property values, improves recreation areas, provides storm surge protection and supports tourism.[205] Ecosystem service valuation contributes to SMP and SMA by:

- justifying investment in environmental outcomes in the context of economic development;
- providing better performance of existing conservation and land use planning tools;
- ensuring sustainability of valuable natural capital;
- strengthening connections between environmental conservation, community, climate change, and economic resiliency.

The SMA shares many commonalities with the Growth Management Act (GMA). Even though the SMA applies to all counties, both statutes relate to land use planning and protection of marine ecosystem functions. Both are required by State government and strive to enhance conservation of critical areas and important ecosystems. Given the close relation of these two statutes some confusion has arisen regarding shoreline management. GMA incorporates shoreline management with Shoreline Management Programs to local overall comprehensive plans and development regulations.

Through ESVs communities can holistically prioritize essential conservation goals that are also stipulated in the SMA and GMA. Legislative documents can sometimes become difficult to understand, given the complexity of natural systems.

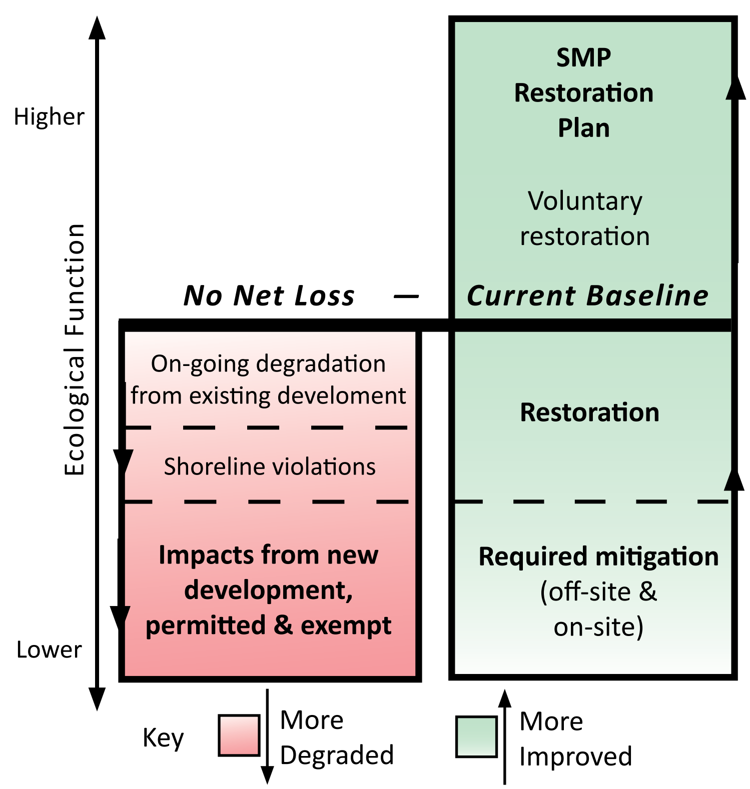
At the time of this writing, Clallam County's SMP update process is well underway. This report references many county documents, reports and programs. Offered here are science-based and pragmatic feedback for updating the SMP. Clallam County can also be a leading and compelling case study for the application of ESV analysis to understand the connection between the environment and the economy, setting an example that can be adapted in other counties throughout the state.

Integrating Ecosystem Service Concepts into SMP and No Net Loss (NNL)

In 2003, Washington State Department of Ecology specified that "NNL of ecological function" is the state standard for local Shoreline Master Program updates. Ecology recently updated their SMP Handbook in 2012 to provide additional guidance on how to achieve NNL and now requires that each jurisdiction write a summary report describing how their SMP meets the state standard. On the surface, preparing a summary report is a relatively straightforward exercise, but achieving NNL of ecosystem functions in the face of continued growth and degradation continues to prove challenging.[206]

The integration of ecosystem service values into public policies is a way to ensure a cross-disciplinary approach to comprehensive management plans that have been shown to create jobs and increase property values and overall quality of life. The SMP handbook calls for a systematic interdisciplinary approach to ensure integrated use of natural and social sciences.

Figure 14. No Net Loss Diagram



Source: Shoreline Master Program Handbook, 2010: http://www.ecy.wa.gov/programs/sea/shorelines/smp/handbook/index.html

Clallam County Shoreline Health Measures

An essential part of the SMP update is the inventory and characterization of the shoreline. The Inventory and Characterization Report (ICR) is a separate report in fulfillment of the SMP regulations. ICR uses scientific data and other technical information that is accurate and currently available. In general terms, ICR strives to identify valuable shoreline resources and describes baseline conditions in order to compare future shoreline condition and function. The ICR is a key document for the SMP, informing the assignment of Shoreline Environment Designations and enhancing future policy and regulatory decisions.

In order to measure the ecological functions that are directly dependent upon shoreline structure, a set of quantifiable indicators are needed. These indicators provide criteria to measure whether or not there was an increase, a decrease or a steady state in ecological functions of a given area.

Criteria Measuring Shoreline Health

Four main criteria were selected to measure shoreline quality in Clallam County including the presence of:

1. Feeder bluffs providing important re-nurturing service contributing to shoreline health.
2. Shoreline areas prone to landslides and erosion serving sediment deposition functions (these are hazard areas for structures and property owners).
3. Submerged aquatic vegetation such as kelp and eelgrass creating important habitat.
4. Closed forest canopy within 200 feet of ordinary high water mark, generating shade habitat, higher quality water, and microclimates.

Three main criteria were selected to measure shoreline alterations:

1. Modified shoreline, in particular feeder bluffs where armoring disrupts natural sediment deposition along beaches.
2. Hard armoring along the shoreline that blocks shoreline and riparian buffers and destroys habitat.
3. Overwater structures, which interrupt sediment transport and other shoreline functions.

As suggested by the Shoreline Management Act, coordinated planning is necessary in order to protect the public interest. Ecosystem service valuation can help this coordination in establishing an inventory of specific ecosystem services and then assessing monetary values provided by the use of existing ecosystems. In finding appropriate and reasonable uses for shorelines, economic valuation helps prioritize land uses and informs decisions on the costs of alternative measures.

Recommendations for Incorporating Ecosystem Services and Investment in Shoreline Health Criteria

These recommendations provided by Earth Economics follow the structural order of Callam County's Inventory Characterization Report. Based on the shoreline health criteria addressed in the SMP, these recommendations justify policy changes or enhance current shoreline management approaches.

Feeder Bluff Area

Identifying the percentage of feeder bluff present in the area is a good indicator of shoreline quality, due to the critical role feeder bluffs play in sediment erosion, deposition and transport processes. The economic value of feeder bluffs has now been estimated. For more information on the percentage of feeder bluff present refer to Appendix C.

Feeder bluffs are hazardous areas. Structures built on feeder bluffs are more prone to landslides and loss, they often decline in property value, pose higher risks to property owners and cost more to federal government (emergency response and other costs) than structures built on structurally stable slopes and soils.[207] Each marine reach is determined by the length and percentage of that which is hazard prone of the feeder bluff area.

Landslide and Erosion Hazards

Erosion and landslides are natural processes, posing dangerous conditions to property owners. Just as landowners in areas certain to be affected by hurricanes or floods take on risk when building or occupying hazard prone areas, feeder bluffs pose similar risks. These risks should be reflected in economic analysis. For example, FEMA recently adopted a policy to value ecosystem services in all disaster mitigation because the choice of locating a structure in a disaster prone area has financial implications for home owners and taxpayers (county, state, and federal) who will pay if structures are damaged in a disaster.[208]

RECOMMENDATION #1

Clallam County, Washington state and federal agencies should consider the value of feeder bluffs in local regulatory policies, environmental impact assessment, and best land management practices.

Clallam County, local, state and federal agencies should take all steps necessary to protect intact feeder bluffs, and restore impaired feeder bluffs. Optimizing sediment delivery associated with Elwha dam removals should be a top priority.

RECOMMENDATION #2

Given the risk posed by areas prone to erosion and landslides, Clallam County should actively monitor ecological functions in hazard prone areas and provide timely information on the economic costs and benefits to relevant stakeholders. Such active monitoring will highlight key changes over time and help decision-makers better evaluate risk mitigation as well as investment decisions over time.

RECOMMENDATION #3

State and local agencies should include the values provided in this report for nearshore systems in the designation of shoreline protective regulations. Further research is needed to delineate the economic values of forage fish .

RECOMMENDATION #4

Clallam and other counties should consider increasing riparian buffers along freshwater and saltwater shores to help prevent rapid erosion, while allowing natural sediment buildup. The ideal recommended buffer width for both freshwater and marine shorelines is 250 ft (as stated by FEMA, DoE and WDFW). Site-specific land use policies may suggest the use of smaller riparian buffers depending on the stated conservation goals.

RECOMMENDATION #5

County and State agencies should provide incentives for implementing wider buffers by offering incentives for creating public benefits on private land. For example, the county's current open-space, public-benefit current use property tax rating system (Table 24) could provide income to private landowners who directly improve the flow of ecosystem services. The rating system would reflect the positive impacts of good stewardship and could include, among others:

(i) buffers that have mature, native vegetation, typically dominated by conifers, and

(ii) landowners who increase their buffer width and quality over the minimum standards to protect and enhance certain functions

Nearshore Ecosystems

Values ($/acre/year) for coastal marine and nearshore vegetation including salt marshes, kelp, eelgrass, estuarine aquatic beds and shoreline (beaches) were provided for storm damage reduction, fisheries production, aesthetic and recreational, habitat and nursery, waste treatment, and nutrient cycling. Forage fish utilize the nearshore for spawning.

