Valuing The Puget Sound Basin

Revealing Our Best Investments 2010

EARTH ECONOMICS

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Version 1.4

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Acknowledgments: The authors would like to thank the board of Earth Economics, Josh Reyneveld, Ingrid Rasch, David Cosman and Josh Farley. This report would not be possible without the assistance from Jennifer Harrison-Cox, Allyson Schrier, Tedi Dickinson, Jon Roberts, Colin Cornin, Kellen Hawley, Jon Stout, Patrick Miller, Caleb Tomlinson, and Zac Christin. The board of Earth Economics provided unwavering and selfless support to help complete these studies.

We would also like to thank Jan Kocian for the cover photo.

This report was made possible by the generous support of The Russell Family Foundation and Social Venture Kids.

Executive Summary

Nature provides goods and services offering magnificent value and extraordinary investment opportunity. 14 goods and services provided by nature within the Puget Sound Basin provide benefits worth between $9.7 billion and $83 billion every year. This "natural capital" includes drinking water, food, wildlife, climate regulation, flood protection, recreation, aesthetic value and more. Valuing the asset that provides this annual flow of goods and services—that is, the natural capital of the Puget Sound Basin, as if it were a capital asset shows it would be valued between $305 billion and $2.6 trillion (at a 3% discount rate).

This wide range in value should not be surprising. Every house or business appraisal has a range in potential values. Appraisers arbitrarily pick a number between these figures to provide to clients. By providing a range this report avoids that arbitrary single number selection. In addition, volatility in asset value is normal. Consider the value of Washington Mutual Bank, $306 billion in January 2008 yet it was sold for $1.3 billion in October 2008. The lower values provided in this study are really base values.

Natural assets examined in this report, such as water, flood protection and recreation, are far more stable in value than many other economic assets.

This study identifies 23 natural goods and services that provide value to people, businesses and government agencies. Of these, 14 were valued. These ecosystem services can also be mapped, showing the provisioning areas, beneficiaries and impairments to ecosystem services; values will be further refined when we are able to take full advantage of modeling systems currently under development (See page 76). Understanding the value ecosystem services provide, where these benefits are provided on the landscape, who benefits from them and where they are impaired sets up a sound scientific and economic basis for developing funding mechanisms to secure this vast value.

> Natural systems in the Puget Sound Basin, if valued as economic assets, would be worth between $305 billion and $2.6 trillion.

Even at the low end of this estimate the value of natural systems in the Puget Sound Basin is enormous. Yet this wealth is being lost. As the ecological health of the region deteriorates, benefits once provided for free and potentially in perpetuity are deteriorating or disappearing. As each ecosystem service is lost, residents, businesses and agencies suffer damage. To reduce damage, new expensive engineered infrastructure is developed to replace nature's lost and previously free services. Levees, stormwater systems, water filtration plants and other built capital all require maintenance, depreciate in value and require replacement every 40-60 years.

The most efficient, least costly, sustainable and robust systems often require a combination of natural and built capital. For example, the Cedar River watershed provides water (natural capital), while pipes (built capital) deliver the water to people's homes. This is not an either/or discussion, it is about how built and natural capital are complements.

> The key to securing ecological sustainability, fairness, and economic prosperity is investment. Today's investment determines the physical nature of tomorrow's economy.

Success in achieving sustainability in the Puget Sound Basin requires a shift to green infrastructure, including ecological restoration, stormwater retention, green building, better industrial processes and far more. Shifting investment requires accounting that includes the value of natural capital, improved jobs analysis, better cost/benefit analysis and economic incentives that reward green investment. Earth Economics worked with diverse institutions to demonstrate improved economic analysis. In **Section 1: Economic Analysis Incentives and Investment** we present a series of briefs from 12 of these studies. The lesson to be drawn from each is summarized below:

Accounting for Natural Capital - Currently natural capital is not recognized as a capital asset that is measurable within standard accounting systems. As a result, these assets are undervalued and investment in the form of capital improvements, maintenance and operations are insufficient. Washington State and the counties of the Puget Sound Basin should lead the way initiating changes in national accounting rules to accommodate the economic value that natural capital provides.

Improving Jobs Analysis for Restoration - As jobs analysis is increasingly important for the allocation of federal funds, counting green jobs from restored ecosystem services is a vital part of any restoration effort. Washington State and the Puget Sound Partnership should have the capacity to calculate jobs resulting from natural system restoration for any restoration or related project in the Puget Sound Basin or in the State.

Adopting New Industrial Indicators - Green businesses can include heavy industry. Industries that use indicators to show their environmental, social and economic footprints can reduce negative impacts on the environment, communities and people—while at the same time enhancing economic development, jobs, productivity, profits and competitiveness. The right information allows firms to make better investments. To do so requires innovation in the environmental, economic and social indicators used by private firms to evaluate their impact. Five paper mills in Washington are pioneering this work. Private investment is vital to securing sustainability. Washington State and Washington State companies should pursue new industrial indicators in an effort to facilitate economic gains to private firms, and to achieve environmental improvements beyond regulatory compliance.

Redefining Green Jobs - Most accepted definitions of green jobs are inappropriately narrow. There is room for a far more visionary and comprehensive definition that would allow nearly every industry to become a green jobs industry. Part of saving Puget Sound—shifting the economy and ensuring a high quality of life at work and at home—is the economy-wide shift to, and investment in, green jobs in virtually all sectors. The spot prawn fishery provides a good example of a fundamental shift from trawling to a trap fishery securing sustainability, fairness and economic prosperity. Clear strategies for shifting economic sectors in the state with sustainability indicators are needed to help expand existing industries and employment, secure greater economic productivity and generate additional green jobs.

Changing Cost/Benefit Analysis - All federal and state agencies, cities, counties and many private firms utilize cost/benefit analysis to make investment decisions, but often these decisions are made without taking into account the value of ecosystem services. The State of Washington and Puget Sound Basin could lead the way by instituting changes in State cost/benefit analysis and requesting improvements in Army Corps of Engineers and other federal agency cost/benefit analyses to include ecosystem services. We have the means to apply this in many areas, such as flood protection. The State should quickly include ecosystem services and pioneer changes in state cost/benefit analysis to lead the nation and hasten rule improvements.

Getting the Scale of Jurisdictions Right - Many Washington State tax districts are tied to ecosystem services. The boundaries of jurisdictions are often set where the service is lost as in the case of flood districts at the base of a watershed. Yet the provisioning of flood protection is watershed-wide. From flood districts to shellfish districts, jurisdictions need to be set at a scale that includes the beneficiaries and the provisioning area. For a flood district, that means a watershed scale. The King County Flood Control District and the Chehalis River Basin Flood Authority are good examples. Washington State should conduct a comprehensive review of the scale and efficiency of existing tax districts. The determination of the scale of these districts should be informed by both the scale of influences contributing to the problem and the scale of assets contributing to the solution. This could save vast expenditures and provide greater benefits.

Rationalizing Tax Districts - Washington State has an abundance of tax districts. Sometimes these districts have shared goals, and sometimes actions of one district have unintended negative impacts on the goals of another. Flood districts, for instance, can invest in massive projects that safeguard against flooding but can damage salmon populations. Stormwater districts may contribute to increased flood waters, forcing greater expenditures by flood districts. Washington State should facilitate institutions and improvements that help coordinate and rationalize current tax districts. The creation of entities to rationalize, coordinate and possibly merge these districts into a more coherent and efficient system should be examined. Water Resource Inventory Area #9 (WRIA 9) in the Green River Valley is leading the way on this issue. Ecosystem services can be a guide for these improvements.

Upgrading Environmental Impact Assessments - Environmental impact statements (EIS) are required by Washington State and the federal government for projects with significant environmental impact. While these studies identify environmental actions to reduce negative environmental impacts or enhance restoration, there is not currently an ecosystem service component that would assign dollar values to the benefits derived from these actions. Public and private institutions should include an ecosystem service analysis to strengthen environmental impact assessments, and Washington State should lead the nation in requiring ecosystem service analysis in all significant environmental impact statements.

Strengthening Watershed Characterization Studies - Watershed characterization studies are performed to gain an understanding of the physical nature of watersheds. It has been demonstrated that they are strengthened by the inclusion of ecosystem service analysis as part of that study. As has been shown in the work done by WRIA 9 salmon habitat plans, too, are stronger when they include ecosystem service analysis. All watersheds in the Puget Sound Basin should have ecosystem service analysis performed, and these analyses should be updated every five years. Staff from government, private firms and non-profits should be trained to apply ecosystem service tools in their work.

Section 2: Key Concepts provides a primer on the field of ecosystem services and their economic importance. Terms and concepts are defined with local examples.

Section 3: Valuing the Puget Sound Basin describes in detail the analysis behind the range of values assigned to the natural capital in the Puget Sound Basin. While this adheres closely to the work done in the 2008 report there are several significant changes, most notably the addition of two new ecosystem values. One of these is the medicinal value of the Pacific yew tree. Taxol, derived from the yew, is one of the most effective chemicals in treating breast, lung and other cancers. The second is the value of snow pack, which is tremendously valuable to the Puget Sound Basin as it provides water storage services for drinking water, irrigation, industrial use and electricity generation.

Our Puget Sound economy is built upon the land and waters of the Puget Sound Basin. We cannot live without the ecosystem services the Puget Sound Basin provides.

Summary of Conclusions:

1. **The Puget Sound Basin provides 23 categories of valuable ecosystem services and goods, which are essential to a prosperous economy and high quality of life.**

2. **The partial annual value of nature's goods and services ranges between $9.7 billion and $83 billion.**

3. **The present value for this flow of benefits, analogous to an asset value is partially valued between $305 billion and $2.6 trillion.**

4. **Ongoing studies are critically needed to update valuations and further justify investment.**

5. **It is possible, in fact imperative, to identify specific providers of ecosystem services, the beneficiaries of those services and impediments to their continued success.**

6. **Modeling of ecosystem services is advancing rapidly.**

7. **Further funding and research can play a key role in informing public and private investment.**

8. **Achieving sustainability requires shifting investment from investments that damage ecosystem services to investments that improve and sustain them.**

9. **Improving economic analysis to secure more productive and sustainable investment requires:**

    - Accounting for natural capital
    - Improving jobs analysis for restoration
    - Adopting new industrial indicators
    - Redefining green jobs
    - Changing cost/benefit analysis
    - Getting the scale of jurisdictions right
    - Rationalizing tax districts
    - Upgrading environmental impact assessments
    - Including ecosystem service valuation in all watershed scale studies
    - Training government, private firm and non-profit staff in ecosystem services and the use of ecosystem service valuation tools

Introduction

In 2008, Earth Economics conducted the first comprehensive valuation of ecosystem services in the Puget Sound Basin. This report updates the 2008 study, taking into account additional ecosystem service values not available two years ago. It also examines the need for transformative infrastructure investment in the Basin's natural and built capital and describes the economic tools to make that happen. Natural capital provides daily benefits including the air we breathe, water we drink, aesthetic value, climate stability and more to the millions of people living in the Puget Sound Basin. It also provides basic inputs to the private and public sectors of the economy. Natural capital is the climate, ecosystems, nutrient cycles, water, geology and topography that provide us with an abundance of goods and services. It is an economic asset vital to our quality of life.

All major cities of this region are located at river deltas and on the shores of Puget Sound. Most of the smaller upland cities and towns were founded to deliver timber, coal, rock, food or other resources to those major cities within the Puget Sound Basin. Our economy has been successful because it was built with the spectacular natural capital of the region. That natural capital is an essential complement to the built economy, and to people's quality of life. A composite satellite photo of the Puget Sound Basin is shown in Figure 1. Areas of high "built capital" (high density urban built infrastructure) are grey. The rest of the photo represents the Basin's natural capital, including forests, agriculture, prairies, and wetlands (in green); Puget Sound (in blue to black); lakes (in turquoise to black); and snow and ice (in white). Our built capital resides within—and depends upon—a landscape of natural capital. This is our home. It is our economy's habitat.

Figure 1. The Puget Sound Basin

Rivers that feed Puget Sound and their watersheds are the key to the health of this ecosystem. Figure 2 shows the major rivers of the Puget Sound Basin.

Figure 2. Major Rivers of the Puget Sound Basin.

This report is primarily about value and economic drivers for green infrastructure solutions. The current state of Puget Sound Basin's natural systems and their continuing degradation is well documented in reports by The Puget Sound Partnership, Department of Ecology, People for Puget Sound, Cascade Land Conservancy, Department of Natural Resources, US Geological Survey and others. The facts of declining health are not repeated in this study, which focuses instead on the economics of providing solutions at the needed scale.

Objectives of the Study and Report Organization

This study has three objectives, each of which is provided in a separate section of the report:

Section 1: Economic Analysis Incentives and Investment

Here we suggest changes in economic analysis to include ecosystem services in public and private decision making to lead toward decisions to invest in a more productive, greener infrastructure.

Section 2: Key Concepts

Here we define concepts key to understanding the nature of ecosystem services and their importance.

Section 3: Valuation of Puget Sound Basin Ecosystem Services

Here we present an estimation of the partial dollar value of 14 ecosystem services in the Puget Sound Basin.

Section 1: Economic Analysis Incentives and Investment

A Sustainable Economy Achieved by Upgrading Economic Analysis

Economic advancement is driven by investment and an economy is the physical product of previous decades of investment. When committing resources to the building of our future economy, we must act with wisdom and responsibility to build solid infrastructure. From high-quality education for our children to transportation, emphasis should be placed on developing structures that are robust and just. And now more than ever, it is imperative to look at the retention or restoration of natural systems as a key component to investment in our future economy as we work toward the development of a greener infrastructure.

Green infrastructure can be both “natural capital” like forests, wetlands and Puget Sound, and green “built capital” such as green buildings, renewable energy or paper mills with low ecological footprints. Green infrastructure is likely best accomplished as a combination of natural and built capital. For example, flood protection is most effective when it utilizes a natural system like a wider floodway in conjunction with built systems like properly located buildings and the judicious use of levees and dams.

Good economic decisions and good infrastructure choices require good information. The large-scale shift to better green infrastructure requires better information through improvements in economic analysis. This is because economic analysis is the guide to both public and private infrastructure investment. Economic rewards must follow good investment and provide greater returns to projects that internalize environmental and social costs (internalizing costs means the costs are fully included in the price of products, projects or services. For example, the price of the glass in a car is included in the final price of the car). On the other hand, financial penalties should result in the case of negative actions like the Deepwater Horizon oil spill that dump costs on others (externalized costs). If environmental and social benefits and costs are not counted, green infrastructure will take a back seat to investments that can shove costs onto the environment and people outside the transactions. As AIG, BP, and others have shown, poor investment choices without diligent attention to risk and potential impact on others can be catastrophic.

Informal interviews with Puget Sound investors indicate that hundreds of billions—if not a trillion dollars—will be spent on private and public investment in the Puget Sound Basin in the next 20 years. Like the investments of past decades, this massive investment will determine the physical nature of the Puget Sound economy. It will also determine most of the environmental impacts of that economy on Puget Sound and the lands which contains the cities, wetlands, houses, prairies, manufacturing facilities, forests, economy, rivers and mountains of this rich basin. Every dollar invested or spent can contribute to further ecological damage or benefit—we can choose now to set up investments that will provide benefit.

It is increasingly clear that the major negative impacts to Puget Sound are the result of environmental impacts from expanding built infrastructure. Stormwater, sewer effluent, non-point pollution and land use changes are all driven by infrastructure investments which do not fully include environmental costs. They demonstrate that our investments in infrastructure can hurt us as well as help us. The Puget Sound Basin cannot be ecologically healthy or restored if both public and private infrastructure investment do not improve beyond that which has historically damaged our area from the mountains all the way to Puget Sound. Increasingly, economic success is tied to ecological sustainability.

The following work is a series of briefs pulled together from a recent suite of Earth Economics reports. (References to full reports are provided.) These reports were designed to have a cumulative value greater than the sum of their individual contributions as together they demonstrate a sea change in investment strategies for greener infrastructure. The wide variety of locations and subjects reflects the uncertainty nonprofits face when seeking funding, and the forward-thinking approaches needed to establish creative and potentially better economic approaches.

The staff and Board of Earth Economics would like to recognize the following institutions in Washington State that paid for the parts of this suite of analyses:

- The Bullitt Foundation
- The Chehalis River Basin Flood Authority
- The Department of Ecology
- The King Conservation District
- King County Water Resources Inventory Area #9 (WRIA 9)
- The Nisqually River Council
- The Nisqually Tribe
- The Packard Foundation
- The Puget Sound Partnership
- The Russell Family Foundation
- Seattle Public Utilities
- Snohomish County
- Walla Walla Community College

All of these institutions were willing to fund economic analysis that they deemed valuable and sensible. This work represents a bold effort at improving on historic economic analysis. While many of the staff of these institutions, as well as many stakeholders and companies, contributed tremendously to these studies, they are not responsible for any errors, and the conclusions do not necessarily reflect their views or the positions of the institutions discussed.