The economic valuation of forage fish related to nearshore habitats in Clallam County was examined. Forage fish spawning has sediment grain size requirements. A lack of primary data and supporting research methods led to an incomplete valuation of the important contribution forage fish have on nearshore ecosystems.

Shoreline Riparian Vegetation

Shoreline riparian provide ecosystem services including disturbance regulation, gas and climate regulation, habitat refugium and nursery, water supply, success of endemic populations of forage fish and invertebrates, among other services.

An abundant scientific literature shows the services provided by marine and freshwater riparian areas with several guidance documents[x] that recommend establishing a riparian buffer width of 250 ft for both marine and freshwater areas. Even though 250 ft wide buffers are ideal for the protection of marine and freshwater ecosystems, site-specific land use policies may support the use of smaller buffers.

With 13,433 acres (refer to table 5.5 in Appendix C) of riparian forest within 200 feet of the ordinary high water line Clallam County receives roughly $280 million to $650 million in annual benefits from these systems. Understanding this value and the location enables decision makers to make smart investments.

[x] A buffer width of 250 ft is recommended in the following publications:

a. Knutson, K.C. and V.L. Naef. 1997. Management Recommendations for Washington's Priority Habitats: Riparian. Washington Department of Fish and Wildlife. Olympia, Washington.
b. Department of Ecology State of Washington. 2011. Shoreline Management Handbook.
c. FEMA - Region 10. January 2010. Model Ordinance for Floodplain Management under the National Flood Insurance Program and the Endangered Species Act

Modified and Armored Shoreline

Modified shores are costly and impair habitat for terrestrial and aquatic species. Ten percent of the coast along the Strait of Juan de Fuca is modified. Of 18 Clallam County reaches, only Sequim Bay and Gibson Spit are classified as armored feeder bluffs (see Table 3.6 and 3.9, Appendix C for marine shore types and the percentage modified in Clallam County). Hard and some soft armoring designs intended to prevent erosion on one property deprive down drift beaches of sediment, promoting erosion on neighboring properties.

RECOMMENDATION #6

Clallam County should consider adopting policies, which can be combined to create a new approach to shoreline protection and restoration by

(i) Reducing the number of permits issued for building bulkheads (armoring) on critical habitat and sensitive ecosystems along the shoreline.

(ii) Using mitigation sequencing[209] in the permit review of bulkhead applications.

(iii) Providing incentives to property owners to encourage conservation/restoration of shorelines in their natural state rather than hard armoring.[210]

Ecosystem service analysis and valuation can show the physical and economic implications modified vs non-modified shores. Data shows that the average rate of sediment transfer is lower in the armored portions of the Elwha drift cell (0.297 tons/foot/year) than the unarmored portions (0.945 tons/foot/year). Slower erosion occurs in armored feeder bluffs. Armored portions of the shoreline produce fewer ecosystem services and less value overall.

The guidance of DOE, WDFW and FEMA for a buffer width of 250 ft. avoids the need for hard armoring, and construction in potentially dangerous areas while still providing view amenities. Where bluff protection is needed for existing structures, alternatives to hard armoring exist. Superior alternatives to bulkheads exist. A well designed bioengineering project, costs less, looks better, likely lasts longer, and provides the ecosystem services that benefit property owners and the public.

Overwater Structure

Overwater structures (OWS) alter wave energy and sediment transport dynamics. In Clallam County within the 18 marine reaches there are a total of 48 overwater structures. Some of these OWS are located in important sediment transport zones. Out of a total of 87.1 miles of transport zone, 15.8 miles are interrupted by OWS.

This can show how value (such as storm risk reduction) is lost or gained and how much income is lost (fisheries income) annually. These may also provide guidelines as to the conditions of the shoreline and opportunities to mitigate past impacts.

Table 24. State Policy for Current Tax Assessment

Washington State policies and laws that govern the administration of Current Use Assessment programs	
Revised Code of Washington (RCW)	Chapters 84.34 and 84.33 of the RCW detail the definitions, policies and procedures for the administration of current use assessment in Washington State. Please refer to Chapter 84.34 for PBRS, Timber Land and Farm and Agriculture and Chapter 84.33 for Forestland.
Washington Administrative Code (WAC)	Chapter 458.30 of the WAC offers further guidance and clarity to the RCW and ''provides definitions for the terms used in conjunction with land classified under the Open Space Taxation Act, codified as chapter 84.34'' of the RCW.
Open Space Taxation Act	The Open Space Taxation Act, first enacted in 1970, is the state law that enables landowners to enroll their land in PBRS, Timber Land or the Farm and Agricultural Land program. This Washington State Department of Revenue publication provides a good summary of many of the most critical policies, procedures and requirements of these three programs.

RECOMMENDATION #7

County and State agencies should consider including ecosystem service valuation and analysis in local land management policies, including overwater structures. All future valuation analysis should provide the following:

(i) An inventory of ecosystem services;

(ii) A list of impacted services;

(iii) A directional impact of rising or falling physical and economic value;

(iv) An estimate of economic values.

RECOMMENDATION #8

Clallam County should invest in existing nearshore conservation efforts, leveraging capacity in organizations currently working on similar goals: implement priorities identified by Elwha Nearshore Consortium (ENC)[xi] that address full ecosystem restoration of the Elwha nearshore.[211]
(ENC priorities: http://www.coastalwatershedinstitute.org/resources_24_905640298.pdf)

RECOMMENDATION #9

Clallam County should invest in identifying critical funding needs and developing new finance mechanisms for nearshore conservation.

Salmonid Stock Status

There are over 200 salmon stocks in freshwater and riparian ecosystems in the North Olympic Rivers in Clallam County. The nearshore is an essential ecosystem for salmon reproduction and development. Clallam County's nearshore habitats support about $57,480 per mile in commercial fishing annually

This can increase the salmon population, recreational and commercial catches and support greater biodiversity associated with great habiabat.

Stream Channels with Levees and Revetments

Clallam County has 40 revetments and levees in streams included in their SMP, making up a total surface area of 66.8 acres. Levee and revetment construction and maintenance is costly and can damage salmon habitat. Maintenance is largely the responsibility of the property owner with certain mandated requirements[212]

Flood hazard management can go beyond built infrastructure. Investing in both built and green infrastructure is more cost-effective than investing in built infrastructure alone.[213] Green infrastructure refers to the natural processes that occur within ecosystems-such as natural floodplain itself, vegetation, wetlands and upland forests that absorb rainwater and reduce runoff. Flood related benefits of leveraging green infrastructure into built infrastructure projects is substantial, and is directly linked to ecosystem services.[214]

[xi] The Elwha Nearshore Consortium (ENC) is a work group of scientist, managers and citizens founded in 2004, dedicated to understanding and promoting the nearshore restoration associated with the Elwha dam removals.

Impervious Surfaces

Impervious surfaces contribute to stormwater runoff can also shed contaminants into water bodies. Nonpoint source pollution is a grave problem in Puget Sound. Avoiding impervious surfaces where possible is the first step in combating this problem. There are relatively few impervious surfaces, within 200 feet of freshwater streams, in Clallam County. The upper reach of the Clallam River, Lake Sutherland and the lower reach of Morse Creek are characterized by shoreline areas that exceed 10% of the impervious surface area. For detailed information refer to table 5.7 in Appendix C.

RECOMMENDATION #10

Clallam County's municipalities should invest in green infrastructure alternatives to levees and revetments to enhance flood protection, improve salmon habitat and water quality and contribute to climate stability.[215]

RECOMMENDATION #11

Clallam County's cities should use green infrastructure to reduce stormwater runoff, such as green spaces and parks in strategic areas of the watershed. Providing vegetation buffers in the problems areas mentioned above can decrease the volume of stormwater runoff. [216]

RECOMMENDATION #12

Cities and Clallam County should consider requiring Low Impact Development Standards (LID) that use the '65/10/0' LID definition to ensure zero stormwater runoff.[xii] The formula allows for a minimum of 65% of the site to remain in natural forest vegetation, with no more than 10% in impervious surface, to enable a result of 0% storm water runoff. In addition, consideration should be given to the creation of a tax on impervious surfaces to supplement clean water regulation and serve as a source of funding for increased investment in green infrastructure.

[xii] This is defined in several references: (a) Washington Department of Ecology Stormwater Manual. The actual standard is listed as BMP T5.30, and is derived from King County's LID standard; and (b) a helpful public information document on the intent and practical aspects, available at http://www.ci.tumwater.wa.us/Water%20Resources/Fact%20Sheets/Fact6.pdf

Summary of Recommendations

The recommendations provided by Earth Economics for the SMP update in Clallam County strive to enhance the health and function of natural areas throughout the county, increasing quality of life for all county residents as well as contributing to the economic foundation of the county. The following table summarizes these recommendations and proposes the targeted audience. The recommendations in the following table are not listed in order of priority but are informed by, and follow that order of, the shoreline health criteria stipulated in the SMP update.

These recommendations can be applied at different governmental scales. These recommendations are specific to Clallam County, and can be implemented across other parts of Washington State, in other states and at the national level. Knowing the value of the services produced by each ecosystem can guide land planning policies and overall management. Increased buffers, investment in green infrastructure, green spaces and parks are all strategies to building stronger and more resilient economy while conserving ecosystems.