The cumulative value of these studies is finally presented in this report, which was generously funded by The Russell Family Foundation.

The lesson of these report summaries is that pursuing ecological sustainability and economic prosperity requires improving economic analysis, indicators, and incentives. These changes must be significant enough to affect a robust shift in infrastructure investment at scale sufficient to achieve complementary ecological health and economic prosperity objectives.

Following is a list of the briefs, which describe areas of economic analysis that should be changed to help shift investment in the Puget Sound Basin. Links to the full reports are referenced in each section:

Accounting for Natural Capital
Improving Jobs Analysis for Restoration
Adopting New Industrial Indicators
Redefining Green Jobs
Changing Cost/Benefit Analysis
Getting the Scale of Jurisdictions Right
Rationalizing Tax Districts
Upgrading Environmental Impact Assessments
Strengthening Watershed Characterization Studies

Accounting for Natural Capital

To shift private and public investment toward green infrastructure, buildings, and investment, requires that natural capital be recognized as a capital asset that is measurable within standard accounting systems. The following example demonstrates legitimate and achievable steps for improved accounting.

The creation of Seattle Public Utilities (SPU) more than a century ago was a visionary and successful institutional development. Purchasing a watershed secured to provide and filter the water supply for the city in perpetuity was a radical and expensive idea at the time. Had the Seattle City Council required a threshold rate of return on investment, it would likely never have justified this daring project. The goal of the investment was not to maximize “net present value,” but to provide safe and reliable drinking water for the people of Seattle forever.

As it turned out, this was a magnificent investment by any measure. Today SPU would have to pay $250 million to build a filtration plant to filter the city’s water supply if the forest did not do the job. In addition, by 2010 it would likely have been the third or fourth filtration plant to be built as filtration plants, like all built capital, depreciate and eventually fall apart. Like most natural capital, the forest did not depreciate or fall apart. Relative to the size of the asset, a forest requires light maintenance. The watershed now provides far more water and value than ever was imagined by the original SPU directors. An additional benefit reaped from this wise investment is that lives were saved as cholera, once a significant problem in Seattle, was eliminated through the development of a clean, reliable water supply.

Every 30 years, the utility conducts an “asset management plan.” To their great credit, SPU was the first public utility in the world to apply an ecosystem service valuation (conducted by Earth Economics in the Tolt River Watershed) as part of its most recent asset management plan. During this process they had to grapple with the fact that while the impressive investment history is accounted for, there is a serious accounting omission.

The problem is that the watershed does not count as an economic asset in the utility’s financial books. Facilities, pipes, vehicles, buildings, roads, computers, copy machines, fences, and pencils all count as assets. If SPU had to install a $250 million filtration plant, it would count as an asset on their books. The value of the forest accomplishing the same task does not.

This is not SPU’s choice, nor is it their fault. They must adhere to standards set by the Governmental Accounting Standards Board (GASB), which sets accounting rules for governments. Why is this a problem?

Consider one big advantage of a valued economic asset: you can invest in it. If SPU needs a new fleet of vehicles, they can borrow money, invest in a new fleet, and pay back the loans. In addition, since the vehicles are assets a sufficient budget for maintenance and operations is justified. The problem with not recognizing the watershed as an economic asset is that the utility cannot have a capital improvement project (borrow money against that asset to pay for improvements) to accomplish needed restoration. In addition, because the utility’s largest asset (the watershed) is not measured as a financial asset, the operations and management budget does not have the same financial justification and may be too small (in the opinion of this report’s authors). Finally, if a road needs to be decommissioned to prevent sediment and runoff from entering the reservoir and degrading water quality, the utility’s assets will take a write-down. The road is counted as an asset even though in reality it is an economic liability.

Again to SPU’s credit, they recently pulled together six other West Coast public utilities to discuss this issue. They are likely the first in the world to take this forward-thinking step. Staff from all six utilities agreed that this is an accounting issue that needs correction.

This is but one example of how accounting rules are blind to the obvious economic value of natural capital and the ecosystem goods and services it provides. There are more. Consider municipal parks with green spaces: they have a net absorption of stormwater yet they often must pay stormwater fees. Green buildings that handle their own stormwater also pay stormwater fees. There is concern that correcting this problem would result in too little funding for stormwater systems. Another solution would be a higher billing rate for those who actually do generate stormwater. Yet in some areas such as Mason County, which has less than two percent impermeable surfaces, this would create a huge tax burden on very few property owners. In Mason County, putting several services together into one institution would likely create greater efficiency, and a more fair funding mechanism. The solutions are present—green infrastructure—but the incentives and funding mechanisms are not.

Private firms and non-profits also have this difficulty. The Financial Accounting Standards Board (FASB), which sets accounting rules for non-governmental institutions also needs updating to recognize natural capital as a capital asset.

Another example is natural systems such as rivers, permeable soils, forests, wetlands, and lakes that provide as much or more flood protection as levees (which divert flood waters) and dams (which store flood waters). Puget Sound itself provides an enormous amount of flood relief for the Puget Sound Basin, yet this natural system does not count as a flood protection asset. Thus investment is inefficiently focused on built systems, such as levees and dams, while natural systems that provide the same service at less cost are degraded. A better solution is to examine and value all the assets that provide flood protection, built and natural, and invest in a combination of natural and built flood protection assets that provide the most robust, dependent, resilient, and least expensive flood protection.

Every year national accounting rules are changed for good reasons. Responsible investment in green infrastructure is a good reason for even more changes.

Washington State and the counties of the Puget Sound Basin should lead the way initiating changes in national accounting rules to accommodate the economic value that natural capital such as the Tolt River Watershed provides.

References:

Batker, D.K. 2005. Supplemental Ecological Services Study: Tolt River Watershed Asset Management Plan. Earth Economics (The Asia Pacific Environmental Exchange). Prepared for Seattle Public Utilities.

Pending publication: Batker, D.K. 2010. Water, Ecosystem Services and Opportunities. Prepared for Seattle Public Utilities. Available through Earth Economics with permission pending from SPU.

Improving Jobs Analysis for Restoration

Ecosystem services and jobs are closely connected. On June 24, 2010, Governor Christine Gregoire broke ground for a new building at Walla Walla Community College. The new Water and Environment Center was funded with a construction grant from the federal Economic Development Administration (co-funded by the State of Washington and Umatilla Tribe). Jobs analysis is increasingly important for the allocation of federal grants, and key to securing this one was an estimation of potential jobs the project would create. Though it was not part of the criteria, it turned out that counting green jobs from restored ecosystem services helped secure the grant. Here is how that was accomplished:

When applying for a highly competitive grant, Walla Walla Community College developed an excellent proposal showing not only the traditional jobs that would be created from construction of their new Center, but also jobs resulting from the watershed and salmon restoration, which the Center will contribute to.

With 6 of over 20 identified ecosystem goods and services, the green jobs and benefits were related to enhanced flood control, increased agriculture (due to water savings), greater salmon populations, greater water availability, improved recreation and greater carbon sequestration. These areas, expected to be enhanced by the proposed facility, provided additional green jobs not generally included in traditional job analysis. Both traditional calculations and the supplemental ecosystem service analysis showed that the benefits in year one were estimated to be 88 temporary construction jobs, 287 permanent jobs and 376 employable college graduates. These are estimated to provide $89.5 million in earnings value, $171.6 million in regional economic benefits, and $141.2 million in additional regional and national GDP.

An examination of jobs created by capital and restoration projects that improve natural systems generally looks at how many construction jobs are created by pushing dirt around or planting native vegetation. Yet most restoration projects also provide quantifiable ecosystem goods and services, which have economic importance and provide an increase in sustainable, well-paid jobs. Establishing an increase in permanent employment is far more important than providing temporary jobs, and federal agencies recognize and measure this accordingly.

Walla Walla Community College has shown how new and better economic analysis brings investment. The EDA awarded the grant and recognized the ecosystem services jobs analysis as highly valuable.

Washington State and the Puget Sound Partnership should have the capacity to calculate jobs resulting from natural system restoration for any restoration or related project in the State or in the Puget Sound Basin.

Reference:

Batker, D., Lovell., B. 2009. The Economic Benefits of the Walla Walla Community College Water and Environmental Center Expansion. Earth Economics. Prepared for Walla Walla Community College.

Adopting New Industrial Indicators

It has been said that “we pay attention to what we measure”.

Is it possible to move the Puget Sound Basin toward sustainability, reducing negative impacts on the environment, communities and people while at the same time enhancing economic development, jobs, productivity and competitiveness? In a word, yes.

Can companies move beyond compliance requirements and regulations to achieve higher environmental goals and improve the bottom line? Again, yes.

If businesses could more accurately measure both their negative impacts and the potential economic gain, including benefits they provide to communities, they could make better investment decisions to reduce negative impacts and risk while improving productivity and returns. The goal is to develop a more accurate measurement of ecological and economic indicators for each industrial sector. Measures for paper mills, chemical plants, aircraft manufacturers and concrete facilities would have many similar indicators, but also indicators very specific to the industry and even to the individual plant. This work would feed directly into improving the bottom line and improved competitiveness of local companies.

By building more green and sustainable basic industries, Washington State businesses can lead the world in green products and competitiveness. This can lead to important higher value markets. When Washington State consumers, businesses and government agencies purchase green and locally produced paper products, for example, there are clearly identifiable ecological, social and economic impacts that contribute to sustainability, employment and economic development.

A collaborative project funded by the EPA and run by the Washington State Department of Ecology shows companies are more than willing to surpass regulatory compliance if provided with information and the potential for savings. For example, this enables them to schedule identified changes into regular maintenance and capital improvement schedules, thereby reducing costs.

In 2010, Earth Economics completed a contract with the Department of Ecology to develop industrial footprint indicators in collaboration with five paper mills: Port Angeles Nippon Paper Industries, Port Townsend Paper Corporation, Simpson Tacoma Kraft, Boise Wallula and Grays Harbor Paper. These paper mills contributed staff time and data to develop the indicators and projects collaboratively. Other mills in the state were invited to join, but declined.

Environmental, social and economic indicators were developed to measure the impacts of paper mills. These indicators were not developed to compare paper mills (many are fundamentally different in products and processes), but to assist mill managers in identifying investments that would reduce environmental impacts and potentially improve the bottom line for the mills. Out of the many indicators considered, the following is the list that was developed collaboratively between the mills, Department of Ecology representatives and Earth Economics.

Environmental indicators: 14 air quality/emissions measures, four energy conservation measures, four raw material measures, one environmental management indicator, two regulatory compliance and waste disposal measures, two water intensity and four water quality measures and a biodiversity measure.

Economic indicators: three economic impact measures, two regional economic impact measures, one capital investment indicator, three community involvement indicators, one economic development measure, three job indicators and a measure of customer satisfaction.

Social indicators: five measures of health and safety, one indicator each of odor, traffic intensity, human rights and eight indicators of employee relations.

As a result of this process numerous areas were identified where local paper mills could move beyond regulatory compliance, reduce costs, lower negative environmental impacts and improve efficiency within the mills. In the end, a strong economic case enables staff within the mills to justify investment that improves performance and sustainability. This allows plant managers and owners to allocate plant improvements and investments in the mill across income, production, maintenance and new equipment installation schedules.

Similar indicators could be developed for all industries in Washington State from concrete to data centers. This would assist individual operations and companies in scheduling investments, which would enable them to surpass compliance requirements and save on energy and water consumption as well as in other areas.

Washington State and Washington State companies should pursue new industrial indicators to facilitate economic gains to private firms and achieve environmental improvements beyond regulatory compliance.

Reference:

Pending publication and title: Fritz, A., Crook, M. 2011. Industrial Footprint Project: Developing Indicators for Sustainable Practices. Washington State Department of Ecology.

Redefining Green Jobs

Most accepted definitions of green jobs are rather narrow, such as planting trees, energy efficiency and organic farming. The vision and definition of green jobs should be far more comprehensive. Washington State produces timber and paper, fish, commercial jets, agricultural products and many, many more goods and services. Nearly every industry can become a green jobs industry. One example is provided here.

Earth Economics, with support from The Russell Family Foundation and Packard Foundation, worked with the fishing industry to shift the West Coast spot prawn fishery to the world's first trap-only—and likely the world's most sustainable—shrimp fishery. Trawl-caught wild shrimp catches often bring in four to ten pounds of bycatch (other species) for every pound of shrimp caught, but trawling has now been phased out in Alaska, British Columbia, Washington, Oregon and California in the spot prawn fishery. Three elements were key to this accomplishment:

- **Sustainability indicators** for robust fisheries management.

- **Fairness** instituted by limits of 500 pots per boat and no more than two boats per owner, which ensure that a few owners cannot monopolize the fishery and that it remains community based.
- **Greater incomes** from the water to the table, as the economics of trap-caught spot prawns provided higher incomes to everyone in the chain of custody. Trawled shrimp are often damaged, but trap-caught shrimp are live and can be sold for a far higher price from the dock to the restaurant.

The spot prawn fishery is a green jobs industry both because it has secured sustainability and fairness, and because it is both highly lucrative and well governed. But there is more to the story about green jobs and the spot prawn fishery.

An oddity of the spot prawn is that they all start out as males and become females at about three years of age. Thus, the most commercially valuable spot prawns are female because they are larger. British Colombia has developed an impressive "stock independent" management structure with a tight grid of small districts. If a district records the ratio of females to males caught has fallen, that district and those immediately adjacent are closed to fishing. Rather than targeting "maximum sustainable yield" when that amount can never be known due to uncertainty, British Colombia has a policy to avoid collapse. This policy actually secures greater long term health and catches than do attempts at maximum sustainable yield, which inevitably miss the target and deplete stocks. Thus, including greater attention to measurement, ecosystems and economics are additional keys to management advances and to securing sustainable, lucrative green jobs.

Fisheries are not the only industry with green job potential, and green jobs need to be the foundation of a robust and diverse economy. Jobs from agriculture, manufacturing, service sectors, paper mills, energy, transportation, education, medicine and other sectors need to become green jobs to strengthen these sectors economically.

Part of saving Puget Sound—shifting the economy, ensuring a high quality of life at work and at home—is the economy-wide shift to, and investment in, green jobs in virtually all sectors. Clear sustainability indicators are needed to help guide industry investment to shift and expand existing industries and employment, secure greater economic productivity and generate additional green jobs.

Reference:

Mormorunni, C.L. 2001. The Spot Prawn: A Status Report. Earth Economics (The Asia Pacific Environmental Exchange).

Changing Cost/Benefit Analysis

All federal and state agencies, cities, counties and many private firms utilize cost/benefit analysis to make investment decisions. This covers a wildly diverse set of investments including health care, levee construction, education investments, road building, economic development, tax breaks and others. The following example demonstrates the importance of taking into account the value of ecosystem services when performing a cost/benefit analysis.

Cost/benefit analysis is the primary factor in flood protection investment decisions at the Army Corps of Engineers. They require that the cost/benefit ratio be above one for any flood control investment to even be considered for funding. That is generally a hard and fast rule. However, the Chief Economist of the Corps allowed an exemption to this rule in levee construction in the Mississippi Delta after Hurricane Katrina. The Army Corps recognized the hurricane protection value of wetlands for the protection they provide to built assets, including levees. Further, they recognized the importance of investments in wetland restoration specifically for hurricane protection.

This exemption was facilitated with overwhelming physical evidence presented by Dr. Paul Kemp, Dr. Hassan Mashriqui and other Louisiana scientists, spurring legislative action. One of the causes of the catastrophic Hurricane Katrina disaster was that the hurricane buffering provided by wetlands had never been counted in cost/benefit analysis of hurricane protection projects. As a result, too little investment was made in wetland protection and restoration. The Army Corps is now funding a $500 million restoration project at Myrtle Grove, Louisiana, one of about six planned large-scale water and sediment diversions.

If cost/benefit analysis is flawed, investments will be flawed.

And flaws still exist. No levee built in Washington State has ever had a cost/benefit analysis that included the value of natural capital for flood protection or the value of many other ecosystem services. A fish processing plant counts as an asset in cost/benefit analysis, yet federal rules dictate that the system that actually produces the fish does not count as an asset and cannot be valued in the analysis. Levees that provide flood protection count, but wetlands, forests, lakes and rivers that provide flood protection don't count unless a special exemption is made. In summary, built capital counts, natural capital does not. This is a significant and potentially catastrophic flaw.

An Earth Economics report on the Cedar River prepared for King County demonstrated that long-term costs of flooding on the river would be reduced with a long term strategy of buying out property and widening the floodway. This would take the energy out of flood waters, provide better flood protection, enhance water quality and salmon habitat, and give far greater longevity to levee investments. Narrower, higher levees actually give greater erosive power to floodwaters and can result in catastrophic levee failures, overtopping and chronic damage to levees.

For about a decade, the United Kingdom has required that ecosystem services be valued and factored into all flood protection cost/benefit analysis. This has resulted in more levee setbacks, which have slowed floodwaters by providing greater floodways. It has also added habitat, improved water quality and provided far more robust and dependable flood protection.

In the US, the federal rules for cost/benefit analysis are currently under consideration for significant changes. Proposed changes include the valuation of ecosystem services. It is uncertain how long this will take.

The State of Washington and Puget Sound Basin could lead the way by requesting improvements in Army Corps of Engineers and other federal agency cost/benefit analysis to include ecosystem services. The State should quickly include ecosystem services and pioneer changes in state cost/benefit analysis to lead the nation and hasten rule improvements.

Reference:

Batker, D., de la Torre, I., Costanza, R., Swedeen, P., Day, J., Boumans, R., Bagstad., K. 2008. Gaining Ground—Wetlands, Hurricanes and the Economy: The Value of Restoring the Mississippi River Delta. Earth Economics.

Getting the Scale of Jurisdictions Right

Every economic decision requires an understanding of scale (size) whether it is a person deciding how much pizza to eat, a firm deciding how many gadgets to produce or a nation deciding the size of the national budget. Scale also applies to how the boundaries of jurisdictions are set with respect to the services that a specific jurisdiction is intended to provide. From school districts to shellfish districts, jurisdictions need to be at the scale of the service needs. Flood districts are the example presented here. If the jurisdiction is not set at the scale of the problem or landscape, the tax district may be dysfunctional from the beginning.

Western Washington has experienced record flooding this decade. Records have been set in flood elevations, damages, or both on the Chehalis, Puyallup, White, Green, Cedar, Snoqualmie, Snohomish, Raging, Cowlitz, Nisqually, Skagit and other rivers. Western Washington is fifth in the nation for receiving federal flood assistance. Billions of dollars have already been spent on flood protection. Rivers have even been relocated, such as shifting the flow of the White River from the Green River into the Puyallup River over 80 years ago. One solution to the ongoing issue of flooding is to reevaluate the scale at which we invest in flood protection and prevention.

Traditionally in Washington State, flood districts were established where flooding took place. Until 2008, King County had six flood districts focused on the flat, flood-prone lower reaches of the watersheds. This meant that flood district investments were limited within their jurisdictions to the lower watershed, omitting the surrounding higher landscape that contributed both flood protection and floodwaters to the flood zone. Restricted as they were to the bottom of the watershed, these flood districts invested heavily in levees. Realizing that flood districts that are restricted to the area of flooding simply could not provide adequate or cost effective flood protection, King County wisely created a new county-wide flood district that included the middle and upper portions of the watershed, allowing for more comprehensive flood prevention investment.

The county-wide approach was an enormous improvement, but better still is an approach that transcends county boundaries and looks at the watershed as a whole. Encompassing the right scale for flood protection, this basin-wide watershed scale is a relatively new but superior approach. The Chehalis River Basin Flood Authority has avoided this "scale" error by setting flood jurisdiction at a basin scale. Other areas in Washington State still retain flood districts restricted to the locations that experience flooding, and do not encompass watershed areas that are both source areas for floodwaters and that provide natural flood protection.

This is not just a problem for flood districts. The Puget Sound Partnership is entrusted with protecting Puget Sound, but the agency's jurisdiction is not fully at the scale of the system affecting Puget Sound, which consists of the full Puget Sound Basin.

Washington State should conduct a comprehensive review of the scale and efficiency of existing tax districts. The determination of the scale of these districts should be informed by both the scale of influences contributing to the problem and the scale of assets contributing to the solution. For example, flood districts should be set at the scale of the watershed.

Reference:

Batker, D., Lovell, B., Kocian, M., Harrison-Cox., J. 2010. Flood protection and ecosystem services in the Chehalis River Basin. Earth Economics. Prepared for the Chehalis River Basin Flood Authority.

Rationalizing Tax Districts

Washington may have more tax districts than any state in the US. This stems from our history as a populist state where citizens did not want any one governmental entity to have too much power. The general philosophy was that government closest to the people is the best government. As a result we have tax districts at the state, county, and city levels. There are tax districts for schools (295), fire, 911 service, hospital, stormwater, sewer, water, energy, conservation, shellfish, flood and flood control, park, police, port, public facility, transportation benefit areas—and the list goes on. Sometimes these districts have shared goals, and sometimes actions of one district have unintended negative impacts on the goals of another. The work accomplished by Water Resource Inventory Area #9 (WRIA 9) with Earth Economics in the Green River Valley demonstrates an impressive, innovative approach for adding a new level of rationality to our existing tax district structure.

WRIA 9 is charged with salmon restoration and encompasses the cities of the Green River Valley from Seattle to Black Diamond. Along with Vashon Island, Seattle Public Utilities, the King Conservation District, King County, Boeing Corporation and other stakeholders, WRIA 9 is likely leading the charge in the state by boldly proposing a path to better coordinate and rationalize watershed-based tax districts as part of their effort to restore salmon populations. Earth Economics' recent report outlines a process that entails changing state law and creating a Watershed Investment District to help rationalize investments from the many districts in the watershed.

As our region has become more crowded, so have our tax districts. Inevitably, there can be conflicts. In the Green River Valley over a dozen stormwater districts, previously invested millions of dollars to build stormwater systems that generally get water out of cities and into the main stem of the river as fast as possible. Prior to 2008, there was a flood district positioned at the lower reaches of the river, which received higher peak flows every year as impermeable surfaces and stormwater systems expanded, contributing to greater flooding. The flood district invested in higher levees, which were increasingly damaged by higher peak water flows. This is infrastructure conflict, and it is part of a vicious cycle that is unhealthy for humans, salmon, the economy and the environment.

WRIA 9 is the first watershed to start examining how multiple benefits can be gained through greater coordination among tax districts. They identified $30-70 million in salmon restoration projects which overlap with identified flood protection projects. In addition, the WRIA 9 Ecosystem Forum has recognized that implementing the Salmon Habitat Plan is an investment that requires a dependable funding mechanism sufficient to get the job done, just like building roads. They have approved pursuing a $300 million funding mechanism for salmon restoration, which will provide jobs, economic development and salmon restoration sufficient to restore wild Chinook salmon populations. Bringing Chinook salmon back from the brink of extinction to abundance increases jobs, recreation, quality of life and flood protection. It opens new opportunities for better stormwater planning already underway.

The choice is clear: Lose self-maintaining ecosystem services and pay, or restore natural capital and gain. One approach is to let natural systems go, and replace every lost service with a new tax district and new concrete system. As we lose wetlands, for example, there is a decline in the recharging of groundwater. As a result there is a quick evacuation of surface water through stormwater systems and waste water through sewerage systems. This allows polluted and treated but nutrient-rich water to wind up in the Sound. Without sufficient wetlands, point source and non-point source pollution moves faster from the source of contamination into creeks, rivers and Puget Sound. With less water soaking in and recharging groundwater, wells go dry in the summer. Creeks go dry. Salmon lose habitat due to levees and less water. Salmon populations decline to the point of near extinction. Because salmon function as a keystone species, this has further implications for their ecosystems.

Another approach is a systems approach—looking at buildings, pavement, ground and surface water, flood protection, stormwater and sewerage within a watershed as a systems problem needing an integrated approach. Integrating wetlands helps slow stormwater flows, promotes infiltration and groundwater recharge, more ground water resources, higher creeks, better salmon habitat, fewer flood waters and greater groundwater resources. Investment in salmon restoration needs to be integrated with flood protection, green building, greater stormwater infiltration and other built investments. Where every previously free, value-providing, self-maintaining ecosystem service is lost, a new tax district is born.

Investment is needed to provide infrastructure for stormwater, salmon, flood protection and water quality improvements. With a systems approach, better coordination, stable funding mechanisms and more rational tax districts, these investments can likely provide this full suite of benefits at less overall cost.

Washington State should help facilitate institutions and improvements that help coordinate and rationalize current tax districts. Ecosystem services can be a guide for improvement.

References:

Earth Economics. 2009. WRIA 9 Funding Mechanism Report: Generating Payments for Ecosystem Services. Prepared for the WRIA 9 Watershed Ecosystem Forum.

Earth Economics. 2010. Toward Implementing the WRIA 9 Salmon Habitat Plan. Prepared for the WRIA 9 Watershed Ecosystem Forum.

Upgrading Environmental Impact Assessments

Washington State and the federal government require environmental impact statements (EIS) for projects with significant environmental impact. An EIS often has an effect on project design and thus investment by identifying actions that reduce the negative environmental impacts or enhance restoration. One of the fundamental problems of environmental impact statements is the lack of an economic interface. In other words, environmental damages can be quantified in scientific terms but this has no common language with project financing, which is denominated in dollars.

Earth Economics will complete the first economic section in an environmental impact analysis that includes a full identification of ecosystem services and valuation of ecosystem services. The EIS will be completed in early July 2010. This work is supported by Snohomish County for the Smith Island restoration project. Three scenarios were examined for ecosystem service enhancement and valuation. Providing this information allows for a stronger understanding of the economic benefits the project provides. Identifying the dollar value of ecosystem services enhanced by the project and provided to the public also strengthens the capacity for funding proposals.

Ecosystem service identification and valuation often strengthens what is the weakest area of environmental planning and analysis: the economic implications and value provided by restoration projects. In 2005 the Green Duwamish Central Puget Sound Watershed (also known as Water Resources Inventory Area #9 or WRIA 9) Salmon Habitat Plan was established. It was the first salmon habitat plan to include an ecosystem service valuation as a core of the socioeconomic analysis for the plan. The Salmon Habitat Plan won the 2020 Award from the Puget Sound Regional Council, who specifically mentioned our analysis in bestowing the award.

The same type of analysis can be conducted to show the dollar value of benefits provided. In addition, an ecosystem service valuation was part of the economic analysis conducted by WRIA 9 for the North Winds Weir. This $4 million salmon restoration project was approved and recently completed on the Green River by WRIA 9, King County, and the Army Corps of Engineers.

Seattle Public Utilities requires economic justification for large infrastructure projects. Earth Economics completed the economic analysis for the Tolt River Levee Setback and Salmon Restoration Project, a $5 million project.

Today, the economics are available to strengthen environmental impact statements, salmon habitat plans and the economic justification of restoration projects. Currently, economic analysis can be conducted in environmental impact statements but is not required.

Private and public institutions should include an ecosystem service analysis to strengthen environmental impact assessments. Washington State should lead the nation in requiring ecosystem service analysis in all significant environmental impact statements.

References:

Batker, D.K. 2005. Supplemental Ecological Services Study: Tolt River Watershed Asset Management Plan. Earth Economics (The Asia Pacific Environmental Exchange). Prepared for Seattle Public Utilities.

Green/Duwamish and Central Puget Sound Watershed Water Resource Inventory Area 9 (WRIA 9) Steering Committee. Salmon Habitat Plan: Making Our Watershed Fit for a King. Prepared for the WRIA 9 Forum.

Pending publication: Earth Economics. 2010. Nature's Value in the Snohomish Basin: Restoring Smith Island. Prepared for Snohomish County.

Strengthening Watershed Characterization Studies

Watershed characterization studies are important to understanding the physical nature of watersheds. Several watershed inventory areas (WRIAs) have included ecosystem service analysis in these studies.

To date ecosystem service analysis and valuation studies have been completed on a watershed, delta, or larger area in the Green River/Duwamish Central Puget Sound Watershed, Nisqually River Watershed, Snohomish River Watershed, Tolt and Snoqualmie sub-watersheds, the Mississippi River Delta, Yazoo River (Mississippi), the State of New Jersey, in Palawan (Philippines), Yasuní National Park (Ecuador), the Amazon River to the coast in Peru, the Osa Peninsula (Costa Rica), Qinghai Province (China) and other areas. The Puget Sound Basin is a leader in both the development and application of ecosystem service analysis at a watershed scale and there is room for them to be even stronger.

Waters Resources Inventory Area 9 was the first watershed to apply ecosystem service analysis, using our study to lay out the economic benefits of the Salmon Habitat Plan. Since then, this work has progressed to the development of funding mechanisms strongly informed by ecosystem services to implement the plan.

Watershed characterizations, salmon habitat plans and other watershed based analysis should be informed by ecosystem service analysis.

It is also important that State agencies, particularly the Department of Natural Resources and Department of Ecology (which has supported ecosystem service analysis) adopt this analysis as a normal part of operations. Training for private firms including consulting companies, government agencies and non-profits in ecosystem service analysis should proceed at a rapid pace.

Watershed characterization studies, salmon habitat plans and other watershed-based analysis should include ecosystem service analysis. All watersheds in the Puget Sound Basin should have ecosystem service analysis. These analyses should be updated every five years. The appropriate staff from government, private firms and non-profits should have ecosystem service training and the capacity to apply ecosystem service tools in their work.

Earth Economics studies cited in this brief are available on our website: http://www.eartheconomics.org.

Each of the above discussions has a common thread, that the economic benefits provided by natural systems are important and need to count. These improvements in economic analysis, which promote better investment, are informed by ecosystem services. The mapping of ecosystem services on the landscape, their provisioning, beneficiaries and impediments inform how institutions should be set up and how incentives and funding mechanisms should be created. Ecosystem services are crucial to solving many of our sustainability issues in the Puget Sound Basin. The next section provides important ecosystem services definitions and concepts.

Section 2: Key Concepts

Our natural environment provides many of the things we need to survive: breathable air, drinkable water, food for nourishment and stable atmospheric conditions, to name a few. These are what we refer to as "ecosystem goods and services." The following section explains the difference between goods and services, how ecosystems provide these essential functions, why they are economically valuable and how we can begin including that value in our economic accounting. When we alter environmental conditions, these services are often lost and must be replaced by costly built alternatives. In some instances, ecosystem goods and services cannot be recovered once they are lost.

Ecosystem Goods and Services

Ecosystem Goods

Goods are things you can drop on your toe. Ecosystem goods are tangible, quantifiable items or flows such as timber, drinking water, fish, crops and wildlife. The production of electricity is sometimes considered a good, sometimes a service. Most goods are exclusive, which means that if one individual owns or uses a particular good that individual can exclude others from owning or using the same good. For example, if one person eats an apple, another person cannot eat that same apple. Excludable goods can be traded and valued in markets. The quantity of water produced per second or number of board feet of timber cut in a 40-year rotation can be measured by the physical quantity an ecosystem produces over time. The current production of goods can be easily valued by multiplying the quantity produced by the current market price.

The sustainable stream of goods provided by an ecosystem is a "flow of goods." These goods can provide enormous economic return. For instance, the Washington State Department of Natural Resources (DNR) estimated over $222 million worth of timber sales and removals for 2009. Timber revenue can be realized by a public agency such as the DNR, or by a private corporation. However, the collection and sales of ecosystem goods can affect the ability of the remaining ecosystem to provide other goods and services such as clean drinking water, flood protection or recreation. In order to achieve economic efficiency, the value of timber revenue and clean water, recreation and other goods and services should be considered. Though timber harvest may be a private good, maximizing its value may lower the value of other, public goods such as drinking water or flood protection. By including the value of the entire suite of ecosystem goods and services in this assessment, relationships and tradeoffs can be better understood.

Ecosystem Services

Services are valuable benefits that you cannot drop on your toe. Examples are things like cooking, cleaning, analysis of geologic features, electricity and dentistry. Ecosystem services are defined as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life" (Daily et al. 1997). Unlike ecosystem goods, ecosystem services are not tangible items that you can weigh or hold. Flood protection, recreational value, aesthetic value, storm prevention, waste treatment, climate stability and water filtration are a few of the services that ecosystems provide. Although they are often more difficult to value because markets (and thus market values) may not exist, ecosystems services are critical both for our quality of life and for economic production (Daily et al. 1997; Costanza et al. 1997).

For the most part, ecosystem services are non-excludable. When one person enjoys a view of Mount Rainier, it does not prevent another person from enjoying the same view (service), unless congestion develops. Similarly, all downstream residents benefit from the flood protection provided by forested land upstream. Many ecosystem services, such as global oxygen production, soil regulation and storm protection are not—or cannot—be packaged and sold in markets. However, some markets for ecosystem services do exist.

Typically in an ecosystem service market, beneficiaries of an ecosystem service pay those who offer to provide the ecosystem service. In Costa Rica, many local public utilities rely on the water purification and provisioning services provided by forested areas. However, the clearing of forest cover for farming and cattle ranching greatly decreased the ability of forestland to provide ecosystem services. Now, these utilities pay landowners for hydrological ecosystem services so the owners will keep trees on their land. Some markets are developing in the Snoqualmie Watershed and elsewhere.