Table 25. Summary Recommendations on Integrating Ecosystem Service Values in SMP update and the intended audiences

Recommendations		Implementing Authority
1	Clallam County, Washington state and federal agencies should consider the value of feeder bluffs in local regulatory policies, environmental impact assessment, and best land management practices. Clallam County, local, state and federal agencies should take all steps necessary to protect intact feeder bluffs, and restore impaired feeder bluffs. Optimizing sediment delivery associated with Elwha dam removals should be a top priority.	Local community, state and federal agencies including City of Port Angeles and Sequim, Clallam County government and Washington state DNR, WDFW, DoE.
2	Given the risk posed by areas prone to erosion and landslides, Clallam County should actively monitor ecological functions in hazard prone areas and provide timely information on the economic costs and benefits to relevant stakeholders. Such active monitoring will highlight key changes over time and help decision-makers better evaluate risk mitigation as well as investment decisions over time.	Clallam County government, WA State government and private property landowners
3	State and local agencies should include the values provided in this report for nearshore systems in the designation of shoreline protective regulations. Further research is needed to delineate the economic values of forage fish.	Clallam County government, WA State government and local non-profits
4	Clallam and other counties should consider increasing riparian buffers along freshwater and saltwater shores to help prevent rapid erosion, while allowing natural sediment buildup. The recommended minimum buffer width for both freshwater and marine shorelines is 250 ft.	Clallam County government, WA State government, private property landowners and NGOs
5	County and State agencies should provide incentives for implementing wider buffers by offering incentives for creating public benefits on private land. For example, the county's current open-space, public-benefit current use property tax rating system (Table 22) could provide income to private landowners who directly improve the flow of ecosystem services. The rating system would reflect the positive impacts of good stewardship and could include, among others: (i) buffers that have mature, native vegetation, typically dominated by conifers, and (ii) landowners who increase their buffer width and quality over the minimum standards to protect and enhance certain functions.	Clallam County government and WA State legislature

Table 25 cont.

Recommendations		Implementing Authority
6	Clallam County should consider adopting policies, which can be combined to create a new approach to shoreline protection and restoration by (i) Reducing the number of permits issued for building bulkheads (armoring) on critical habitat and sensitive ecosystems along the shoreline. (ii) Using mitigation sequencing in the permit review of bulkhead applications. (iii) Providing incentives to property owners to encourage conservation/ restoration of shorelines in their natural state rather than hard armoring.	Clallam County government and WA State government
7	County and State agencies should consider including ecosystem service valuation and analysis in local land management policies, including overwater structures. All future valuation analysis should provide the following: (i) An inventory of ecosystems services; (ii) A list of impacted services; (iii) A directional impact of rising or falling physical and economic value; (iv) An estimate of economic values.	Clallam County government and WA State government
8	Clallam County should invest in existing nearshore conservation efforts, leveraging capacity in organizations currently working on similar goals: implement priorities identified by Elwha Nearshore Consortium (ENC) that address full ecosystem restoration of the Elwha nearshore. (ENC priorities: http://www.coastalwatershedinstitute.org/ resources_24_905640298.pdf)	Local community, state and federal agencies, CWI, Clallam County government and Washington state DNR, WDFW, and DoE.
9	Clallam County should invest in identifying critical funding needs and developing new finance mechanisms for nearshore conservation.	Local community, state and federal agencies, CWI, Clallam County government and Washington state DNR, WDFW, and DoE.
10	Clallam County's municipalities should invest in green infrastructure alternatives to levees and revetments to enhance flood protection, improve salmon habitat and water quality and contribute to climate stability.	Local community, state and federal agencies, CWI, Clallam County government and Washington state DNR, WDFW, and DoE.
11	Clallam County's cities should use green infrastructure to reduce stormwater runoff, such as green spaces and parks in strategic areas of the watershed. Providing vegetation buffers in the problems areas mentioned above can decrease the volume of stormwater runoff.	Local community, state and federal agencies, CWI, Clallam County government and Washington state DNR, WDFW, and DoE.
12	Cities and Clallam County should consider requiring Low Impact Development Standards (LID) that use the '65/10/0' LID definition to ensure zero stormwater runoff. The formula allows for a minimum of 65% of the site to remain in natural forest vegetation, with no more than 10% in impervious surface, to enable a result of 0% storm water runoff. In addition, consideration should be given to the creation of a tax on impervious surfaces to supplement clean water regulation and serve as a source of funding for increased investment in green infrastructure.	Local community, state and federal agencies, CWI, Clallam County government and Washington state DNR, WDFW, and DoE.

*** Even though these recommendations are specific to Clallam County, they are applicable to other counties with nearshore ecosystems.**

Illustrative Application of Ecosystem Service Valuation with Setback Policies between 1992-2013

The SMP draft has established several different policies and regulations that will enable increased conservation of nearshore ecosystems throughout the county. Chapter 2 of the SMP, Shoreline environment designations reflects the changes that were implemented in the 2012 SMP draft. All environment designations include existing ecological conditions, land use patter, zoning, the types of health and safety factors, geology and other characteristics. Even though Chapter 2 of the SMP designates several setbacks, for the purpose of this example we will value the setbacks implemented in shoreline residential areas. Given the pressure for development along the waterfront in Clallam County, setbacks in this area are focal points in the current SMP update and in this report.[217]

In the 2012 SMP draft, shoreline residential areas are described by two types: conservancy designation (SRC) and intensive designation (SRI) as described in Table 26.

The 2012 SMP draft specifies the development uses for each of the shoreline designations. For shoreline residential areas new development, agricultural activities and dredging is either allowed, limited, conditional or prohibited depending on specifics of planned development. Shoreline habitat buffers depend on the size of the development and the location it is intended. The updated SMP defines the adequate buffer width criteria by: minor new development (existing lost <200ft), minor new development (existing lots >200ft), major new development and land divisions.

However, the 1992 SMP more simply defined the criteria by single-family unit and multi-family.[220] In order to value the increase of marine buffer width from the 1992 SMP to the recent 2012-2013 draft, we focused on the equivalent of the different development types.

Table 26. Types of designation for shorelines in residential areas

Type	Application	Purpose
Shoreline Residential Conservancy Designation (SRC)	Rural shorelines (low development) and unincorporated areas within the urban growth shoreline. These shorelines are currently residential (1 unit per acre; less than 1 unit per 20 acres) but are generally well-preserved natural landscapes.	To conserve marine and freshwater shorelines that have forest cover and are minimally degraded but still allowing low intensity development that will not cause a loss to the existing shoreline functions.[218]
Shoreline Residential Intensive Designation (SRI)	Shorelines with moderate to high intensity development, including urban areas. These areas are mostly entirely developed, native forest cover has been cleared or is fragmented and shoreline in completely or partially armored (bulkheads, etc).	To accommodate moderate to high residential density in the zones mapped as such, while ensuring that new development occurs in a manner that avoids or minimizes impact to shoreline functions.[219]

Table 27. Difference in width (ft) of marine riparian buffers in previous SMP (1992) and updated SMP draft (2013)

Riparian buffers	Shoreline Residential Conservancy			Shoreline Residential Intensive		
	1992	2013	Increase	1992	2013	Increase
Minor New Development	50ft	100ft	50ft (50%)	35ft	75ft	40ft (46.6%)
Major New Development	100ft	150ft	50ft (66.6%)	50ft	100ft	50ft (50%)

For minor new development in SRC there was a 50ft increase all around, similar for SRI with the exception of the 40ft increase for minor new development. In order to value this increase we must first calculate the amount (acres) of shoreline riparian buffers in Clallam County (about 10,462 acres). This acreage was calculated as described in Part III.

As explained in tables 28-30, riparian buffers are extremely valuable given their ability to naturally serve as a disturbance regulator, biological control, form new soil, treat waste and also supply Clallam County residents with water. If the area of riparian buffers throughout the county increases then so will it's economic contribution. The SMP separates the designation of buffers depending on whether they expect minor or major development, regulating heavier larger development. Depending on the shoreline residential area, whether it is conservancy or intensive, the value of this increase is demonstrated.

Valuing the setbacks for shoreline residential areas is an example of the true value of conserving our landscape. The updates SMP is valuing greatly the services provided by buffer zones and the also the safety of the county's residents.

There are several other examples throughout the SMP that can be calculated using the values in this study. The economic contribution of each would be similar to the ones seen for riparian buffers, millions of dollars.

General Opportunities for Applying Study Results

Natural assets are not indestructible and they are under pressure in Clallam County. The following steps will ensure a flow of economic value of Clallam County's natural capital continues in perpetuity:

— **Perform ecosystem service valuation per designated reach.** Identify and value the services present in each reach to help prioritize decisions and efforts. Valuing each reach may also enable integration of ESV to SMP updates (for example designation of critical areas, augmentation of vegetated buffers and revision of regulatory policies).

— **Protect and restore natural capital.** Consider both the conservation and the restoration of Clallam County's ecosystems as a key investment for the future economy. The valuation here provided is applicable to decision-making at every jurisdictional level.

— **Apply ecosystem service valuation results to support funding investment in natural assets.** Use the ecosystem service valuation to calculate the rate of return on conservation and restoration investment. With the Earth Economics' EVT (Ecosystem Valuation Toolkit), a web-based tool assessed at http://esvaluation.org, values in this report can be regularly updated as new data is made available.

— **Adopt an ecosystem services approach to rural economic development.** Include sustainable forestry, forest product development, agriculture, and access to quality outdoor recreation in all aspects of economic and infrastructure planning. Formally tie ecosystem services to long-term and sustainable jobs. Restoration projects can and should be effectively linked to economic advancement, sustainability and long-term job creation.

— **Review institutional options for planning and management of natural assets.** Facilitate discussions about institutional improvements that coordinate activities that promote investment in natural capital. Ecosystem services can be a guide for improvement by setting a context wherein alternative goals, such as transportation planning, salmon restoration, natural flood control, storm water conveyance and water quality can be simultaneously improved, thus avoiding infrastructure conflict.

Table 28. Current acreage of marine riparian buffer and its economic value in ecosystem services provided (1992)

Riparian buffer along Clallam County shoreline	Current acreage in Clallam Co.	Value of riparian buffer per acre		Value of previous riparian buffer setbacks (1992)	
		Low	High	Low	High
Total	10,462	$21,295	$49,040	$222 million	$513 million

Table 29. Estimate increase in acreage by expansion marine shoreline buffers in Shoreline Residential Conservancy Areas and their values (2013)

Shoreline Residential Conservancy					
Estimated acreage in 2013 update		Value of proposed riparian buffer setbacks in 2013 update			
Minor New Development	Major New Development	Minor New Development	Major New Development	Minor New Development	Major New Development
		Low	High	Low	High
15,693	16,739	$334 million	$769 million	$356 million	$820 million

Table 30. Estimate increase in acreage by expansion marine shoreline buffers in Shoreline Residential Intensive Areas and their values (2013)

Shoreline Residential Intensive					
Estimated acreage in 2013 update		Value of proposed riparian buffer setbacks in 2013 update			
Minor New Development	Major New Development	Minor New Development	Major New Development	Minor New Development	Major New Development
		Low	High	Low	High
15,275	15,693	$325 million	$749 million	$334 million	$769 million

Part V. Conclusions

Land use planning and management efforts as extensive as Shoreline Master Programs can provide opportunities for establishing economic measures that ensure quality and overall health of shorelines. Shoreline management includes many disciplines to create successful strategies and actions. Earth Economics valued 15 ecosystems services present in Clallam County. These values provide opportunities for decision-makers and community leaders to understand economic trade-offs in planning, growing and building Clallam County's cities and rural communities. We have an opportunity to make better decisions concerning how to meet the SMP required No Net Loss standards for the county's ecologically and economically important shorelines.

A detailed ecosystem service valuation of Clallam County's ecosystem services finds that natural capital contributes approximately $18 billion to $52 billion annually to the regional economy. The range in values accounts for varying states of ecosystem health and function. Healthier ecosystems provide more value. Nearshore economic values, calculated using county-specific data, provide an annual flow of benefits ranging between $99,000 to $15 million depending on the health of the shoreline and the presence or absence of shoreline armoring:

1. Carbon storage and sequestration, creation of habitat and forage fish supportive value contribute more than $15 million annually;

2. Commercial and recreational fishing provide a minimum of $20 million annually;

3. Feeder bluffs contribute on average between $99,000 to $506,000 every year within the Dungeness and Elwha drift cell.

Ecosystem services can also be treated as assets and their value over time can be calculated similar to built infrastructure such as levees, building and bridges. These benefits over time are calculated as an asset value using discount rates. If a 4% discount rate over 100 years is applied, the net present value of ecosystem services in Clallam has an asset value of between $451 billion to $1.2 trillion dollars. The minimum asset value for Clallam County's nearshore area is $103 million. These appraisal values are based on scientific data and are applicable to decision-making at every jurisdictional level.

Understanding and measuring the economic value of natural capital in Clallam County is essential to enhance effective and efficient natural resource management. Valuation of natural benefits leads to their protection and provides measures to influence policy development and decision-making. While this report provides a valuation of ecosystem services in the county and its nearshore, it is only a first step towards developing policies, measures and indicators that support discussions about the tradeoffs in investments of public and private money that ultimately shape the regional economy for generations to come.

This study provides many case studies, applied examples and recommendations for ensuring a flow of economic value of Clallam County's natural capital continues in perpetuity. Specific recommendations for the 2013 Shoreline Master Program (SMP) update are provided and range from calculating ecosystem service values per designated shoreline reach to calculating the rate of return on conservation and restoration investment. With the Earth Economics' EVT (Ecosystem Valuation Toolkit), a web-based tool, values in this report can be regularly updated and can be accessed at http://esvaluation.org. Ecosystem services can be a guide for improvement by setting a context wherein alternative goals, such as salmon restoration, natural flood control, storm water conveyance and water quality can be simultaneously improved, thus avoiding infrastructure conflict.

Economic sustainability relies on environmental sustainability. The loss of nature's bounties has monetary costs. Maintaining the health of ecosystem in Clallam County provides benefits for everyone. Conserving and protecting Clallam County's natural assets is critical to improving quality of life and securing sustainable economic progress for residents in the region.

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4 Introduction
Source: Clea Rome, WSU Clallam County Beach Watchers

5 Eroded Bluff on Clallam County Coastline
Source: WSU Clallam County Beach Watchers, 2007

5 Cape Alava
Source: Lola Flores, 2013

5 Cape Alava at sunset
Source: Tyler Buntain, 2013

5 Elwha Dam Removal, 2012
Source: http://www.video-monitoring.com/construction/olympic/js.htm (Retrieved February, 2013)

8 Part I: Clallam County
Source: Adbar, http://commons.wikimedia.org/wiki/File:Lake_Crescent_spring.jpg

9 Cape Flattery-Neah Bay Clallam County
Source: http://alexquick.deviantart.com/art/Cape-Flattery-119412442 (Retrieved July, 2013)

9 Dungeness drift cell: Dungeness Spit and Shoreline
Source: Ian Miller

10 Lavender Fields- Sequim, Clallam County
Source: http://garb02.wordpress.com/2012/01/03/sequim-lavender-farm-faire/#respond (Retrieved July, 2013)

10 Jamestown S'Klallam Tribe: Tribal Center
Source: http://www.jamestowntribe.org/ (Retrieved July, 2013)

11 Dungeness Spit-Recreation Area
Source: Coastal Watershed Institute

11 Dungeness Crab and Seafood Festival
Source: http://www.crabfestival.org/_images/photo-gallery/large/3.jpg (Retrieved July, 2013)

12 Research Group Monitoring
Source: Coastal Watershed Institute

13 Ozette Triangle Trail
Source: Lola Flores

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Source: Lola Flores

14 Freshwater Bay
Source: WSU Clallam County Beach Watchers

14 Eelgrass beds
Source: Division of Forests and Lands http://www.nhdfl.org/about-forests-and-lands/bureaus/natural-heritage-bureau/photo-index/eelgrass-bed.aspx (Retrieved July, 2013)

15 Makah-Eagle and salmon print
Source: http://140.99.52.113/nw_coast/drum1.html (Retrieved July, 2013)

17 Sandy Point beach-Clallam County
Source: Tyler Buntain

18 Fishing dock-Quileute Nation
Source: Lola Flores

18 Feeder bluff (aerial photo) and sediment from Elwha River
Source: Ian Miller

18 Feeder bluff on the Clallam County Coast
Source: Anne Shaffer, Coastal Watershed Institute

19 Extensive shoreline modification in Clallam County
Source: Coastal Watershed Institute

19 Whidbey Island Landslide, 2012
Source: KOMO News http://www.komonews.com/news/local/Homes-evacuated-after-major-landslide-on-Whidbey-Island-200251371.html (Retrieved September 2013)

21 Bluff erosion in Clallam County
Source: Keith Thorpe-Peninsula Daily News http://www.peninsuladailynews.com/article/20100212/NEWS/302129992

24 Chinook Salmon in the Elwha River after dam removal
Source: National Park Service-The Peninsula Daily

24 Kelp beds in Clallam County
Source: Callie Miner, 2007

25 Large Woody Debris, Clallam County
Source: Coastal Watershed Institute

29 Elwha Dam before removal
Source: http://www.nps.gov/olym/historyculture/dam-construction.htm

29 Elwha Dam, 2012
Source: http://www.nps.gov/olym/historyculture/dam-construction.htm

29 Glines Canyon Dam before removal
Source: http://www.nps.gov/olym/historyculture/dam-construction.htm

29 Glines Canyon Dam, 2012
Source: http://www.nps.gov/olym/historyculture/dam-construction.htm

30 Elwha River sediment flow into the Strait of Juan de Fuca
Source: Tom Roorda

30 Elwha River sediment flow into the Strait of Juan de Fuca
Source: Tom Roorda

31 Elwha River sediment flow into the Strait of Juan de Fuca
Source: Tom Roorda

31 Elwha River sediment flow into the Strait of Juan de Fuca
Source: Tom Roorda

32 Part II: Ecosystem Services in Clallam County
Source: DimiTalen, http://commons.wikimedia.org/wiki/File:Quillayute_River_and_James_Island.jpg

33 Marine Life
Source: Shelly Ament

33 Sea Kayaking in Clallam County
Source: Jamie Michel

34 Chinook salmon, Oncorhynchus tshawytscha
Source: Zureks, 2008 http://commons.wikimedia.org/wiki/File:Chinook_salmon,_Oncorhynchus_tshawytscha.jpg