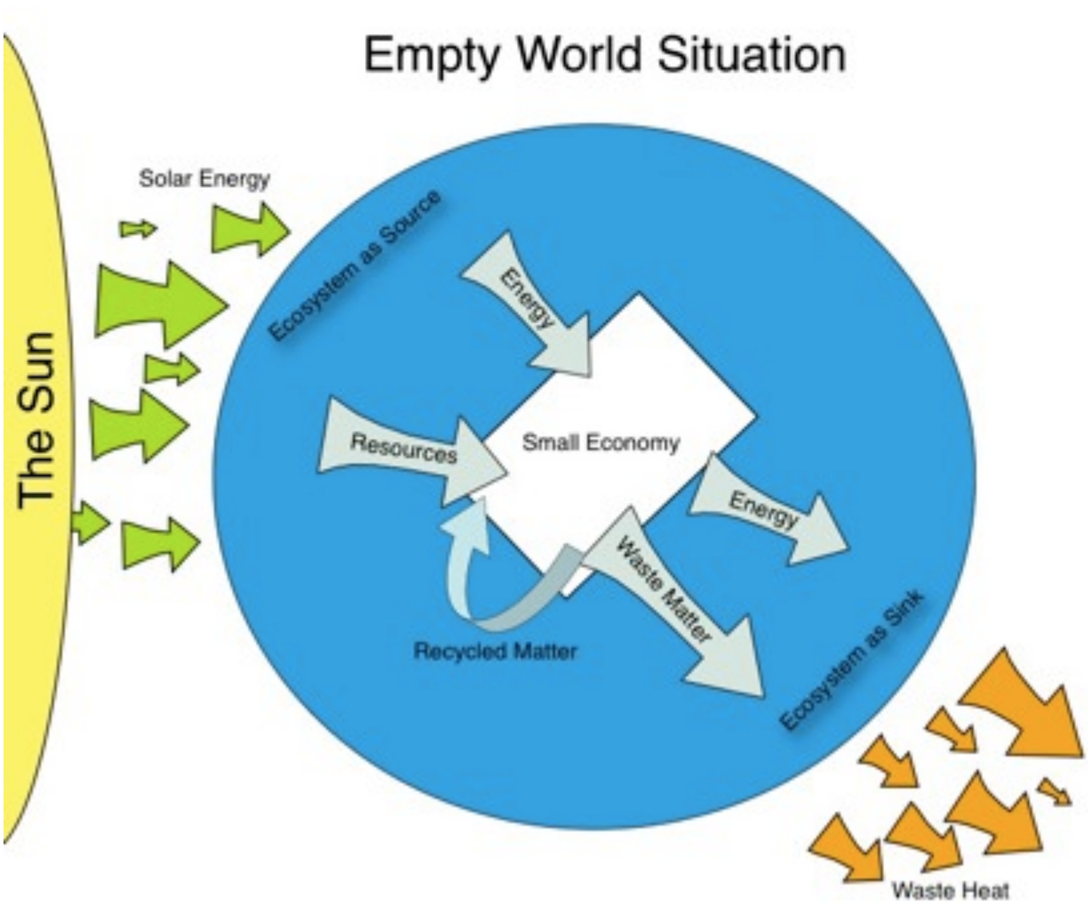
The effectiveness of markets for ecosystem services will likely be seen in the coming years as markets develop for habitat, climate control (carbon), temperature and water quality in the United States and internationally. A number of factors make ecosystem service markets more challenging than markets for goods. A flow of services, or “service flux,” cannot be measured in the same terms—quantitative productivity over time—as goods. Quantifying the amount of flood protection provided by a given forest tract and the value of that flood protection is much more difficult than calculating the potential for timber harvest.

Though the value of a service flux may be more difficult to measure, in many cases its value may significantly exceed the value of the flow of goods. For example, a study of Philippine mangroves showed that the services of storm protection and fishery nursery functions produced several times the value of shrimp aquaculture operations, which had displaced mangrove forests. Because 85% of commercial fish species are dependent on the mangroves for a period of time within their life cycle, the lost nursery and habitat services resulted in a significant economic loss far exceeding the economic gain in aquaculture production. This case also highlights the issue of excludability: if the beneficiary of a good or service is a private enterprise, they may act to the detriment of public goods and services. While a single owner can capture the revenue from a shrimp aquaculture operation, a greater number of local people can benefit from fish in mangroves and along the coastline (Boumans et al., 2004).

Natural Capital in our Economy

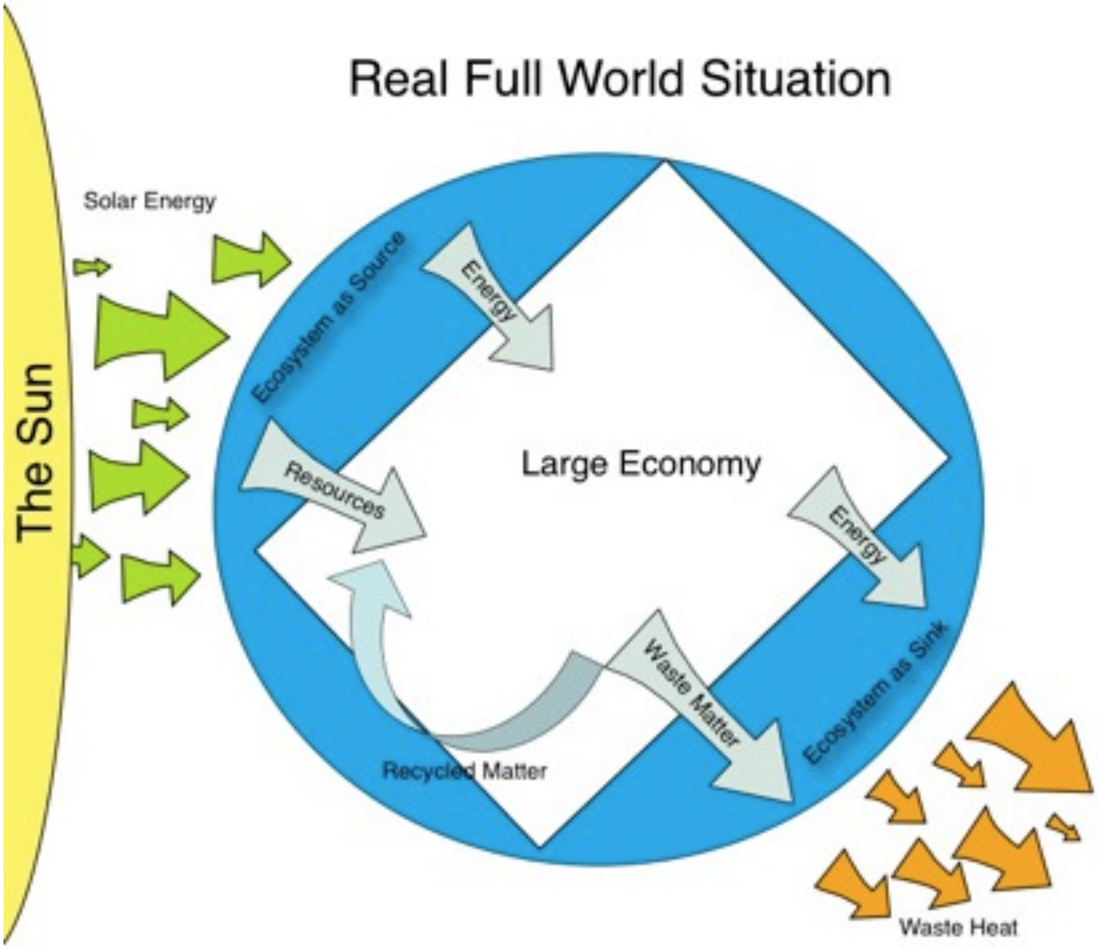
A century ago, it seemed that the forests, waters, fish and other resources were virtually unlimited. There were few people, and the size of the economy relative to the natural systems that supported it was small. A funding mechanism for schools based on logging of state lands, for example, worked well with a state full of trees and housing relatively few kids. However, as timber resources have shrunk and kids multiplied, the system is no longer sufficient to fund the state's educational needs. This reflects a shift from a world with few people and lots of resources to a world that is filling up. Figure 3 shows an "Empty" world economy where human labor is scarce and natural resources are abundant. Figure 4 illustrates what happens when the economy expands relative to the size of the natural systems that sustain and maintain it. As the economy expands, ecosystems are impacted by its increasing size and demands. In the past century, we have shifted from a relatively empty world of abundant and stable resources and natural systems with relatively few people to a full world scenario where natural resources are becoming scarce and even global systems like climate and ozone protection can be disrupted.

Figure 3. Empty World



Based on Goodland, Daly, and El Serafy, 1992

Figure 4. Full World



Based on Goodland, Daly, and El Serafy, 1992

As scarcity shifts, so do our economic goals. In the 1930s when paved roads were scarce, road-building yielded high returns. Today, roads are abundant. The services of naturals systems are scarce and improvements to natural systems provide high returns. Thus investment in restoring and securing these systems, investments in green building, better stormwater and flood systems that incorporate the services of wetlands, forests and rivers are good, high return investments.

Economic Goals

Economic sustainability relies on environmental sustainability. The loss of nature's bounty has real economic costs because natural systems provide valuable goods and services across vast spans of time and well beyond their physical boundaries. Restoring healthy natural systems in the Puget Sound Basin is critical to improving quality of life and to securing sustainability, justice, and economic progress in the area.

Economics is retooling for the 21st century with four essential goals: sustainability, justice, economic progress and good governance.

Sustainability requires living within a physical scale that does not destroy the basic natural systems that maintain the economy. Natural systems are part of our "commonwealth," which can be mismanaged at great cost or managed sustainably at great economic benefit to all.

Justice and rights are core American values. Rights frame and help define value; market valuations do not determine rights. Markets remain healthy and efficient because they are subject to a just and fair legal framework. The distribution of the value of many goods and services is determined by how rights are conferred. Consider water rights, tribal rights to wildlife, fish and shellfish, and citizens' rights to clean water and air. By securing treaty rights to salmon and shellfish, the Nisqually Tribe quickly increased economic development, diversification and quality of life for tribal members. The Nisqually Tribe's experience shows that the recognition and enforcement of environmental rights can help establish a fair and just framework for better resource management, sustainability, value creation and economic progress. See *The Natural Economy of the Nisqually Watershed* in our publications on www.eartheconomics.org for further analysis.

Economic Progress has traditionally been measured by a single yardstick: quantity of "built capital" production. The Gross Domestic Product (GDP) measures the production and sales of stuff. The houses and garages of today are filled with far more stuff than those of a generation ago, yet surveys show that people are not as happy now as they were then. Thanks to the tremendous productivity of modern economies, many marketed goods and services are now plentiful. In contrast, nature's goods and services, leisure time and family time are now scarce. Economic progress now needs to be defined more broadly, depending on five capitals: human, social, built, financial and natural.

Good governance is essential for securing all three of the above goals. Creating and sustaining institutions—private or public, market or non-market—is critically important to governing how sustainability, justice and economic progress are achieved. Markets require sufficient regulation and oversight, otherwise cheaters will take advantage of fair competitors. Markets need to include the full cost of activities, otherwise there will be distortion toward damaging (externalized) activities. Private corporations require good governance, lest the debacles of Enron, AIG and BP be repeated. Government institutions need to operate efficiently at the scale of the issue or problem they are meant to address and provided with sufficient powers and resources to get the job done.

Five Capitals

In 1910, catching more fish required more nets and boats. Nets and boats were scarce while fish were plentiful, so we invested in factories and built more nets and boats. In 2010, nets and boats are plentiful; fish are scarce. The 20th century concept of capital was heavily weighted toward financial and built assets. Today, natural capital (as well as human and social capital) is increasingly scarce and increasingly valuable, with the returns on investing in natural capital rising. Adding more fishing boats to the salmon fishery really does not increase salmon production—increasing salmon habitat does. To meet the economic goals listed above, the concept of capital must be broadened.

Here are five capitals required to secure economic progress and a high quality of life:

- **Natural Capital:** This is the earth's stock of organic and inorganic materials and energies, both renewable and nonrenewable, as well as the planetary inventory of living biological systems (ecosystems). When taken as one whole system, natural capital provides the total biophysical context for the human economy. Nature provides natural resources as inputs, energy and ecosystem functions that allow for the continued production of natural resources and the purification and recycling of waste products. Human wellbeing depends on these resources and services.

- **Human Capital:** This includes self-esteem; knowledge acquired through education; interpersonal skills such as communication, listening, cooperation; and individual motivation to be productive and socially responsible. It is well recognized that education and training are essential to economic progress, innovation and a high quality of life.

- **Social Capital:** Social capital is comprised of the inventory of organizations, institutions, laws, informal social networks and relationships of trust that make up or provide for the productive organization of the economy. Without a functioning society in which people respect each other and have some concern for the well-being of others, most economic activity would be impossible.

- **Built Capital:** This is the productive infrastructure of technologies, machines, tools and transport that humans design, build and use for productive purposes. Coupled with our learned skills and capabilities, our built techno-infrastructure is what directly allows raw materials to be converted into goods and services, the typical products that we find in markets.

- **Financial Capital:** Financial capital is a subset of social capital. Trust that others will honor money for goods and services is required in monetary transactions. Currency, retirement funds, stocks, bonds and banks all rely on this social trust. The value of financial capital is realized when it is exchanged for real goods and services.

Natural Capital and Economic Value

All built capital requires natural capital inputs of material and energy. Natural capital, including ecosystem goods and services, is an essential component of our economic vitality. Valuation techniques for understanding the connection between ecosystem processes, functions, and economic value are advancing.

Complements

In fact, natural capital and built capital are most often productively used as complements rather than substitutes (Daly and Farley 2004). Neither one can reach optimum efficiency and productivity without the other. Fishing boats, which are human built capital, are useless without fish, the natural capital. Built and natural capitals are most often complements in generating economic value and meeting human needs.

Healthy Ecosystems are Self-maintaining

If healthy, natural systems can be self-maintaining, natural capital can appreciate in value over time and provide a sustainable output of valuable goods and services in perpetuity. In contrast, built capital depreciates in value over time, eventually falling apart. Factories do not produce goods across time like a watershed can produce water, and built capital requires consistent capital investment and maintenance.

How ecosystem value is provided and protected

Natural capital assets are different from built capital assets in a few important ways. These differences serve to increase the value of ecosystem goods and services, and also to change the way that they should be valued over time. In instances such as a specific animal species where there is no built alternative, the value may be relatively constant up to the point at which the population is near extinction when value rises. Environmental thresholds greatly affect value.

Ecosystem Structure and Process

Structural components within an ecosystem include things like trees, wetland plants, soil and hill slopes. Ecosystem processes include dynamic processes like water flows, animal life cycles, photosynthesis and many others. Together, ecosystem structures and processes support ecosystem functions such as water catchment, soil accumulation, habitat creation, reduced fetch and buffers to hurricane storm surges. These ecosystem functions generate ecological goods and services. Figure 5 summarizes these relationships in a simplified diagram.

Figure 5. Relationship of Ecosystems to the Goods and Services Produced

Different types of ecosystems support different types of infrastructure and processes. Marine areas with eelgrass beds contribute to water purification, food provisioning and habitat. Salt marshes, herbaceous wetlands, forested wetlands, coniferous forests and deciduous forests all contain different infrastructure and maintain different ecosystem functions, producing varied goods and services. The infrastructure itself is dynamic. For example, our rivers show a great deal of dynamism when grading the deposition of gravel, sand and silt to provide just the right habitat (sorted pea gravel) for salmon spawning. These functions vary widely in spatial boundaries: oxygen migrates globally and salmon range throughout the North Pacific, while drinking water production is locally confined. Thus ecosystems may provide benefits that extend globally (carbon sequestration) or locally (drinking water production).

Like human health, the provisioning of ecosystem goods and services relies on many of these processes working together over time. A heart cannot function without the body, nor can the body function without a heart. The same is true for ecosystems. Interactions between the components make the whole greater than the sum of its individual parts—if they existed separately, the physical and biological components of the watershed would not be capable of generating the same goods and services provided by the processes and functions of an intact watershed system (EPA 2004).

Ecosystem Value Over Time

Unlike a building, most healthy ecosystems are self-maintaining. Ecosystems have the potential to appreciate in value over time—potentially forever. A forest provides water control, flood protection, aesthetic and recreational values, slope stability, biodiversity and other services without maintenance costs. Human-produced goods and services like cars, houses, energy and telecommunications require maintenance costs and usually degrade, depreciate, and are ultimately disposed of, requiring further energy inputs for disposal or recycling. Destruction of ecosystem functions thus disrupts economically valuable ecological services.

Identifying and Classifying Ecosystem Services

Identifying and classifying ecosystem services is an ongoing task. In 2001, scientists from NASA, the World Bank, the United Nations Environmental Program, the World Resources Institute, and other institutions examined the effects of ecosystem change on human well-being. The product of this collaboration was the Millennium Ecosystem Assessment (MEA), which classifies ecosystem services into four broad categories describing their ecological role (MEA 2003):

- **Provisioning services** provide basic materials, mostly ecosystem service goods. Forests grow trees that can be used for lumber and paper, berries and mushrooms for food, and other plants for medicinal purposes. Rivers provide fresh water for drinking and fish for food. The waters of the Puget Sound provide fish, shellfish and seaweed. Provisioning of these goods is a familiar service provided by nature, and is easiest to quantify in monetary terms. (Farber, et al., 2006)
- **Regulating services** are benefits obtained from the natural control of ecosystem processes. Intact ecosystems provide regulation of climate, water and soil, and keep disease organisms in check. Degraded systems propagate disease organisms to the detriment of human health. (UNEP 2005)
- **Supporting services** include primary productivity, nutrient cycling and the fixing of CO2 by plants to produce food. These services are the basis of the vast majority of food webs and life on the planet.
- **Cultural services** are those that provide humans with meaningful interaction with nature. These services include spiritually significant species and natural areas, enjoying natural places for recreation, and learning about the planet through science and education.

Table 1 describes these four services, with further detail provided in Appendix A.

Table 1. Table of Ecosystem Services

Ecosystem Service	Description
Provisioning	
Drinking Water	Water for human consumption
Food	Biomass for human consumption
Raw Materials	Biological materials used for fuel, art and building. Geological materials used for construction or other purposes
Medicinal Resources	Biological materials used for medicines
Regulating	
Gas & Climate Regulation	Regulation of greenhouse gases, absorption of carbon and sulfur dioxide, and creation of oxygen, evapotranspiration, cloud formation and rainfall provided by vegetated and oceanic areas
Disturbance Regulation	Protection from storms and flooding, drought recovery
Soil Erosion Control	Erosion protection provided by plant roots and tree cover
Water Regulation	Water absorption during rains and release in dry times, temperature and flow regulation for plant and animal species
Biological Control	Natural control of pest species
Waste Treatment	Absorption of organic waste, filtration of pollution
Soil Formation	Formation of sand and soil from through natural processes
Supporting	
Nutrient Cycling	Transfer of nutrients from one place to another; transformation of critical nutrients from unusable to usable forms
Biodiversity & Habitat	Providing for the life history needs of plants and animals
Primary Productivity	Growth by plants provides basis for all terrestrial and most marine food chains
Pollination	Fertilization of plants and crops through natural systems
Cultural	
Aesthetic	The role which natural beauty plays in attracting people to live, work and recreate in an area
Recreation & Tourism	The contribution of intact ecosystems and environments in attracting people to engage in recreational activities
Scientific & Educational	Value of natural resources for education and scientific research
Spiritual & Religious	Use of nature for religious or historic purposes

Based on Daly and Farley 2004 and de Groot 2005

Valuing Ecosystem Services

The value of ecosystem goods can be quantified by the market—what are people willing to pay for them? The value of ecosystem services can sometimes be measured by the market, but many services are not for sale. For example there is no market price for clean air. Instead, the value of ecosystem services is measured using seven additional valuation methods including replacement cost, hedonic value and contingent valuation.

When determining the value of ecosystem goods and services in the Puget Sound Basin one would ideally like to perform studies on each specific good and service using the methods described above, but such an endeavor would be financially impractical, and in some cases feasibly impossible. How then, were we able to assign value to the ecosystem goods and services of the Basin? While we certainly relied extensively on first-hand studies, we also turned to studies cited in academic peer reviewed literature to find comparable data. This “benefit transfer” methodology, common in studies such as this one, is similar to the use of “comps” in a house appraisal where value is determined by looking at similar homes. But unlike a house appraisal where the realtor has high and low values and out of that simply picks the best professional guess at a single value, this study provides the full range of values from the lowest in the academic peer reviewed literature to the highest. The high estimates, and certainly the low estimates, both understate the true value because many ecosystem services, which clearly have value, are still lacking valuation studies, and thus show no value.

A full discussion of the valuation methods used in this report was provided in the 2008 report and is discussed in greater detail in Appendix A.

Section 3: Valuing the Puget Sound Basin

What has Changed Since the 2008 Report?

This updated report is intended to incorporate values that have been updated since publication of the 2008 report, and to address criticisms of the values originally used. Out of more than 100 studies in the earlier analysis, two were criticized. Pollination was seen as an intermediate good that should not be counted. Just as the production of glass and metal (intermediate goods) that go into producing a car are not counted in the Gross Domestic Product, it was argued, pollination of coniferous forests should not be counted. This would be a valid criticism if pollination of timber were like the production of cars, where the costs of input goods like glass and metal are directly included in the final cost of the car (metal and glass have to be purchased as an input). However, pollination of coniferous forests to be used as seeds for planting and harvesting is not included in the price of timber. If glass were free in car production, the cost of producing glass would not be included in the final price of the car. If glass producers were not paid, they would quickly quit providing glass. Car production would stop. The cost of pollination for many fruit crops is paid for and included in the final product. However, because pollination is not included in the price of timber, but is valuable and quantifiable, it is correctly included in this study.

Another criticism had to do with the storm protection value provided by wetlands. It was argued that a value based on a study in the Gulf of Mexico should not be used in Puget Sound where hurricanes do not occur. This is a valid criticism. That storm protection analysis and the value provided was not included in this 2010 study. Still, it is worth considering that Puget Sound has experienced many tsunamis in the past and coastal systems provide defense to inland areas. There is no study quantifying this infrequent, but valuable service for Puget Sound coastal systems and so no value was included.

Two areas of important values not included in the 2008 study but examined here are medicinal value and the value of snow pack. Only one medicinal plant value was included, out of many identified. That is the Pacific yew tree from which we derive Taxol, a cure for breast and other cancers.

Snow pack is tremendously valuable to the Puget Sound Basin as it provides water storage services for drinking water, irrigation, industrial use and electricity generation. The value of snow pack per acre varies depending on elevation, snowfall and the beneficiaries served.

Medicinal Value

People have derived medicinal benefits from nature since the Paleolithic age. The Puget Sound Basin derives a great number of medicinal benefits from nature. These include medicines used by indigenous peoples, homeopathic remedies and naturally derived medicines widely recognized by the scientific community to have saved many lives. This study only includes one medicinal substance derived from a Puget Sound Basin plant, Taxol, an organic chemical derived from the bark of the Pacific yew tree, native to the Pacific Northwest.

Taxol is one of the most effective cancer-fighting substances ever discovered. It was first used to treat breast cancer patients, but has since been found to be effective against lung and ovarian cancer as well as Kaposi's sarcoma in AIDS patients. A single gram of pure Taxol is more than sufficient to fully treat one cancer patient (Choi, 2007). Taxol was discovered in the bark of a Pacific Yew tree in a sampling project north of Packwood, Washington (Goodman and Walsh, 2001). The Pacific Yew tree is native to and grows almost solely in the Pacific Northwest, making it a highly valuable asset unique to the region.

Stripping the bark kills the yew tree and heavy harvests were reducing its abundance. Since then, Taxol has been found in the berries of the tree, in the soil where yew trees grow or once grew and in hazelnuts (Hoffman et al, 1998; Daley, 2000). These discoveries provide hope that Taxol may be economically extracted without overharvesting and death of ancient yew trees. Although the chemical can be synthesized, the process is far more difficult and expensive than extraction (Susman, 2000).

Since its release on the market in 1992, Taxol has generated over $11 billion in revenue (Stephenson, 2002). Peak sales were reached in 2000 at $1.6 billion. By dividing the highest annual revenue value and the lowest annual value of revenue by the total acreage of Pacific Yew (10,608,943 acres) on the Pacific Coast, a very rough approximation of the value of Taxol per acre at between $4.71/acre/year and $150.82/acre/year where yews occur.

For decades, yew trees were logged off, slash burned (considered a waste tree) and not replanted on millions of acres of timberlands in the Northwest. Thus, yew trees rarely occur on recently cut, pole, or 40-80 year old forestlands where yew trees were once found in abundance. Though yew trees occur on some of these lands, they were given a zero value in this study. Abundance varies widely: one half-acre site in a Parkland, Washington riparian area contains over 20 yew trees each over 200 years in age.

The total value in the Puget Sound Basin, obtained by applying value per acre per year to late and old growth forest and riparian evergreen forest where yew trees are most abundant (see Tables 12 and 13), adds $12,798,647.85 and $409,828,464.70 per year to Puget Sound's economy.

This represents only the market value of the drug. In the ten years following FDA approval, over 100,000 people were treated with Taxol (PR Newswire, 1993). Like many ecosystem services, the market value of Taxol does not reflect the full value provided. The full value includes, for

example, the added income of cancer patients who survived or—far more importantly—the value of extended life to many women, and to their spouses and their children.
The story of Taxol is a prime example of the interconnectedness of natural, social, human and built capital. Had yew trees gone the way of the passenger pigeon, driven to extinction, this drug would likely never have been discovered.

Snowpack Value

Snowpack is an important link between the economy and the water cycle in the Puget Sound Basin. Snowpack retains water from the wet winter and slowly releases it in the spring, during the summer dry season and in the fall. Snowpack provides drinking water supply, water flow regulation (including groundwater recharge and stream flows for salmon), energy generation, recreation, habitat and climate stability. Snowpack maintains stream flows during periods of low precipitation.

In the western portion of the United States, including Puget Sound, snowmelt provides approximately 70% of drinking water annually (Chang et al., 1987). In the absence of a snowpack, winter rains would need to be captured in reservoirs for later use. This is particularly true in the Puget Sound Basin, where approximately 75% of annual precipitation in the Cascades falls during the cool season (Snover and Miles, in review). Further, current reservoir systems in the Puget Sound depend on snowpack to supplement water storage; almost all of the major municipal water systems west of the Cascades have storage to instream flow ratios of less than 10% (Hamlet et al., 2001).

Thus, snowpack in Puget Sound may be viewed as essentially a large, inexpensive system of water reservoirs. Economists can establish value for some ecosystem services by examining the replacement cost. In this report the economic value of snowpack to Puget Sound residents has been assessed by exploring the costs of an alternative storage system, i.e. surface water reservoir construction, and was found to be in the range of $100 million - $15 billion annually. If the environmental costs of such reservoir systems were included, such as disruption of salmon runs and loss of vegetation, the replacement cost of snowpack might be substantially higher.

The water storage function of snowpack is also important for flood protection, particularly in the Pacific Northwest, where flooding is a common occurrence in many watersheds. Much of the precipitation that falls in the Cascades is stored as snowpack, thus reducing potential surface runoff that might exacerbate floodwaters. This can work both ways, however: under certain conditions, warm heavy rain falling on snowpack can cause “rain-on-snow” events, where existing snowpack quickly melts and exacerbates surface runoff. Under these conditions, the flood protection value of snowpack will shift: from a source of *flood protection* it becomes a source of *floodwater.* The Washington snowpack is especially sensitive to climate change because of its relatively low elevations (Elsner et al., 2009).

The gradual release of snowmelt not only benefits humans. Many fish species (e.g. trout) living or rearing in the rivers and streams of Puget Sound rely on snowmelt to provide a source of cool water throughout the year. The presence of fish in turn attracts recreational anglers who spend substantial sums on equipment, transport and accommodation costs. For example, trout alone generated a net economic value of $145,903,900 in Washington State during 2006 (TCW Economics).

Valuation of the Ecosystem Services of the Puget Sound Watershed

Partial valuation of 14 ecosystem services across 17 land cover types in the Puget Sound Basin shows an annual flow of $9.7 billion to $83 billion. This figure will likely to change with the inclusion of more values and analyses that other ecosystems provide.

From this annual flow of value a capital asset value analogous to an "asset value" can be calculated. This is like the difference between the sum of monthly mortgage payments across a year (the annual flow of value for living in a house in one year) and the full sale value of that house (the asset value, or present value). In order to determine value of ecosystems to society, we apply a depreciation (or discount) rate of 3% over 100 years, from the present day, to obtain its *present value*. Natural assets appreciate, rather than depreciate, thus this value is likely much larger. A zero discount rate was also calculated, which treats the value that these ecosystems will provide to future generations as equal to that of present generations. This takes into account the assumption that breathable air, for instance, will be as valuable to people one-hundred years from now as it is to us today.

Using a 3% discount rate (for no better reason than it is convention), the asset or present value provided by these 14 ecosystem services in the Puget Sound Basin is between $305 billion and $2.6 trillion. As the analysis is refined the range of values may decrease. Using a 0% discount rate the asset or present value of ecosystem services in the Puget Sound Basin would be $967 billion to $8.3 trillion. The asset value of marine and terrestrial ecosystems in the Puget Sound Basin alone is certainly in the many billions of dollars, with *annual* benefits between $9.7 and $83 billion.

These values, even on the low side, clearly justify consideration of significantly higher investment in restoration and conservation than is currently provided. The rate of return on a particular restoration or green infrastructure investment depends on the specific characteristics of the investment. In the past, this has not been calculated. Today, we can estimate the expected dollar value of ecosystem services provided by restoration or green infrastructure investments.

Earth Economics Ecosystem Service Valuation Analysis Summary

A total of 23 ecosystem services were identified in the watershed. Valuation proceeded on 14 of them. Table 2 shows the ecosystem services that were valued for each land cover type.

Table 2. Valued Ecosystem Services for Each Land Cover Type

	Mid Forest	Late/Old Growth Forest	Riparian Forest	Pole Forest	Wetland	Shrub	Grassland	Agriculture
Gas and Climate Regulation	✓	✓	✓	✓	✓	✓	✓	
Disturbance Regulation			✓					
Water Flow Regulation	✓	✓		✓	✓		✓	
Waste Treatment							✓	
Water Supply			✓		✓			
Habitat Refugium		✓	✓		✓	✓		
Pollination	✓	✓					✓	✓
Soil Erosion Control							✓	
Soil Formation							✓	
Biological Control							✓	
Genetic Resources		✓	✓					
Nutrient Cycling					✓			
Aesthetic and Recreational	✓	✓	✓		✓	✓	✓	✓
Medicinal Resources			✓					

	Pasture	Rivers & Lakes	Urban Green Space	Beach	Estuary	Salt Marsh	Eelgrass Beds	Marine Water
Gas and Climate Regulation			✓					
Disturbance Regulation				✓		✓		
Water Flow Regulation			✓					
Waste Treatment						✓		
Water Supply		✓			✓			✓
Habitat Refugium		✓			✓	✓		
Pollination								
Soil Erosion Control								
Soil Formation	✓							
Biological Control								
Genetic Resources								
Nutrient Cycling							✓	
Aesthetic and Recreational	✓	✓	✓	✓	✓	✓		
Medicinal Resources								

*Snowpack values not included

Land cover data, provided by the EPA National Land Cover Data, reflects the best available GIS data for Puget Sound.

Table 3 summarizes the land cover classes and acreage for each class in the Puget Sound Basin. Valuation data exists for eelgrass beds, however the NLCD does not include area coverage of eelgrass beds, which can be incorporated with data from surveys conducted by Washington State Department of Natural Resources.

Table 3. Overall Land Cover Summary

OVERALL LAND COVER SUMMARY (NLCD)

NLCD Code	Description	Acres
0	Unclassified	2,766
11	Open water (total)	1,802,508
	River	15,905
	Lakes	106,000
	Estuary+Salt water	1,680,603
	Estuary	552,712
	Salt water	1,127,891
12	Perennial ice/snow	97,849
21	Developed open space	421,574
22	Developed low density	429,382
23	Developed medium density	167,844
24	Developed high density	66,678
31	Barren (rock/sand/clay) (total)	340,592
	Beach	48,341
	Non-beach	292,251
41	Deciduous forest	267,010
42	Evergreen forest	4,534,878
43	Mixed forest	677,680
52	Scrub/shrub	794,631
71	Grassland/herbaceous	320,443
81	Pasture/hay	307,242
82	Cultivated crops	73,266
90	Woody wetlands	174,132
	Saltwater woody wetlands	7,024
	Freshwater woody wetlands	167,109
95	Emergent herbaceous wetlands	124,918
	Saltwater herbaceous wetlands	76,120
	Freshwater herbaceous wetlands	48,798
Total		**10,603,394**

Table 4 shows the acreage of Riparian land cover drawn from a hydrography layer (OR/WA Hydrography Framework Partnership, 2005). This was used to identify the riparian areas within a 50 meter buffer and to calculate the riparian forest and riparian shrub values. To avoid double counting, the riparian areas were deducted from the total area of corresponding vegetation classes in the NLCD figures.