34 Marine life in Sequim, WA
Source: Shelly Ament

35 Collecting a water sample at Port Williams in Sequim, WA.
Source: WSU Clallam County Beach Watchers

35 Bluff in Clallam County
Source: WSU Clallam County Beach Watchers

36 Johnston Farm, Port Angeles, Washington
Source: http://farmersmarketportangeles.com/market/managers-blog/

36 Dungeness Spit
Source: Nat Bocking, 2004 http://commons.wikimedia.org/wiki/File:Dungeness_Spit.JPG?uselang=de

37 Aerial view of Port Angeles Landfill
Source: Kathryn Neal, City of Port Angeles

37 Trash on beach due to bluff failure at Port Angeles Landfill
Source: Kathryn Neal, City of Port Angeles

38 Port Angeles Landfill Seawall during construction, 2007
Source: Heather Trim

38 Completed seawall-Port Angeles Landfill
Source: Kathryn Neal, City of Port Angeles

39 Active bluff on east cell 304 and beginning of seawall at west cell 304
Source: Kathryn Neal, City of Port Angeles

39 Current site conditions east end cell 304
Source: Kathryn Neal, City of Port Angeles

39 Aerial view of Clallam County coastline - Elwha Mouth to Ediz Hook
Source: Kathryn Neal, City of Port Angeles

40 Aerial view of Port Angeles landfill with sediment
Source: Kathryn Neal, City of Port Angeles

42 Up-close Kelp
Source: Anna Maj Michelson, 2006 http://en.wikipedia.org/wiki/File:Kelp_in_Neskowin.jpg

43 Nurse log with fern, Olympic National Forest
Source: Lola Flores

43 Sequim Washington, Lavender farm
Source: Kgrr, 2004 http://commons.wikimedia.org/wiki/File:Sequim_WA_Lavender_Farm.JPG?uselang=de

44 Timber Industry
Source: Lola Flores

44 City Pier Marine Life Workshop, Port Angeles
Source: Arwyn Price, Peninsula Daily News http://www.peninsuladailynews.com/article/20130122/news/301229996/a-marine-life-marriage-in-port-angeles-feiro-national-marine

45 Soil Profile
Source: 2007 Holger K http://en.wikipedia.org/wiki/File:Stagnogley.JPG

45 Washington Conservation Corps crew removing beached creosote-contaminated wood at 3 Crabs Beach, Clallam County
Source: Jamie Michel

46 Elwha River
Source: ElwhaJeff, 2008 http://commons.wikimedia.org/wiki/File:Elwha_River_-_Humes_Ranch_Area2.JPG

48 Part III: Valuation of Clallam County
Source: Public Domain

76 Part IV: Applying Valuation Findings to Policy and Investment Decisions
Source: Anne Shaffer, Coastal Watershed Institute

90 Part V: Conclusions
Source: Clea Rome

Appendix A. Ecosystem Service Categories

Provisioning

Energy and Raw Materials
Providing fuel, fiber, fertilizer, minerals and energy

Food
Producing crops, fish, game and fruits

Medicinal Resources
Providing traditional medicines, pharmaceuticals, and assay organisms

Ornamental Resources
Providing esources for clothing, jewelry, handicraft, worship and decoration

Water Supply
Provisioning of surface and ground water for drinking water, irrigation, and industrial use

Information

Aesthetic
Enjoying and appreciating the presence, scenery, sounds, and smells of nature

Cultural and Artistic Inspiration
Using nature as motifs in art, film, folklore, books, cultural symbols, architecture and media

Recreation and Tourism
Experiencing natural ecosystems and enjoying outdoor activities

Science & Education
Using natural systems for education and scientific research

Spiritual and Historical
Using nature for religious and spiritual purposes

Regulating

Air Quality
Providing clean, breathable air

Biological Control
Providing pest and disease control

Climate Stability
Supporting a stable climate at global and local levels through carbon sequestration and other processes

Moderation of Extreme Events
Preventing and mitigating natural hazards such as floods, hurricanes, fires, and droughts

Pollination
Pollination of wild and domestic plant species

Soil Formation
Creating soils for agricultural and ecosystems integrity; maintenance of soil fertility

Soil Retention
Retaining arable land, slope stability and coastal integrity

Waste Treatment
Improving soil, water and air quality by decomposing human and animal waste, and removing pollutants

Water Regulation
Providing natural irrigation, drainage, ground water recharge, river flows and navigation

Supporting

Genetic Resources
Improve crop and livestock resistance to pathogens and pests

Habitat and Nursery
Maintaining genetic and biological diversity, the basis for most other ecosystem functions; promoting growth of commercially harvested species

Appendix B.
History of Shoreline Master Program and No Net Loss Policy

Almost 40 years ago the Washington State Legislature identified a "clear and urgent demand for a planned, rational, and concerted effort, jointly performed by federal, state, and local governments, to prevent the inherent harm of an uncoordinated and piecemeal development of the state's shorelines".[1] Since then, local governments have worked to put the broad policies of the Shoreline Management Act into practical terms through the development and implementation of Shoreline Master Programs.

With modern development practices, shorelines and nearby wetlands have become increasingly vital areas that provide critical economic benefits such as flood protection, erosion control, water filtration, recreation, and habitat for fish and wildlife. These natural assets benefit the whole community and contribute directly to a healthy local and regional economy. When shorelines and wetlands are lost, they are difficult and expensive to replace. It is for these reasons that the Washington State Shoreline Management Act requires municipalities and local governments to create Shoreline Master Programs.[2]

Each SMP seeks to establish shoreline plans that acknowledge present development while regulating future development with the goal of best serving the public interest and minimizing community cost.[3] In doing so, counties such as Clallam can prioritize positive practices and the uses of their particular ecosystems.

Clallam's Shoreline Master Program Update

Clallam County has a diverse shoreline that residents and visitors enjoy daily. Many ecosystem services are provided by the shoreline. Visitors come from near and far to fish and boat in these waters, camp along shores, and simply revel in the views. While tourism is a welcome component of Clallam's economy, it is equally important to residents that the County's shorelines be managed to the benefit of those who live there now and will live there in the future.[4]

The goal of the SMP is to conserve, to the fullest extent possible, the scenic, aesthetic, economic, and ecological qualities of the shorelines of Clallam County. To achieve this goal, the previous Shoreline Master Program of 1992 adopted several general policies that, to this day, are still applicable and serve as baseline principles for the required update. These policies include the restriction of private and public development or access that destroys the ecological integrity of the ecosystem and the economic benefits provided.[5]

The 2012 update has many similar goals and will be a continuation of the policies established in the 1992 SMP. New, required policies include a measurement of ecological functions for existing ecosystems. These requirements and goals are explained further in the No Net Loss Policy (NNL).

[1] Kramer J., MacIlroy C., Clancy M. 2010. No Net Loss of ecological Function Guiding Questions and Summary Examples. Shoreline Master Program.
[2] Kramer J., MacIlroy C., Clancy M. 2010. No Net Loss of ecological Function Guiding Questions and Summary Examples. Shoreline Master Program.
[3] Shoreline Master Program Handbook, 2010: http://www.ecy.wa.gov/programs/sea/shorelines/smp/handbook/index.html
[4] Clallam County Shoreline Master Program (SMP) Update 2012: http://www.clallam.net/RealEstate/html/shoreline_management.htm
[5] Clallam County SMP Inventory and Categorization Report (ICR) Update 2012: http://www.clallam.net/RealEstate/html/esa-icr-draft6-11.htm

Appendix C. Tables referenced from the Inventory and Characterization Report - Clallam County

Table 3.3 Suggested indicators of marine shoreline ecological function that can be systematically tallied using existing data for Clallam County. Clallam County ICR, 2012.

Metrics that Indicate Shoreline Quality	Why Selected?
— Percent of shoreland area mapped as feeder bluff (Table 3-7) — Percent of shoreland area mapped as landslide and erosion hazards (Table 3-8) — Percent of aquatic area supporting submerged aquatic vegetation (kelp) (Table 3-12) — Percent closed canopy forest within 200 feet of the ordinary high water line (Figure 3-14)	— Feeder bluffs play a critical role in sediment erosion and deposition and transport processes, which are key determinants of the health of marine beaches (Johannessen and MacLennan 2007). — Landslides and erosion are natural shoreline processes that deposit sediment on marine beaches but create hazardous conditions for property owners. — Kelp and other submerged aquatic plants provide food and refuge for a wide variety of invertebrates (e.g., sea urchins and abalone) and fishes (e.g., juvenile rockfishes, forage fish, and salmon) and orca whales (Mumford, 2007; Shaffer 2008). — Marine riparian vegetation has a major influence on functions including habitat, water quality, organic and nutrient inputs and microclimate (Brennan and Culverwell 2004).
Metrics that Indicate Shoreline Alteration	**Why Selected?**
— Percent of shoreline classified as modified (Table 3-6) Percent of feeder bluffs with armoring (Table 3-9) — Percent of hard armoring along shoreline (Figure 3-9) — Number of overwater structures per mile of shore (Table 3-10) and number of overwater structures per mile of sediment transport zone (Table 3-11)	— Modified shores are missing important structural elements that provide habitat for various terrestrial and aquatic species. — Armoring can cause loss of beach and backshore habitat which important areas for forage fish spawning. Armoring also affects movement of materials and organisms between the riparian and the aquatic zone or alter natural drainage patterns (Shipman et al., 2010; Hirschi et al. 2003). — Overwater structures impact sediment transport process, solar incidence and exchange of aquatic organisms, which affects wood web functions, habitat availability and species distribution (Schlenger et al. 2010; Nightengale and Simenstad 2001)

Feeder-bluff Area

Table 3.7 provides survey data on the percentage of each reach of the Clallam County shoreline that has been mapped as feeder bluff along the Strait of Juan de Fuca. This provides a good basis for understanding the current condition of feeder bluffs and provides a foundation for valuation work.

Table 3.7 from the ICR (Clallam County, 2012)- Percent of each reach mapped as feeder bluff along the Strait of Juan de Fuca in Clallam County (data from CGS 2011).

		Feeder Bluff Area as a Percent of Reach Length		
Marine Reach	Reach Miles (approx.)	Feeder Bluff - Exceptional	Feeder Bluff	Feeder Bluff - Talus
1- Diamond Point	12.5	14%	30%	0%
2 - Sequim Bay	8.2	0%	28%	0%
3 - Gibson Spit	6.1	28%	10%	0%
4 - Kulakala Point	7.9	0%	6%	0%
5 - Dungeness Spit	15.7	0%	0%	0%
6 - Green Point	10.4	63%	8%	0%
7 - Angeles Point	7.3	3%	22%	1%
8 - Observatory Point	4.9	0%	0%	0%
9 - Crescent Bay / Low Point	10.7	0%	4%	35%
10 - Twin Rivers	7.4	7%	7%	68%
11 - Deep Creek	5.3	0%	0%	47%
12 - Pysht River	2.4	0%	0%	4%
13 - Pillar Point	2.1	0%	0%	63%
14 - Slip Point	6.8	0%	0%	0%
15 - Clallam Bay	5.7	0%	0%	0%
16 - Sekiu River / Kaydaka	3.6	0%	0%	14%
17 - Shipwreck Point	6.9	0%	0%	0%
18 - Rasmussen / Bullman Creek	4.6	0%	0%	0%

Table 3.8 from the ICR (Clallam County, 2012)- Percent of each reach mapped as landslide and erosion hazard along the Strait of Juan de Fuca in Clallam County (data from WDNR 2007).

Marine Reach	Reach Miles (approx.)	Landslide and Erosion Hazard Areas as Percent of Reach Length
1 - Diamond Point	12.5	62%
2 - Sequim Bay	8.2	11%
3 - Gibson Spit	6.1	5%
4 - Kulakala Point	7.9	3%
5 - Dungeness Spit	15.7	7%
6 - Green Point	10.4	61%
7 - Angeles Point	7.3	26%
8 - Observatory Point	4.9	8%
9 - Crescent Bay / Low Point	10.7	54%
10 - Twin Rivers	7.4	68%
11 - Deep Creek	5.3	66%
12 - Pysht River	2.4	27%
13 - Pillar Point	2.1	96%
14 - Slip Point	6.8	90%
15 - Clallam Bay	5.7	27%
16 - Sekiu River / Kaydaka	3.6	67%
17 - Shipwreck Point	6.9	11%
18 - Rasmussen / Bullman Creek	4.6	37%

Modified Shoreline

Table 3.6 from the ICR (Clallam County, 2012)- Strait of Juan de Fuca shoretype mapping and criteria for Clallam County (CGS 2011).

Marine Shoretype	Percent of Shoreline
Accretion Shoreform	30.5%
Transport Zone	19.2%
No Appreciable Drift	12.7%
Feeder Bluff - exceptional	10.3%
Feeder Bluff	9.2%
Feeder Bluff-talus	8.1%
Modified	10.0%

Feeder Bluffs with Armoring

Table 3.9 from the ICR (Clallam County, 2012)- Reaches where armoring occurs at the base of mapped feeder bluffs along the Strait of Juan de Fuca in Clallam County.

Reach ID	Length Feeder Bluff w/ Armor (Miles)	Total Feeder Bluff Length (Miles)	Reach Length (Miles)	Percent of Feeder Bluff that is Armored
2 - Sequim Bay	0.17	1.4	8.2	12.1%
3 - Gibson Spit	0.05	1.1	6.1	4.6%
Grand Total	*0.22*			

** Reaches 2 and 3 are the only reaches that have feeder bluffs with armoring*

Overwater Structure

Table 3.10 from the ICR (Clallam County, 2012)- Effects of hard armoring on some marine species (from Thom et al. 1994).

	Armoring Effects[a]						
Resource Species	Armoring-related Habitat Shift	Loss of Spawning Habitat	Loss of Shoreline Riparian Vegetation	Loss of Wetland Vegetation	Loss of Large Organic Debris	Changes in Food Resources	Loss of Migratory Corridors
Surf Smelt	●	●	●		⊕		
Pacific Sand Lance	●	●	●		⊕		
Rock Sole	●	●	●		⊕		
Juvenile Salmonids	●		●	●	●	●	●
Pacific Herring	⊕	⊕					
Hardshell Clams	●	⊕				●	
Geoduck	○						
Oysters	○	○				○	
Dungeness Crab	⊕	⊕				⊕	
Sea Cucumber	○					○	
Sea Urchins	○					○	

[a] Filled circles represent well documented evidence of negative effects, cross-filled circles represent high potential for negative effects but not documented, and open circles indicate some potential for longterm effects but not documented.

Table 3.11 from the ICR (Clallam County, 2012)- Reaches where overwater structures occur within sediment transport zones along the Strait of Juan de Fuca in Clallam County (data from PSNERP 2009 and CGS 2011).

Marine Reach	# OWS	Total Miles of Transport Zone	# OWS/ Miles of Transport Zone
1 - Diamond Point	2	9.2	0.2
2 - Sequim Bay	15	6.2	2.4
3 - Gibson Spit	4	3.5	1.1
4 - Kulakala Point	4	6.6	0.6
5 - Dungeness Spit	2	12.1	0.2
6 - Green Point	0	9.7	0
7 - Angeles Point	0	6.3	0
8 - Observatory Point	0	0	0
9 - Crescent Bay / Low Point	0	9	0
10 - Twin Rivers	0	6.8	0
11 - Deep Creek	1	4.7	0.2
12 - Pysht River	0	2	0
13 - Pillar Point	0	0.6	0
14 - Slip Point	0	0	0
15 - Clallam Bay	16	2.1	7.6
16 - Sekiu River / Kaydaka	0	2.5	0
17 - Shipwreck Point	1	4.9	0.2
18 - Rasmussen / Bullman Creek	3	0.9	3.3

Salmonid Stock Status

Table 5.4 from the ICR (Clallam County, 2012)- Summary of salmon stock status for North Olympic Coast rivers in Clallam County (from NOPLE 2005, adapted to correspond to SMP study area).

Geographical Unit (Revised 15June03)	No. of Stocks or Stock Component on a Historic Basis	Critical and Extirpated		Current Known Trends as per NOP TRG		Specific Stocks at Risk of Extirpation as per NOP TRG
		Crit.	Ext.	Healthy or Depressed but Declining	Critical and Declining	
Central Strait Clallam Independents (McDonald, Siebert, & Bagley)	4		Fall chum	Fall coho, winter steelhead		Coho
Clallam Basin	4	Fall chum				Chum
Deep Basin	1	Fall chum			Fall chum	Chum
Dungeness Basin	11	Spring/ summer chinook, fall pink, summer steelhead			Fall pink, summer steelhead	
E&W Twin	4	Fall chum		Fall coho, winter steelhead	Fall chum	Chum
Eastern Strait Clallam Independents (Bell, Gienn, Cassalery, Cooper, Meadow brook)1	1					Coho
Elwha Basin	10	Summer pink, fall chum	Spring/ summer Chinook	Summer/fa ll Chinook bull trout	Summer pink, fall chum	
Ennis Basin	3		Fall chum	Fall coho		
Goodman Complex (Cedar, Goodman, Mosquito)	1	Unkown	Unkown			
Hoko Basin	5	Fall chum				Chum
Jimmy Come Lately	4	Summer chum			Summer chum	Chum, coho
Lyre-Crescent Basin	5	Fall coho		Fall chum		Chum

Table 5.4 cont.

Geographical Unit (Revised 15June03)	No. of Stocks or Stock Component on a Historic Basis	Critical and Extirpated		Current Known Trends as per NOP TRG		Specific Stocks at Risk of Extirpation as per NOP TRG
		Crit.	Ext.	Healthy or Depressed but Declining	Critical and Declining	
Morse Basin	8	Fall coho, summer pink, fall chum	Spring/ summer Chinook			
Nearshore	124+	24+	7+	16+	11+	See basins
Pysht Basin	5	Summer/ fall Chinook		Fall chum		Chinook
Salt Basin	4					
Sekiu Basin	5	Summer/ fall Chinook, fall chum				Chinook, chum
Sequim Bay (Johnson, Chicken Coop, Dean)2	3			Fall coho		
Western Strait Clallam Independents (Village east to Colville Creek)	4	Fall coho, fall chum			Fall coho, fall chum	Coho, chum

Table 5.5 from the ICR (Clallam County, 2012)- Acres of closed canopy forest within 200 feet of the ordinary high water line (Data from Point No Point Treaty Council 2011).

Reach Name	Acres of Riparian Forest within 200' Shoreline	Total Acres of Reach	% of Riparian Forest
Bear_Cr_01	121	130	93%
Boun_Cr_01	54	55	99%
Brow_Cr_01	10	13	75%
Bull_Cr_01	11	18	58%
Cany_Cr_01	71	77	91%
Char_Cr_01	30	42	72%
Clal_Rv_01	59	110	53%
Clal_Rv_02	19	30	64%
Clal_Rv_03	31	89	35%
Clal_Rv_04	291	322	90%
Covi_Cr_01	15	15	100%
Deep_Cr_01	258	280	92%
Dung_Rv_01	15	45	33%
Dung_Rv_02	114	263	43%
Dung_Rv_03	83	175	48%
Dung_Rv_04	238	250	95%
Dung_Rv_05	326	330	99%
Dung_Rv_06	170	170	100%
Elli_Cr_01	35	44	79%
Elwh_Rv_01	104	214	49%
Elwh_Rv_02	51	147	34%
Elwh_Rv_03	68	102	67%
Etwi_Rv_01	201	216	93%
Gray_Rv_01	375	392	96%
Gree_Cr_01	27	33	83%

Table 5.5 cont.