Table 4. Riparian Land Cover

RIPARIAN AREAS - USING 50m BUFFER AND DNR HYDROGRAPHY LAYER		
NLCD Code	**Description**	**Acres**
0	Unclassified	66
11	Open water (total)	14,202
12	Perennial ice/snow	4,693
21	Developed open space	69,982
22	Developed low density	34,010
23	Developed medium density	8,472
24	Developed high density	2,792
31	Barren (rock/sand/clay) (total)	32,127
41	Deciduous forest	61,154
42	Evergreen forest	1,027,004
43	Mixed forest	162,159
52	Scrub/shrub	200,180
71	Grassland/herbaceous	55,429
81	Pasture/hay	36,762
82	Cultivated crops	10,812
90	Woody wetlands	58,917
n/a	Eel grass beds	49,422
95	Emergent herbaceous wetlands	18,665
Total		**1,797,362**

Forest Successional Stage

Not all forests provide equal ecosystem services. A recently cut and planted area does not prevent flooding, provide water filtration, or recreational values the way a mature or an old growth forest does. In this study the stand size—that is, the diameter of the timber—in a forest is used to determine age and maturity, or what we label as successional stages. Table 5 shows the successional stages and acreage of forest areas in the Puget Sound Basin.

To avoid overestimating the value of forests, five forest successional stages for the Puget Sound region were identified based on recent successional stage mapping data (Interagency Vegetation Mapping Project, 2004). This data was provided as total forest acreage; the areas for coniferous, deciduous, and mixed forests could not be separated. Because this database does not exactly match the NLCD for total forest acres, we assumed that each of the forest types, including riparian, has the same ratio of stages in the NLCD database as the total forested area in the Interagency Vegetation Mapping Project. NLCD data in Table 5 was used to calculate the ecosystem services within these successional stages. Because logging in riparian areas is restricted, this assumption underestimates the actual successional stage for riparian areas; the value that riparian areas provide is embedded with the ecosystem services examined, and is an underestimate because these areas are generally of a later successional stage than is extrapolated from the Interagency data.

Table 5. Forest Stand Size Data

FOREST SUCCESSIONAL STAGE SUMMARY

Size	Stage	Acres
0-4.9	Early successional	911,059
5-9.9	Pole	892,615
10-19.9	Mid successional	1,682,082
20-29.9	Late successional	931,873
30+	Old growth	758,458
TOTAL		**5,176,087**

Earth Economics maintains and is consistently expanding a database of ecosystem service valuation studies. The following tables show the dollar values for the low and high boundaries for ecosystem service values after an extensive literature review. Table 10 shows estimates based on peer-reviewed academic journal articles for the Puget Sound Basin using a benefit transfer methodology.

Table 6. High and Low Dollar per Acre Estimates for Wetland and Salt Marsh

	Wetland		**Salt Marsh**	
Ecosystem Service	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Gas & Climate Regulation	$31.32	$284.58		
Water Regulation	$6,765.49	$6,765.49		
Genetic Resources				
Aesthetic & Recreational	$33.49	$9,946.87	$5.19	$103.82
Habitat Refugium & Nursery	$6.30	$13,341.27	$1.25	$1,082.32
Water Supply	$193.92	$33,418.85		
Disturbance Regulation			$258.49	$102,105.30
Waste treatment			$116.82	$18,807.44
Soil Formation				
Nutrient Cycling	$7,346.62	$7,346.62		
Biological Control				
Soil Erosion Control				
Pollination				
Medicinal resources				
Total by Cover Type	**$14,377.14**	**$71,103.69**	**$381.75**	**$122,098.87**

Table 7. High and Low Dollar per Acre Estimates for Grassland and Shrub

	Grasslands		Shrub	
Ecosystem Service	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Gas & Climate Regulation	$0.06	$4.10	$6.60	$78.00
Water Regulation	$1.76	$2.16		
Genetic Resources	$0.01	$0.01		
Aesthetic & Recreational			$0.19	$678.72
Habitat Refugium & Nursery			$1.31	$532.33
Water Supply				
Disturbance Regulation				
Waste treatment	$50.98	$50.98		
Soil Formation	$0.52	$0.59		
Nutrient Cycling				
Biological Control	$9.74	$13.47		
Soil Erosion Control	$16.99	$19.04		
Pollination	$10.77	$14.65		
Medicinal resources				
Total by Cover Type	**$90.83**	**$105.00**	**$8.10**	**$1,289.05**

Table 8. High and Low Dollar per Acre Estimates for Agricultural Lands and Riparian Buffer

	Agricultural lands		Riparian buffer	
Ecosystem Service	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Gas & Climate Regulation				
Water Regulation				
Genetic Resources				
Aesthetic & Recreational	$29.26	$29.26		
Habitat Refugium & Nursery				
Water Supply				
Disturbance Regulation				
Waste treatment				
Soil Formation				
Nutrient Cycling				
Biological Control				
Soil Erosion Control				
Pollination	$2.55	$12.88		
Medicinal resources			$5.01	$160.49
Total by Cover Type	**$31.82**	**$42.14**	**$5.01**	**$160.49**

Table 9. High and Low Dollar per Acre Estimates for Urban Green Space and Pasture

	Urban green space		Pasture	
Ecosystem Service	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Gas & Climate Regulation	$28.53	$930.90		
Water Regulation	$6.09	$181.85		
Genetic Resources				
Aesthetic & Recreational	$1,342.21	$3,934.57	$0.03	$0.03
Habitat Refugium & Nursery				
Water Supply				
Disturbance Regulation				
Waste treatment				
Soil Formation			$6.62	$6.62
Nutrient Cycling				
Biological Control				
Soil Erosion Control				
Pollination				
Medicinal resources				
Total by Cover Type	**$1,376.83**	**$5,047.32**	**$6.65**	**$6.65**

Table 10. High and Low Dollar per Acre Estimates for Eelgrass beds and Beach

	Eel grass beds		Beach	
Ecosystem Service	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Gas & Climate Regulation				
Water Regulation				
Genetic Resources				
Aesthetic & Recreational			$149.20	$48,441.03
Habitat Refugium & Nursery				
Water Supply				
Disturbance Regulation			$23,637.86	$38,316.19
Waste treatment				
Soil Formation				
Nutrient Cycling	$5,860.22	$16,410.10		
Biological Control				
Soil Erosion Control				
Pollination				
Medicinal resources				
Total by Cover Type	**$5,860.22**	**$16,410.10**	**$23,787.06**	**$86,757.22**

Table 11. High and Low Dollar per Acre Estimates for Marine and Pole Forest

	Marine		Pole Forest	
Ecosystem Service	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Gas & Climate Regulation			$24.04	$464.33
Water Regulation			$10.23	$10.23
Genetic Resources				
Aesthetic & Recreational				
Habitat Refugium & Nursery				
Water Supply	$275.97	$822.24		
Disturbance Regulation				
Waste treatment				
Soil Formation				
Nutrient Cycling				
Biological Control				
Soil Erosion Control				
Pollination				
Medicinal resources				
Total by Cover Type	**$275.97**	**$822.24**	**$34.27**	**$474.55**

Table 12. High and Low Dollar per Acre Estimates for Mid Forest and Late/Old Forest

	Mid Forest		Late/Old Forest	
Ecosystem Service	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Gas & Climate Regulation	$34.34	$663.37	$46.35	$895.47
Water Regulation	$10.23	$10.23	$10.23	$10.23
Genetic Resources				
Aesthetic & Recreational	$5.20	$339.36	$10.41	$678.72
Habitat Refugium & Nursery			$287.16	$532.33
Water Supply				
Disturbance Regulation				
Waste treatment				
Soil Formation				
Nutrient Cycling				
Biological Control				
Soil Erosion Control				
Pollination	$33.51	$150.48	$67.01	$300.96
Medicinal resources			$5.01	$160.49
Total by Cover Type	**$83.28**	**$1,163.45**	**$426.17**	**$2,578.20**

Table 13. High and Low Dollar per Acre Estimates for Riparian Forests

	Riparian Forest (pole)		Riparian Forest (mid to late)	
Ecosystem Service	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Gas & Climate Regulation	$24.04	$464.33	$46.35	$895.47
Water Regulation	$10.23	$10.23	$10.23	$10.23
Genetic Resources				
Aesthetic & Recreational	$1,109.90	$11,305.57	$1,109.90	$11,305.57
Habitat Refugium & Nursery			$287.16	$532.33
Water Supply			$2,240.01	$13,849.87
Disturbance Regulation			$8.04	$250.85
Waste treatment				
Soil Formation				
Nutrient Cycling				
Biological Control				
Soil Erosion Control				
Pollination				
Medicinal resources			$5.01	$160.49
Total by Cover Type	**$1,144.16**	**$11,780.13**	**$3,706.70**	**$27,004.81**

Table 14. High and Low Dollar per Acre Estimates for Estuaries and Lakes/Rivers

	Open Water Estuary		Lakes/Rivers	
Ecosystem Service	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Gas & Climate Regulation				
Water Regulation				
Genetic Resources				
Aesthetic & Recreational	$11.51	$1,381.50	$1.69	$19,699
Habitat Refugium & Nursery	$92.75	$354.14	17.13	$1,479.84
Water Supply	$5.88	$127.47	$58.89	$843.44
Disturbance Regulation				
Waste treatment				
Soil Formation				
Nutrient Cycling				
Biological Control				
Soil Erosion Control				
Pollination				
Medicinal resources				
Total by Cover Type	**$110.15**	**$1,863.11**	**$77.71**	**$22,022.28**

To estimate an "appraisal" value of The Puget Sound Basin, per acre values were summed up for each land cover type across ecosystem services. Table 15 shows the acreage of each vegetation type within the watershed and the total $/acre for that vegetation type across the ecosystem services where values exist. Because no valuation studies exist for some of these vegetation type/ecosystem service value combinations, these are clearly underestimates (see Table 2).

Table 15. High and Low Estimates of Ecosystem Value Flows in the Puget Sound Watershed

		Total $/ac/yr by cover type		**Total $/yr by cover type**	
Cover Type	***Acres***	***Low***	***High***	***Low***	***High***
Freshwater Wetland	215,907	$14,377.14	$71,103.69	$3,104,124,725	$15,351,783,369
Salt Marsh	83,144	$381.75	$122,098.87	$31,740,187	$10,151,788,468
Grasslands	320,443	$90.83	$105.00	$29,107,437	$33,646,096
Shrubs	594,451	$8.10	$1,289.05	$4,813,927	$766,274,677
Agricultural Lands	73,266	$31.82	$42.14	$2,331,162	$3,087,425
Urban Green Space	421,574	$1,376.83	$5,047.32	$580,434,423	$2,127,819,908
Pastures	307,242	$6.65	$6.65	$2,043,428	$2,043,428
Eel Grass Beds	49,422	$5,860.22	$16,410.10	$289,623,742	$811,020,108
Beach	48,341	$23,787.06	$86,757.22	$1,149,890,361	$4,193,930,606
Marine	1,127,891	$275.97	$822.24	$311,268,667	$927,396,752
Lakes/Rivers	121,905	$77.71	$22,022.28	$9,473,238	$2,684,626,043
Open Water Estuaries	552,712	$110.15	$1,863.11	$60,880,747	$1,029,761,570
Early Forest	964,475	$-	$-	$-	$-
Pole Forest	729,333	$34.27	$474.55	$24,990,820	$346,107,333
Mid Forest	1,374,387	$83.28	$1,163.45	$114,458,395	$1,599,024,432
Late/Old Forest	1,381,127	$426.17	$2,578.20	$588,590,456	$3,560,819,411
Riparian Forest (pole)	215,617	$1,144.16	$11,780.13	$246,701,064	$2,539,995,336
Riparian Forest (mid to late)	814,628	$3,701.70	$26,844.31	$3,015,505,308	$21,868,130,544
Riparian Shrub	200,180	$-	$-	$-	$-
Snowpack*	N/A	N/A	N/A	$100,403,350	$15,450,313,315
TOTAL	**9,596,045**			**$9,666,381,437**	**$83,447,568,821**

*Values not presented per acre

Table 16. Present Value of Ecosystem Service of the Puget Sound Basin

Discount Rate	Low Estimate	High Estimate
0% (100 years)	$967 billion	$8.3 trillion
3% (100 years)	$305 billion	$2.6 trillion

Appendix B describes the land cover type, ecosystem service, authors of papers used in the study, the lowest average presented in the papers and the highest value known for each value utilized in this study. There is also a single value column where low and high values do not exist.

Conclusion

The key to securing ecological sustainability, fairness and economic prosperity is investment—today's investment determines the physical nature of tomorrow's economy. Success in achieving sustainability in the Puget Sound Basin requires a shift to green infrastructure including ecological restoration, stormwater retention, green building, better industrial processes and far more. Shifting investment requires accounting that includes the value of natural capital, improved jobs analysis, better cost/benefit analysis and economic incentives that reward green investment.

Our Puget Sound economy is built upon the land and waters of the Puget Sound Basin. We cannot live without the ecosystem services the Puget Sound Basin provides.

Summary of Conclusions:

1. The Puget Sound Basin provides 23 categories of valuable ecosystem services and goods, which are essential to a prosperous economy and high quality of life.

2. The partial annual value of nature's goods and services ranges between $9.7 billion and $83 billion.

3. The present value for this flow of benefits, analogous to an asset value is partially valued between $305 billion and $2.6 trillion.

4. Ongoing studies are critically needed to update valuations and further justify investment.

5. It is possible, in fact imperative, to identify specific providers of ecosystem services, the beneficiaries of those services and impediments to their continued success.

6. Modeling of ecosystem services is advancing rapidly.

7. Further funding and research can play a key role in informing public and private investment.

8. Achieving sustainability requires shifting investment from investments that damage ecosystem services to investments that improve and sustain them.

9. Improving economic analysis to secure more productive and sustainable investment requires:

   - Accounting for natural capital
   - Improving jobs analysis for restoration
   - Adopting new industrial indicators
   - Redefining green jobs
   - Changing cost/benefit analysis
   - Getting the scale of jurisdictions right
   - Rationalizing tax districts
   - Upgrading environmental impact assessments
   - Including ecosystem service valuation in all watershed scale studies
   - Training government, private firm and non-profit staff in ecosystem services and the use of ecosystem service valuation tools

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Appendix A. Greater Detail on Ecosystem Services

In 2001, an international coalition of scientists within NASA, the World Bank, the United Nations Environmental Program, the World Resources Institute, and others initiated an assessment of the effects of ecosystem change on human wellbeing. The product of this collaboration was the Millennium Ecosystem Assessment, which classifies ecosystem services into four broad categories describing their ecological role (MEA 2003). Ecological economists generally use these same categories.

- **Provisioning services** provide basic materials; mostly ecosystem service goods. Forests grow trees that can be used for lumber and paper, berries and mushrooms for food, and other plants for medicinal purposes. Rivers provide fresh water for drinking and fish for food. The waters of the Puget Sound provide fish, shellfish and seaweed. Provisioning of these goods is a familiar service provided by nature, and is easiest to quantify in monetary terms (Farber et al., 2006).

- **Regulating services** are benefits obtained from the natural control of ecosystem processes. Intact ecosystems provide regulation of climate, water, soil, and keep disease organisms in check. Degraded systems propagate disease organisms to the detriment of human health (UNEP, 2005).

- **Supporting services** include primary productivity, nutrient cycling and the fixing of CO_2 by plants to produce food. These services are the basis of the vast majority of food webs and life on the planet.

- **Cultural services** are those that provide humans with meaningful interaction with nature. These services include spiritually significant species and natural areas, enjoying natural places for recreation, and learning about the planet through science and education.

Within each category, there are many more specific ecosystems services. These services are identified in the following table.

Table 1A. Table of Ecosystem Services

Provisioning	
Drinking Water	Water for human consumption
Food	Biomass for human consumption
Raw Materials	Biological materials used for fuel, art and building. Geological materials used for construction or other purposes
Medicinal Resources	Biological materials used for medicines
Regulating	
Gas and Climate Regulation	Regulation of greenhouse gases, absorption of carbon and sulfur dioxide, and creation of oxygen, evapotranspiration, cloud formation and rainfall provided by vegetated and oceanic areas
Disturbance Regulation	Protection from storms and flooding, drought recovery
Soil Erosion Control	Erosion protection provided by plant roots and tree cover
Water Regulation	Water absorption during rains and release in dry times, temperature and flow regulation for plant and animal species
Biological Control	Natural control of pest species
Waste Treatment	Absorption of organic waste, filtration of pollution
Soil Formation	Formation of sand and soil from through natural processes
Supporting	
Nutrient Cycling	Transfer of nutrients from one place to another; transformation of critical nutrients from unusable to usable forms
Biodiversity and Habitat	Providing for the life history needs of plants and animals
Primary Productivity	Growth by plants provides basis for all terrestrial and most marine food chains
Pollination	Fertilization of plants and crops through natural systems
Cultural	
Aesthetic	The role which natural beauty plays in attracting people to live, work and recreate in an area
Recreation and Tourism	The contribution of intact ecosystems and environments in attracting people to engage in recreational activities
Scientific and Educational	Value of natural resources for education and scientific research
Spiritual and Religious	Use of nature for religious or historic purposes (i.e., heritage value of natural ecosystems and features)

Based on Daly and Farley 2004 and de Groot 2005

These are the primary categories of ecosystem services, and are discussed below. It should be kept in mind that these can be further broken down into sub-categories. For example, recreation contains boating, fishing, birding, hiking, swimming and other activities. Every year, ecosystem services are added to the more detailed categories.