Reach Name	Acres of Riparian Forest within 200' Shoreline	Total Acres of Reach	% of Riparian Forest
HERM_CR_01	51	84	61%
HERM_CR_02	37	55	68%
HOKO_RV_01	36	44	81%
HOKO_RV_02	66	115	57%
HOKO_RV_03	264	319	83%
HOKO_RV_04	64	103	63%
HOKO_RV_05	185	246	75%
HOKO_RV_06	131	179	73%
HOKO_RV_07	110	150	73%
HOKO_RV_08	90	117	77%
HOKO_RV_09	105	124	85%
INDI_CR_01	174	238	73%
LAST_CR_01	2	3	67%
LHOK_RV_01	149	211	71%
LITT_RV_01	111	115	96%
LYRE_RV_01	171	187	91%
LYRE_RV_02	65	65	100%
MCDO_CR_01	242	350	69%
MORS_CR_01	274	424	65%
NBHE_CR_01	43	52	82%
NFSE_RV_01	206	244	84%
OLDR_CR_01	13	24	56%
PYSH_RV_01	60	92	65%
PYSH_RV_02	189	264	72%
PYSH_RV_03	41	69	60%

Table 5.5 cont.

Reach Name	Acres of Riparian Forest within 200' Shoreline	Total Acres of Reach	% of Riparian Forest
PYSH_RV_04	183	251	73%
ROYA_CR_01	17	17	100%
SALM_CR_01	25	47	52%
SALT_CR_01	9	37	24%
SALT_CR_02	158	183	86%
SBLI_RV_01	69	70	100%
SEKI_RV_01	178	272	66%
SFPY_RV_01	44	67	66%
SFPY_RV_02	116	145	80%
SFSE_RV_01	114	124	92%
SILV_CR_01	34	34	100%
SUTH_LK_01	1	3	39%
WTWI_RV_01	206	256	80%
Grand Total	6,623	8,695	76.2%

Table 5.6 from the ICR (Clallam County, 2012)- Acres and Number of Revetments and Levees on SMP streams in WRIA 17, 18 and 19 streams in Clallam County by reach (no systematic data available; estimates are from Clallam County staff and local experts).

	Revetments / Levees	
Freshwater Reach	ACRES	COUNT
Dungeness River Reach 01	7.1	2.0
Dungeness River Reach 02	4.8	1.0
Dungeness River Reach 03	6.7	5.0
Elwha River Reach 01	14.6	22.0
Elwha River Reach 03a	7.3	2.0
Little River Reach 01	3.9	1.0
Morse Creek Reach 01	3.7	4.0
Pysht River Reach 01	18.6	3.0
Grand Total	*66.8*	*40.0*

Table 5.7. Impervious surface area as a percent of the shoreland jurisdictional area for streams in WRIA 17, 18 and 19 streams in Clallam County by reach (From National Land Cover Data Set).

Freshwater Reach	Percent Impervious
Bullman Creek Reach 01	5.0%
Canyon Creek Reach 01	1.1%
Charlie Creek Reach 01	0.9%
Clallam River Reach 01	3.0%
Clallam River Reach 02	4.9%
Clallam River Reach 03	15.0%
Clallam River Reach 04	1.3%
Deep Creek Reach 01	0.5%
Dungeness River Reach 01	2.4%
Dungeness River Reach 02	3.0%
Dungeness River Reach 03	6.1%
Dungeness River Reach 04	0.3%
East Twin River Reach 01	0.8%
Elwha River Reach 01	0.6%
Elwha River Reach 02	3.7%
Elwha River Reach 03	7.9%
Green Creek Reach 01	0.0%
Hoko River Reach 01	2.4%
Hoko River Reach 02	1.6%
Hoko River Reach 03	1.3%
Hoko River Reach 04	1.1%
Indian Creek Reach 01	5.8%
Lake Sutherland Reach 01	18.1%
Little River Reach 01	0.7%
Lyre River Reach 01	1.3%
McDonald Creek Reach 01	2.4%

Table 5.7 cont.

Freshwater Reach	Percent Impervious
Morse Creek Reach 01	9.8%
Pysht River Reach 01	0.2%
Pysht River Reach 02	4.1%
Pysht River Reach 03	5.7%
Pysht River Reach 04	2.1%
Salt Creek Reach 01	2.3%
Salt Creek Reach 02	1.5%
Sekiu River Reach 01	7.5%
Grand Total	*3.5%*

Appendix D. Reference Table for Benefit Transfer Values

Land Cover	Author(s) (Primary)	Low	High
Grasslands		**$0.01**	**$26,941.07**
	Zhongwei	$6,525.01	$11,315.12
	Butler and Workman	$4.46	$111.41
	Qiu et al.	$246.26	$1,206.32
	Ready et al.	$0.01	$0.01
	Rein, F. A.	$23.80	$26,941.07
	Wilson, S. J.	$10.57	$411.65
Marine		**$0.05**	**$724.32**
	Costanza et al. (1997)	$0.05	$106.88
	Hanley, N., Bell, D. and Alvarez-Farizo, B.	$13.12	$13.12
	Kahn, J. R. and Buerger, R. B.	$2.40	$724.32
	Nunes, P and Van den Bergh, J.	$105.42	$105.42
	Soderqvist, T. and Scharin, H.	$66.45	$110.47
Riparian Buffer		$16.56	$26,941.07
	Rein, F. A.	$23.80	$26,941.07
	Zavaleta	$16.56	$561.67
Seagrass/algae beds		$1.23	$17,198.60
	Costanza et al. (1997)	$1.23	$17,198.60
	Johnston, R. J. et al.	$1,571.92	$1,571.92
	Mazzotta, M.	$10,864.67	$10,864.67
	Stern and Boscolo	$1.92	$273.83
Wetlands		**$0.44**	**$53,546.42**
	Allen, J. et al.	$342.56	$342.56
	Brouwer, R., et al.	$27.66	$67.53
	Cooper J. and Loomis, J.	$13.91	$331.12
	Costanza et al.	$2,745.57	$2,745.57
	Costanza et al. (1997)	$2,052.36	$2,052.36
	Costanza, R., et al.	$103.89	$9,491.02
	Creel, M. and Loomis, J.	$550.55	$603.10

Table cont.

Land Cover	Author(s) (Primary)	Low	High
Wetlands (cont.)	Doss, C. R. and Taff, S. J.	$4,248.85	$5,142.12
	Haener, M. K. and Adamowicz, W. L.	$2.18	$14.94
	Hayes, K. M., et al.	$1,347.94	$3,556.97
	Hicks et al.	$143.24	$143.24
	Jenkins et al.	$7.21	$562.48
	Jenkins et al.	$72.30	$95.96
	Kazmierczak, R.F.	$282.31	$673.56
	Kreutzwiser, R.	$201.44	$201.44
	Lant, C. L. and Roberts, R. S.	$0.44	$0.65
	Lant, C. L. and Tobin, G.	$195.11	$2,148.10
	Leschine et al.	$1,663.57	$7,596.07
	Mahan, B. L., et al.	$38.62	$38.62
	Mahan, B.L.	$10,461.77	$10,461.77
	Mazzotta, M.	$8,953.28	$8,953.28
	Olewiler, N.	$313.39	$880.54
	Pate, J. and Loomis, J.	$53,546.42	$53,546.42
	Roel calculation for LA	$30.75	$279.40
	Roel/Ken	$34.73	$1,660.64
	Roel/Ken (for low value); Woodward and Wui, (for high value)	$67.79	$1,566.69
	Thibodeau, F. R. and Ostro, B. D.	$44.54	$22,434.51
	van Kooten, G. C. and Schmitz, A.	$6.00	$6.00
	van Vuuren, W. and Roy, P.	$1,390.79	$1,390.79
	Whitehead, J. C.	$1,059.87	$2,334.36
	Whitehead, J. C., et al.	$245.21	$245.21
	Wilson, S. J.	$4.83	$2,480.41
	Woodward, R., and Wui, Y.	$1.72	$9,668.76
Estuary		$0.76	$106,639.46
	Aburto-Oropeza et al.	$16,463.98	$16,463.98
	Anderson, G. D. and Edwards, S. F.	$411.29	$411.29
	Batie, S. S. and Wilson, J. R.	$7.07	$1,400.74
	Bauer D.M., et al.	$366.58	$366.58
	Breaux, A., et al.	$150.22	$29,015.16
	Costanza, R., et al.	$269.97	$106,639.46
	Everard, M.	$47.31	$47.31
	Farber, S.	$10.17	$31.34
	Farber, S. and Costanza, R.	$1.49	$1,409.26

Table cont.