The following sections provide an overview of provisioning, regulating, supporting and cultural ecosystem services. For this basic ESV report, three specific examples for the Puget Sound Basin are provided in special “Spotlight on the Puget Sound Basin ” figures within orange text boxes throughout this section. Should a full ESV report be done by Earth Economics, each service would contain regional analysis.

Provisioning Services

Fresh Water
Watersheds provide fresh water for human consumption and agriculture; including surface water and ground water for large metropolitan areas, wells, industry and irrigation. The hydrological cycle is affected by structural elements of a watershed such as forests, wetlands and geology, as well as processes such as evapotranspiration and climate. Over 60% of the world’s population gets their drinking water from forested watersheds (UNEP 2005). Some Puget Sound Basin residents are among these. Increasing loss of forest cover around the world has decreased water supply, due to lower ground water recharge and to lower flow reliability (Syvitski, 2005).

The Puget Sound Basin is heavily influenced by its proximity to the Pacific Ocean and the Olympic and Cascade Mountains. Local ecosystems capture precipitation in the form of rain and snow. Water is filtered through forests and other vegetation to produce clean ground water and surface water.

Fresh Water in the Puget Sound Basin

In the Snoqualmie Basin, nearly 90% of private, municipal, industrial, and agricultural water comes from groundwater sources. Most of this water comes from wells, which are treated with fluoride and chlorine. Much of the groundwater is incorporated into the East King County Groundwater Management Area, which covers 225 miles of land in or near the Snoqualmie River Valley. A Groundwater Protection Committee met from 2002-2004, at which time the Committee disbanded.

Although local, short-term demand for water withdrawal is predicted to remain fairly stable in the Snoqualmie Basin, experts predict pressure from elsewhere in the Puget Sound will contribute to increasing water demand. Additionally, Washington State climate change predictions indicate that prolonged droughts and decreased snowmelt might exaggerate low-flow summer conditions (EKCRWA 2007). Currently, there are some projects to alter stream flow in the Snoqualmie Watershed, both for human use and for aquatic species. This work is discussed in the section on "Water Regulation".

Food

Food includes biomass for human consumption, provided by a web of organisms and a functioning ecosystem. Providing food is one of the most important functions of marine ecosystems. Globally, fish and seafood provide the primary source of protein to one billion people. Fishing and fish industries provide direct employment to some 38 million people (UNEP, 2006). Agricultural land also provides a great deal of food value. Agricultural lands in the U.S. are forecasted to produce $63 billion worth of crops and livestock in 2010 (USDA, 2010). Berries, peas, potatoes, flower bulbs, seeds and dairy products are the major economic yields of Puget Sound farms. Berries are especially high value products for the region.

Food in the Puget Sound Basin

Historically, the Snoqualmie Valley has been an area rich in natural resources. Before settlers arrived, the area supplied deer, mountain goats, edible bulbs and plant roots, berries, and above all, abundant salmon. The Snoqualmie Tribe managed the prairie's productivity with occasional burns. Arriving settlers later developed a large hops industry in the 1880's, which flourished until the late 1890's. Other agriculture filled its place until the 1960's, when agriculture in the valley declined (King County website, 2010).

Today, the Snoqualmie Agricultural Production District (APD) covers 14,000 acres, largely located along main-stem rivers and along lowland tributaries. Over 4,500 acres of this land has been protected under the Farmland Preservation Program (King County, 2010). According to a 2003 survey by King County, approximately half of total agricultural activity in the Snoqualmie Basin is located within the APD. These lands provide both local and national food, as well as local employment and ecosystem benefits. Livestock and dairy farms cover the largest amount of acreage (4,300 acres of forage lands for livestock), with other significant uses including produce, tree farms, corn, and nurseries (Kaje, 2009).

Additionally, agricultural lands, both active and fallow, provide aesthetic and cultural value. The King County Conservation District assisted with the purchase of the historical Meadowbrook farm, which remains as an open space corridor in the Valley. The King County Historic and Scenic Corridors Project helped develop the West Snoqualmie River Road Heritage Corridor, which capitalizes on historical corridor features as well as views of agricultural lands such as cut flower fields and pastures, and historic architecture such as dairy farmsteads and barns (KCDOT, 2009).

The Snoqualmie Basin has a large amount of critical salmon habitat, which traditionally provided a valuable food source to the Snoqualmie Tribe and others. The details of the habitat and non-commercial values will be discussed in later sections.

However, agricultural production, particularly cattle operations, can degrade water quality and fish habitat when not properly managed. One of our partners on this project, Stewardship Partners, with support from King County, has helped many farms within the Snoqualmie Valley improve practices to reduce negative environmental effects. Through activities such as planting riparian vegetation, both the value of this farmland is increased, and the local economy is enhanced. Better salmon habitat will provide greater return in fishing, local food, and will draw recreational and sports fishers as tourists.

Raw Materials

Raw Materials include biological materials used for medicines, fuel, art and building, and geological materials used for construction or other purposes.

Raw Materials in the Puget Sound Basin

The Snoqualmie Basin contains a great deal of working forestlands, with over 75% of its land in the Forest Production District. Trees have been harvested from the area from the late 1800s to the present. Logging of old-growth timber peaked in the 1920s, so there are no old growth stands remaining, and most of the current forest is third or fourth generation growth. Timber production is still active in the area, and about twenty mining claims (primarily for quartz crystals) are still active in the nearby National Forest. The Snoqualmie Valley also has a significant amount of land in tree farms.

Regulating Services

Gas and Climate Regulation

Ecosystems help to regulate the gaseous portion of nutrient cycles that effect atmospheric composition, air quality and climate regulation. This process is facilitated by the capture and long-term storage of carbon as a part of the global carbon cycle. Forests and individual trees play an important role in regulating the amount of oxygen in the atmosphere and in filtering pollutants out of the air, including removal of tropospheric ozone, ammonia, sulfur dioxide, nitrogen oxide compounds (NOx), carbon monoxide and methane.

Carbon sequestration is a specific and important type of gas regulation. Forests, agricultural lands, wetlands and marine ecosystems all play a role in carbon sequestration. Undisturbed old growth forests have very large carbon stocks that have accumulated over thousands of years. Replacing old growth forests with new trees results in net carbon emissions caused by the loss of hundreds of years of carbon accumulation in soil carbon pools and large trees (Harmon, 1990).

Maintaining a climate within a stable range is increasingly a priority for local, federal and international jurisdictions. The role of forests and other ecosystems in controlling Greenhouse Gases (GHGs) – those that contribute to global warming – is essential to the continuation of life on earth. However, carbon sequestration is not the only value provided by gas and climate regulation. Low air quality can cause health care costs to spike, as respiratory diseases develop. In the Puget Sound, the gases sequestered by forests saved $166.5 million per year in avoided health care costs and other costs in 1996. The extensive forest cover of the entire Puget Sound Basin thus likely provides a significant amount of gas regulation services that is very valuable in terms of public health.

Managed forests have the potential to sequester nearly as much carbon as old growth forests, but this requires longer rotations than current industrial standards and other changes (Harmon and Marks, 2002). Agricultural soils can also sequester more carbon when certain techniques are used, including crop rotations, livestock waste disposal and conservation tillage, especially no-till (West and Post, 2002; Tweeten et al., 1998). Because these types of practices could provide significant global value – $8 to $59 per ton by some estimates – there is increased interest in including agricultural lands in carbon trading markets, with farmers receiving payments for their sequestration. The potential of this market and others related to agricultural lands will be discussed in the section on funding mechanisms

Gas and Climate Regulation in the Puget Sound Basin
The Snoqualmie Basin still contains a great deal of forested land, though working forests and farmland could play a larger role in climate and gas absorption in the Snoqualmie Watershed. Payments to farmers may someday incentivize no-till agriculture and longer forest rotations for working forests. Additionally, some cities, such as Snoqualmie, have taken measures to improve sustainability. The city expects to save $1,000 annually in stormwater costs from urban tree planting; these trees will likely also contribute to additional carbon sequestration.

Disturbance Regulation
Estuaries and bays, coastal wetlands, headlands, intertidal mudflats, seagrass beds, rock reefs and kelp forests provide storm protection. These areas 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 (Costanza et al., 2008; UNEP, 2005).

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 the future of economic development in the Snoqualmie Watershed. In order to have productive agricultural and forested lands, protected built capital and high value, productive ecosystems, flood protection must be effective and efficient. Given that significant infrastructure can be damaged during large storm events, tourism and recreation could be harmed as well.

One of the most significant factors in an ecosystem's ability to prevent flooding is the absorption capacity of the land. This is determined by land cover type (forest vs. pavement), soil quality and other hydrological and geological dynamics within the watershed. In the Puget Sound, impermeable surface area has increased by over 10% in the past 15 years. The USGS estimates that urban development leads to increases in flood peak discharges flows of 100-600% for 2-year storm events, 20-300% for 10-year events and 10-250% for 100-year events (Konrad, 2003). One recent study in Renton found that wetlands provide over $40,000 per acre of flood damage protection (Leschine, 1997). Another pilot study in King County demonstrated that flood hazard reduction projects in the floodplain and Cedar River could avoid $468 to $22,333 per acre per year in damages to homes and county flood control facilities (Swedeen and Pittman, 2007).

The retention of forest cover and restoration of floodplains and wetlands provides a tangible and valuable ecosystem service. Most notably, it reduces the devastating effects of floods, which include property damage, lost work time, injury and loss of life. Unfortunately, Puget Sound estuaries have lost about 60% of their salt marshes since European settlement (Buchanan et al., 2001). Wetlands and intact riverine floodplains, including riparian forests, absorb the increased river flows that result from storm events and high snowmelt. Upland forests also absorb rainwater, reducing surface runoff into major stream and river systems. Greater over-land water flows during winter storms cause more flood damage when wetlands are lost, riparian areas are disconnected from rivers and streams or forestland is replaced by houses and commercial development (Kresch and Dinicola, 1997).

Disturbance Regulation in the Puget Sound Basin

Prior to its recent settlement and industrial development, the Snoqualmie Basin experienced regular storms and flooding, just as it does today. Without any concrete levees, wetland and riparian vegetation was forced to adapt to these regular natural disturbances. An array of complex plant communities arose, which withstood natural disturbances by absorbing their energy. During storms old growth forests soaked up a great deal of water, allowing only a low level of surface runoff. Flooding was further buffered by large tracts of wetland and riparian vegetation which served as a sink for excess water and prevented buildup of water downstream.

Today, existing forest within the Snoqualmie Basin has become increasingly fragmented, partly due to pressures such as land use value increases, changing ownership patterns and residential development (King County WLR, 2010; McCaffrey, 2004). Riparian vegetation and wetlands are following similar trends of fragmentation and altered hydrology (Catchpole and Geggel, 2009a). As a result, the watershed's ability to absorb the energy of natural disturbances has been significantly reduced.

In the Snoqualmie Basin, urban areas line the riverbanks - often in areas that are natural floodways. It was recently estimated that a 100-year flood along the Snoqualmie River would displace approximately 1600 residents in Snoqualmie alone and cost more than $29 million (King County Flooding Services, 2010). Also, the close proximity of urban areas to natural floodways means that during a flood there is a greater likelihood that floodwaters will pick up land-based pollutants such as industrial and residential chemicals, manure and agricultural fertilizer (Kaje, 2009).

If global temperatures continue to rise, models predict that the Pacific Northwest will experience wetter winters and drier summers (Mote and Salathe, 2009). In Puget Sound watersheds, snowpack is likely to decrease, while rain will increase (Elsner et al., 2009). A reduction in upland vegetation, along with these climatic changes, will result in an increase in rain-on-snow events, further adding to the severity of surface water buildup, flooding and landslides (Coffin and Harr, 1992).

Residents in the Snoqualmie Basin understand that storms and flooding are regular events in the Watershed, and employ a variety of strategies to reduce the stress and danger that comes from such disturbances. After the 2006 floods in Snoqualmie, for example, 90 residents applied to have their houses raised, while 12 applied to have their houses bought out (Catchpole and Geggel, 2009b). Local government continues to maintain flood levees along key riverbanks, but is more often beginning to implement non-traditional flood protection measures, such as levee setbacks and the planting of riparian vegetation along riverbanks (Catchpole and Geggel, 2009b). Policies that recognize the Snoqualmie River's natural tendency to flood will save money in the long term.

Soil Erosion Control

Natural erosion and landslides provide sand and gravel to streams, creating habitat for fish and other species. Additionally, these processes can move Large Woody Debris (LWD) through the process of recruitment, which are needed for healthy aquatic processes. However, if too many areas become unstable, too much LWD will be deposited, causing unnatural jams that damage habitat and infringe on recreational activity.

Natural erosion protection is provided by plant roots and tree cover. Soil erosion control is closely linked with disturbance prevention. While the absorption capacity of the land will largely determine floodwater levels, the retention of this water can play a significant role in preventing landslides and other damaging forms of erosion. Sedimentation from a large number of landslides can harm salmon habitat.

On the other hand, human alteration of shoreline and stream corridors can prevent the type of natural erosion upon which salmon and other species depend. Forested and vegetated areas naturally provide stability and erosion control, while impermeable built surfaces or deforested areas cannot retain soil well. Human activities may not only affect an area's ability to retain soil, but can also increase the flow of water that may mobilize soil particles. Accidental surface-water discharges or increased storms related to climate change can both increase erosion risk.

Soil Erosion Control in the Puget Sound Basin

Erosion control in the Snoqualmie Watershed is an important service, as the sedimentation from large amounts of erosion can be extremely damaging to downstream water quality and fish habitat (KCDES et al., 2004). Erosion Hazard Areas were mapped by King County beginning in the late 1980s. The susceptibility of a given slope is determined by grain-size, soil cohesion, slope gradient, rainfall frequency and intensity, surface composition and permeability, and type of land cover (Kresch and Dinicola, 1997).

The best management in the Snoqualmie Basin will allow for natural erosion while protecting habitat and built value by avoiding development and deforestation in areas that are at risk of severe erosion or landslides.

Water Regulation

Ecosystems absorb water during rains and release it in dry times, and also regulate water temperature and flow for plant and animal species**.** The amount and timing of water flow in the Puget Sound Basin is important for many reasons; the supply of adequate amounts of cool water at critical times is important for salmon migration, the provisioning of drinking and irrigation water allows for ecosystem goods such as clean drinking water and agricultural products and the maintenance of adequate water flows generates electricity for hydroelectric dams. Forest cover, riparian vegetation and wetlands all contribute to modulating the flow of water from upper portions of the watershed to streams and rivers in the lower watershed. Agricultural and urban development often results in lost forest cover or riparian vegetation. This shift in land cover is among the most important causes of a smaller fresh water flow to coastal wetlands and bays. When forested basins are heavily harvested, they become dominated by recently clear-cut or young stands, causing the remaining vegetation and litter layer on the forest floor to absorb less water. More water then flows over land into streams and rivers, contributing to higher peak flows, flood events, erosion and landslide issues (Moore and Wondzell, 2005). Heavy harvesting also reduces the ability of forests to slowly release water during dry summer months and moderate stream temperatures. The soil from erosion entering streambeds injures fish and fills spawning beds. These cumulative effects can damage built and natural capital.

Coastal freshwater wetlands form a salinity gradient with saltwater marshes and the ocean.

These freshwater wetlands keep salt water from intruding on coastal freshwater supplies, both at the surface and in aquifers. Alteration of hydrology by diverting water from estuaries is considered to be a major threat to coastal areas. Hypersalinization can occur when too much fresh water is prevented from reaching estuaries, threatening fresh water supplies, habitat and other services.

As was discussed in the section on Drinking Water, ecosystems are able to naturally both supply and then filter clean water for human use. One way to understand the economic value of intact watersheds is to compare it to the cost of building and maintaining water supply and treatment facilities. To the extent that loss of ecological systems results in reduced supply, value can also be ascertained through the cost of having to import water from elsewhere. These are examples of what economists call replacement costs (see Appendix B).