Land Cover	Author(s) (Primary)	Low	High
Estuary (cont.)	Lynne, G. D., et al.	$0.76	$0.76
	Roel/Ken	$5.07	$1,660.64
	Roel/Ken (for low value); Woodward and Wui, (for high value)	$67.79	$1,566.69
Shoreline		$110.67	$50,592.13
	Bell, F.W. and Leeworthy, V.R.	$2,869.56	$3,176.25
	Kline, J. D. and Swallow, S. K.	$39,202.78	$50,592.13
	Pompe, J. J. and Rinehart, J. R.	$259.38	$684.97
	Silberman, J., et al.	$24,528.98	$24,528.98
	Taylor, L. O. and Smith, V. K.	$465.24	$465.24
	Wilson, S. J.	$110.67	$110.67
Shrub		$0.27	$1,300.20
	Bennett, R., et. al.	$276.57	$276.57
	Boxall, P. C., et al.	$0.27	$0.27
	Costanza, R., et al.	$0.63	$1,300.20
	Haener, M. K. and Adamowicz, W. L.	$0.30	$12.86
	Kenyon, W. and Nevin, C.	$555.96	$555.96
	Maxwell, S.	$13.09	$13.09
	Paula Sweden	$6.89	$69.24
	Prince, R. and Ahmed, E.	$1.66	$2.11
	Willis, K.G.	$0.47	$211.90
Forests		$0.08	$17,237.97
	Zhongwei	$276.39	$277.54
	Adger et al. (1995)	$0.08	$42.83
	Amigues, J. P., et. al.	$15.32	$3,016.00
	Bennett, R., et. al.	$276.57	$276.57
	Bishop, K.	$40.97	$2,243.45
	Boxall, P. C., et al.	$0.21	$0.21
	Costanza, R., et al.	$0.43	$2,569.72
	Haener, M. K. and Adamowicz, W. L.	$0.50	$0.50
	Hougner, C.	$69.98	$314.32
	Kenyon, W. and Nevin, C.	$555.96	$555.96
	Knowler, D. J. et al.	$10.92	$50.07
	Knowler, D.J., et al.	$10.92	$50.15
	Krieger, D.J.	$9.99	$9.99
	Lant, C. L. and Tobin, G.	$346.50	$346.50
	Loomis J.B.	$10.68	$10.68

Table cont.

Land Cover	Author(s) (Primary)	Low	High
Forests (cont.)	Mates. W., Reyes, J.	$59.34	$261.99
	Maxwell, S.	$13.09	$13.09
	Nowak et al.	$4,218.48	$17,237.97
	Olewiler, N.	$32.52	$32.52
	Paula Sweden	$64.19	$1,100.28
	Pearce and Moran (1994)	$65.52	$65.52
	Pimentel et al.	$15.87	$15.87
	Pimentel et al. (1996)	$2.46	$53.44
	Pimentel et al. (1997)	$1.79	$17.92
	Prince, R. and Ahmed, E.	$2.26	$2.88
	Ribaudo, M. and Epp, D. J.	$1,440.04	$1,826.01
	Shafer, E. L., et al.	$3.03	$599.03
	Willis, K. G. and Garrod, G. D.	$4.17	$4.17
	Willis, K.G.	$0.69	$211.90
	Wilson, S. J.	$11.05	$657.28
Cultivated Crops		**$2.13**	**$1,888.32**
	Bergstrom et al.	$33.68	$85.86
	Canadian Urban Institute.	$6.11	$119.58
	Cleveland et al.	$13.66	$194.72
	Hauser, A and van Kooten, C.	$11.02	$44.73
	Knoche and Lupi	$2.13	$4.93
	Pimentel et al. (1995)	$127.17	$127.17
	Robinson, W. S., et al.	$13.45	$13.45
	Sandhu, H.S., et al.	$6.01	$6.01
	Smith, W.N. et al.	$29.04	$29.04
	Southwick, E. E. and Southwick, L.	$2.67	$2.67
	Wilson, S. J.	$2.30	$411.65
	Winfree et al.	$45.50	$1,888.32
Fresh Water		**$1.71**	**$842,933.84**
	Berrens, R. P., et al.	$2,339.61	$2,339.61
	Bouwes, N. W. and Scheider, R.	$626.45	$695.02
	Bowker, J. M., et al.	$7,029.54	$16,894.50
	Burt, O. R. and Brewer, D.	$576.89	$631.96
	Cordell, H. K. and Bergstrom, J. C.	$152.92	$2,815.44
	Costanza, R., et al.	$1.71	$1,946.54
	Croke, K., et al.	$574.15	$628.95
	Duffield, J. W., et al.	$1,749.31	$18,036.95
	Everard and Jevons	$2.57	$15.14

Table cont.

Land Cover	Author(s) (Primary)	Low	High
Fresh Water (cont.)	Gramlich, F. W.	$1,119.68	$1,119.68
	Greenley, D., et al.	$21.21	$21.21
	Kealy, M. J. and Bishop, R. C.	$13.12	$14.37
	Kreutzwiser, R.	$183.89	$183.89
	Kulshreshtha, S. N. and Gillies, J. A.	$79.33	$79.33
	Loomis J.B.	$12,370.94	$21,893.37
	Mathews, L. G., et al.	$14,464.89	$14,464.89
	Mullen, J. K. and Menz, F. C.	$295.90	$424.02
	Oster, S.	$76.80	$76.80
	Piper, S.	$32.81	$266.96
	Ribaudo, M. and Epp, D. J.	$8.40	$937.39
	Rich, P. R. and Moffitt, L. J.	$7.83	$7.83
	Roel/Ken	$29.89	$779.61
	Sanders, L. D., et al.	$2,553.31	$2,553.31
	Shafer, E. L., et al.	$4,526.12	$17,287.22
	Streiner, C., Loomis, J.	$842,933.84	$842,933.84
	Ward, F. A., et al.	$4,589.09	$4,589.09
	Wu and Skelton-Groth	$136.78	$2,975.27
	Young, C. E. and Shortle, J. S.	$83.05	$90.97
Pastures		$0.05	$411.65
	Boxall, P. C.	$0.05	$0.05
	Costanza, R., et al.	$2.68	$30.69
	Pimentel et al.	$6.91	$6.91
	Wilson, S. J.	$411.65	$411.65

Appendix E. Full References for Benefit Transfer Values

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Appendix F. Study Limitations

The results of the first attempt to assign monetary value to the ecosystem services rendered by Clallam County have important and significant implications on the restoration and management of natural capital. Valuation exercises have limitations that must be noted, although these limitations should not detract from the core finding that ecosystems produce a significant economic value to society. A benefit transfer analysis 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.

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, pastureland, 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 (Howarth & Farber, 2002). These aggregates (i.e. GDP) routinely impute values to public goods for which no conceivable market transaction is possible. The value of ecosystem services of large geographic areas is comparable to these kinds of aggregates.

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 Clallam County would make this approach to valuation extremely difficult and costly. Responses to the above critiques can be summarized as follows (See Costanza et al., 1998; and Howarth and Farber, 2002 for more detailed discussion):

— 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 the County's ecosystem 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 that are 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 (Batker et al, 2010).

- 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. 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 extremely precise. However, they are much better estimates than the alternative of assuming that ecosystem services have zero value, or, alternatively, of assuming they have infinite value. Pragmatically, in estimating the value of ecosystem services, it seems better to be approximately right than precisely wrong.

- The estimated value of the world's ecosystems presented in Costanza et al. (1997), for example, has been criticized as both (1) a serious underestimate of infinity and (2) impossibly exceeding the entire Gross World Product. 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.

- Upon some reflection, it should not be surprising that the value ecosystems provide to people exceeds the gross world product. Costanza's estimate of the work that ecosystems do is an underestimate of the "infinity" value of priceless systems, but that is not what he sought to estimate. Consider the value of one ecosystem service, such as photosynthesis, and the ecosystem good it produces: atmospheric oxygen. Neither is valued in Costanza's study. Given the choice between breathable air and possessions, informal surveys have shown the choice of oxygen over material goods is unanimous. This indicates that the value of photosynthesis and atmospheric oxygen to people exceeds the value of the gross world product – and oxygen production is only a single ecosystem service and good.

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 ecosystem services become more limited. The values of many ecological services rapidly increase as they become increasingly scarce (Boumans et al. 2002). If Clallam County's ecosystem 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 this service 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). Having economic information on ecosystem services usually helps this process because traditionally, only opportunity costs of forgoing 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.

— **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.

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 ecosystem service valuation assumes spatial homogeneity of services within ecosystems, i.e. that every acre of forest produces the same ecosystem 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 ecosystem services have shown that including interdependencies and dynamics leads to significantly higher values (Boumans et al., 2002), as changes in ecosystem 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 ecosystem 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. Table 5 illustrates which ecosystem services were identified in Clallam County for each land cover type, and which of those were valued.

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. Most 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 ecosystem 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 ecosystem 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 (Limburg et al., 2002). 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 ecosystem 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.

Appendix G.
About Earth Economics

Earth Economics is a non-profit located in Tacoma, Washington. Earth Economics provides robust, science-based, ecologically-sound, economic analysis, policy and tools to governments, agencies, NGOs, and grassroots organizations. This information is intended to positively transform international, national and regional economic systems and business accounting practices. Earth Economics has a small in-house staff of economists that collaborate with experts in economics, ecology, hydrology, policy and systems modeling. Our goal is to help communities shift away from the failed economic policies of the past, towards an approach that is both economically viable and environmentally sustainable.

Mission Statement

Earth Economics applies new economic tools and principles to meet challenges of the 21st century: achieving the need for just and equitable communities, healthy ecosystems, and sustainable economies.

Program Work

Ecosystem Service Valuations: Quantifying the value of the goods and services provided by regional ecosystems.

Economic Environmental Impact Statements: Analyzing specific projects and scenarios based on comprehensive environmental economic analysis.

Jobs Analysis: Calculating the jobs that will be created, maintained, or lost by doing or not doing a project.

Accounting and Management Strategies: Identifying new management approaches that value ecosystem services in addition to built infrastructure and raw materials.

Scenario Mapping and Modeling: Mapping ecosystem services provisioners, beneficiaries and impairments under different planning scenarios.

Funding Mechanisms for Conservation and Restoration: Applying innovative approaches to fund critical natural infrastructure and conservation work.

Educational Outreach: Conducting workshops, lectures and media events to increase awareness about ecological economics.

Conversion to Sustainability: Catalyzing the shift from unsustainable to sustainable technology.

EARTH ECONOMICS

Earth Economics
107 N. Tacoma Avenue
Tacoma, WA 98403
www.eartheconomics.org
253.539.4801