A wide variety of stream-flow augmentation techniques have been adopted in the United States, Great Britain, and elsewhere. In order to balance human desire to maximize water supply with other services such as water regulation and habitat, these types of management techniques must be carefully evaluated regarding their impact on water flows elsewhere in the watershed. Much of the science behind stream-aquifer relationships and other hydrologic relationships within the watershed are still not fully understood, and will greatly impact our ability to protect other ecosystem services as we utilize this valuable one.

Water Regulation in the Puget Sound Basin

Currently, the East King County Regional Water Association (EKCRWA) - in conjunction with the Department of Ecology (DOE) and Seattle Public Utilities (SPU) - is pursing projects to impact ground and surface water resources in the Snoqualmie Basin, documented in an extensive Streamflow Enhancement Report produced in 2007. Studies in the 1980s and 1990s indicated that East King County might experience future water shortages, sparking an investigation by the EKCRWA. This work has analyzed the potential of various stream flow augmentation techniques in the Snoqualmie Basin, specifically the Snoqualmie Aquifer Regional Water Supply Project.

The project would deliver water from the upper Snoqualmie Basin to the regional supply system. However, since such action could jeopardize flows needed for salmon and other species, the EKCRWA has proposed managing ground water together with surface water, so that groundwater would be withdrawn from wells in the upper Middle and South Fork basins, added to the Snoqualmie River as it flows through Duvall, and withdrawn once past critical salmon areas.

Additionally, high temperatures during summer months threaten aquatic populations, and temperature is now the largest water quality concern in the mainstem of the Snoqualmie River (Kaje, 2009). Future conditions may vary due to climate change, including reduced snowmelt and lower summer flows. New water management strategies will need to be developed to meet both increasing human demand and increasing pressure to restore and protect salmon and other aquatic species.

Pollination

Pollination supports wild and cultivated plants, which are an important supply of food for people. Pollination also 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 (Nabhan and Buchmann, 1997). Wild habitats near croplands are necessary in order to provide sufficient habitat to keep populations of pollinators, so vital to crop production, intact. The loss of forestlands and native shrubby riparian areas in suburbanizing rural areas has a negative impact on the ability of wild pollinators to perform this service.

Pollination in the Puget Sound Basin

Pollination drives many of the ecosystem services provided by the Snoqualmie Basin. Agriculture, for example, relies heavily on pollination. Insect-pollinated market crops were valued at approximately $20 billion to the U.S. economy in 2000 (Morse and Calderone, 2000). The Snoqualmie Valley Agricultural Production District (APD), found within the Snoqualmie Basin, is the second largest APD in King County. In terms of acreage, its market crops account for around half of the King County total (this includes flowers) (KCDNRP and KCAC, 2009), many of which rely on natural pollinators. Livestock make up around a third of the valley's APD, and is indirectly reliant on pollinators, in that forage crops such as alfalfa are grown with the help of pollinators. Pollinators also ensure that local flowering plants are able to reproduce. These plants in turn provide us with a number of ecosystem services, such as breathable air, and some of the natural beauty that attracts visitors to the Snoqualmie Basin.

Biological Control

Biological Control is the ability of ecosystems to limit the prevalence of crop and livestock pests and diseases. A wide variety of pest species destroy human agricultural crops, reducing worldwide harvest by an estimated 42%, thereby causing a loss of $244 billion each year (Pimentel et al., 1997). A number of natural predators for pest species contribute to natural control of damages. These predators also play a role in protecting forests from pests. Birds, for example, are a natural predator of some harmful insects. Unfortunately, many exotic pests, for which no natural predators exist, have been introduced to areas beyond their natural range. These new pests have caused annual damage ranging from $1.1 to $134 million dollars in the United States alone (Chapin et al., 2000).

In recent years, humans have turned increasingly towards pesticides to control crop losses. While pesticides can reduce the risk of specific pest attacks, they can also harm natural predator populations and lead to resistance among pests, making them even more difficult to control in the future. Overuse of pesticides is also known to reduce provisioning of some other ecosystem services, particularly water quality. While there may be a role for pesticide control in agricultural practice, there are also ways to manage crops so as to enhance biological control services. These techniques include crop diversification and genetic diversity, crop rotation and promoting an abundance of smaller patches of fields (Dordas, 2009; Risch et al., 1983).

Biological Control in the Puget Sound Basin

Because the Snoqualmie Basin has a substantial agricultural community, there is ample opportunity to improve the use of biological control measures to assist farming practices. There are a number of resources available; The National Sustainable Agriculture Information Service provides both English and Spanish language information on sustainable farming, including pest management approaches. The Snoqualmie Basin is also home to Stewardship Partner's pilot "Salmon Safe" Program, which requires farm owners to adopt natural pest control methods and increase diversity (Stewardship Partners, 2010).

Water Quality and Waste Processing

Microorganisms in sediments and mudflats of estuaries, bays and nearshore areas break down human and other animal wastes (Weslawski et al., 2004). They can also detoxify petroleum products. The physical destruction of habitat, alteration of food webs, or overload of nutrients and waste products disrupts disease regulation and waste processing services. Changes to ecosystems can also create breeding sites for disease vectors where they were previously non-existent. People can be exposed to disease in coastal areas through direct contact with bacterial or viral agents while swimming or washing in fresh or saltwater, and by ingesting contaminated fish, seafood or water. The recent rise of cholera outbreaks in the southern hemisphere is associated with degradation of coastal ecosystems (UNEP, 2006).

The Puget Sound area has had several incidents of shellfish and beach closures due to red tide and amnesic shellfish poisoning in recent years. While the algae that cause toxic blooms are native to west coast waters, and toxic blooms can occur as natural events, there is evidence that increasing pollution loads and climate change exacerbate the conditions that lead to toxic blooms (Rabalais, 2005). Many areas in Puget Sound also have health advisories due to high bacteria counts from human and domestic animal waste, especially in late summer, and many shellfish harvest areas have been closed as a result (PSAT, 2007). Reduced access to beaches, fish and shellfish due to disease has obvious impacts to human health and economic activity in the Puget Sound counties.

Wetlands, estuarine macroalgae and nearshore sedimentary biota play a crucial role in removing nitrogen and phosphorous from water (Garber et al., 1992; Weslawski et al., 2004). The removal of these nutrients maintains offshore water conditions that are conducive to native fish and invertebrate biota. The rise of nutrient overload and hypoxic zones caused by a combination of agricultural run-off, failed septic systems and the dumping of fish carcasses have become a major issue in Hood Canal in recent years. Land use patterns also play an important role. Researchers have found that more agriculturally active and heavily urbanized watersheds contribute three times the nitrogen and phosphorous loads to the Puget Sound than the forested watersheds in the Olympic Mountains (Inkpen and Embrey., 1998).

Waste Treatment in the Puget Sound Basin

Water Quality in the Snoqualmie Watershed has remained relatively high, but there may be reason for concern as conditions change in the coming years. A 2009 report produced by King County, “Snoqualmie Water Quality Synthesis”, found that growing population, changing land use and climate change may all present threats to water quality. Population growth will require additional waste processing and sewage facilities, though it is possible that some natural management approaches could be used. Growing urban and rural populations will also add development pressure to wetlands, forests, and riparian areas. However, there are some positive trends as well. Agricultural land uses have diversified in recent years, moving away from historically common dairy farming, which may help water quality.

Thus far, nutrient inputs to the mainstem have been small enough that the River continues to meet state standards, though many sites occasionally exceed fecal coliform bacteria limits. A number of tributaries have consistent water quality problems, especially Kimball, Patterson, Ames, Cherry and Tuck Creeks. Problems include high temperature, excessive bacterial load largely due to livestock operations and septic system failures, low pH, and low dissolved oxygen. Some of the current conditions likely result from long-term changes in soil and drainage patterns resulting from past conversion of forest to agricultural land and logging practices. Still, the findings of the 2009 report support previous sections of this document: intact wetlands and forests are the best defense against water quality degradation. Local jurisdictions should place a premium on protecting these assets in perpetuity. They also reduce flooding and bank erosion while sustaining the aesthetic beauty of rural communities.

Supporting Services

Nutrient Cycling

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 in 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. It is living things that facilitate the movement of nutrients between and within ecosystems and which turn them from biologically unavailable forms, such as rocks or the atmosphere, into forms that can be used by others. Without functioning nutrient cycles, life on the planet would cease to exist. As plants and plant parts 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 they die. 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 (Vitousek et al., 1997).

The marine environment plays a central role in all major global nutrient cycles. Marine organisms fix nitrogen and take up carbon, phosphorous and sulfur from the water or from

other organisms. Much of the mass of these macronutrients is deposited in sediments where it is either stored for the long term or taken back up to surface waters by upwelling. The ability of marine environments to cycle nutrients can be negatively affected but nutrient overloads, which result largely from human actions that cause water pollution such as fertilizer runoff.
The removal of forests, riparian areas and wetlands has had a significant effect on nutrient cycles. 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 occurred as a result. The number of marine dead zones in the world has doubled every decade since the advent of nitrogen fertilizers after World War II (UNEP, 2005). The presence of these dead zones is a clear indication that global nutrient cycles have been severely altered by human actions.

Nutrient cycling is a supporting service because many other services depend on it. Given that ecosystem productivity would cease without it, production is impaired when these cycles become significantly altered. Nutrient cycling is a fundamental precursor to ecosystem and economic productivity. This fundamental role cannot be fully substituted by human-made solutions, and operates at multiple, overlapping scales, so it is difficult to arrive at an accurate economic value for this service, and it is often undervalued (Farber et al., 2006). Given that nutrient cycling is fundamental to the operation of life on the planet, it is important that biological science inform policy that will protect this critical service.

Soil Formation

Soil is formed over thousands of years through a process that involves parent material, climate, topography, organisms and time. Soil quality and abundance is critical for human survival, yet human actions can also affect nature's ability to provide high quality soils (USDA-SCS, 1983). Soil should be considered a capital asset providing a suite of benefits into the future depending on the health and abundance of the soil.

Soil Formation in the Puget Sound Basin

There are five significant factors in soil formation:

- Parent material is for the most part chemically weathered mineral or organic matter that contributes to soil formation. In Snohomish and King Counties, most of the soil was formed from deposits of glacial drift, though some was deposited by till, outwash and material mixed with volcanic ash.
- Topography affects soil formation by changing the drainage and surface flow of rain and runoff. The slope of the land, the ways in which topography dictates water flows and absorption, and solar evaporation are all examples of ways in which topography can relate to soil formation and soil characteristics.
- Living organisms contribute to soil formation as they decompose. Plants, microorganisms, earthworms, insects, fungi and other life forms contribute organic matter and nitrogen. The type of plants in an area can determine characteristics of the soil. Animals contribute less to this process, but earthworms, insects and small animals assist with soil aeration and deposit nutrients.
- The climate in Snohomish County has three distinct zones: Western (lower elevation, lower precipitation, a high period of frost-free days and a mean temperature of 55 degrees F), Central (elevation ranging from 800 – 1,800 ft, slightly more precipitation, fewer frost free days and an average air temperature of 45 degrees F) and the Eastern (elevation above 1,800 ft, high annual precipitation, short frost-free period and mean annual air temperature is 42 degrees F.) The amount of precipitation and the air temperature are primary factors in the climate's influence on soil formation processes. Because of the colder temperatures and higher precipitation in the Eastern area, soils have a distinct surface layer and subsurface layer.
- Time is absolutely essential to soil formation. In the Snohomish area, soil-forming processes began following glacial melting, around 12,000 years ago. Some types of soils develop more slowly than others, but all develop over the course of thousands of years.

Biodiversity and Habitat

Puget Sound Basin is home to a rich diversity of species and ecosystems. Biological diversity is defined as the number and types of species and the ecosystems they comprise. It is measured at gene, population, species, ecosystem and regional levels (Magurran, 1988). For all ecosystems, biodiversity is both a precondition of the flow of ecosystem services and an ecosystem service in itself (UNEP, 2006). It is a precondition because ecosystems, with their full native complement of species, tend to be more productive and more resilient to change in environmental conditions or external shocks. Biodiversity is also an ecosystem service in itself because novel products have been derived from genetic and chemical properties of species, it provides a secure food base (multiple sources of food with different seasonal availability), and people ascribe value to it simply for its existence.

Habitat is the biophysical space and process in which wild species meet their needs – a healthy ecosystem provides physical structure, adequate food availability, appropriate chemical and temperature regimes, and protection from predators. Habitat may provide refugium and nursery functions; a refugium refers to general living space for organisms, while nursery habitat is specifically habitat where all the requirements for successful reproduction occur (De Groot et al., 2002). In addition to the physical structure provided to species, food web relationships are important components of habitats that support all species. For instance, food webs based on

kelp and eelgrass beds provide the conditions necessary for salmon, crab, sea cucumbers and sea urchins – all commercially important species in the Puget Sound (Mumford, 2007).
A recent assessment found that there are at least 7,013 species, including animals (vertebrate and invertebrate), flowering plants, fungi and marine algae in the habitat types of the Puget Sound Basin (CFBD and FSJ, 2005). Given that little is known about some invertebrates and most microorganisms, the total is likely much higher. Western Washington forests are home to 82 species of mammals, 120 bird species, 27 amphibian species, 14 reptile species (Olson et al., 2001) and several thousand invertebrate species including fresh water mussels, insects and arthropods (FEMAT, 1993). All seven species of salmonids found in the Puget Sound use forested streams and rivers for part of their life cycle. Many forest species depend on, or are at their highest abundance, in late-successional or old growth forests (FEMAT, 1993).

Habitat areas in the Puget Sound Basin have widely suffered degradation due to development, conversion from a natural to a heavily managed type, logging, pollution or the impact of invasive species (Buchanan et al., 2001; Olson et al. 2001). Toxic and biological pollution continue to pose a threat to nearshore and pelagic habitats and their associated species in the Puget Sound (PSAMP and PSAT, 2007).

A recent meta-analysis of marine data and studies examining the effects of biodiversity on ecosystem services found strong evidence that loss of biodiversity leads to fisheries collapse, lower potential for stock and system recovery, loss of system stability, and lower water quality. The relationship is one of an exponential loss of ecosystem services with declining diversity (Worm et al., 2006). In contrast, Worm et al. also found that restoration of biodiversity, including the establishment of marine reserves protected from fishing pressures, leads to a fourfold increase in system productivity and a 21% decrease in variability (i.e., an increase in stability). This study provides the best evidence to date of the direct relationship between biological diversity and ecosystem services in the marine environment.

At a global scale, the loss of biodiversity in all ecosystems through over-harvest, habitat degradation and loss has been substantial in marine and coastal ecosystems, forests, grasslands and agricultural systems. This has large implications for maintenance of ecosystem services. Over-fishing and habitat loss have affected Puget Sound's fish stocks; urbanization and industrial development have led to the loss of large portions of historical forest and wetland cover; pollution and land loss from residential and commercial development continue to threaten the continued persistence of many species and ecosystems. There are currently 17 species listed as federally threatened or endangered that live in the Puget Sound Basin, though the Center for Biodiversity (2005) estimates that there are at least 285 species that are critically imperiled.

Habitat contributes significantly to other ecosystem services, namely, fisheries, recreation through wildlife watching, and cultural or spiritual values, which are often expressed though people's willingness to pay for protection of natural areas and through public or private expenditures on acquiring and protecting habitat.

Biodiversity and Habitat the Puget Sound Basin

The US Fish and Wildlife service lists species as “endangered” or “threatened,” in order to assure protection of these species under the Endangered Species Act. In the Snoqualmie Basin, listed species that are likely present include bald eagles, Chinook salmon, bull trout, steelhead, northern spotted owls and marbled murrelets.

Primary Productivity

Primary productivity is another supporting service upon which all other ecosystem services depend. It refers to the conversion of energy from sunlight into forms that living organisms use. Marine and land plants perform this function, using the sugars that are products of photosynthesis for their own respiration. Human life depends directly on primary productivity through consumption of crops, wild plants, seaweed, fish and seafood, and livestock.
In the past, we depended mainly on the direct energy flow from food consumption to survive. Then we used the help of draft animals and simple machines. At the onset of the industrial age, humans increasingly depended on fossil fuels, which are ancient stored energy from photosynthesis. Since humans started to perform work with the use of fossil fuels, the number of people and amount of consumption has far exceeded what would have been possible just by operating on current energy flows. Humans appropriate over 40% of the planet’s terrestrial primary productivity. This share is increasing – with massive ecological implications for the rest of planet’s organisms and energy budget (Vitousek, 1986). One likely consequence is a loss of biological diversity, which, as discussed above, would have severe consequences on the delivery of many other ecosystem services.

About 8% of total primary productivity of ocean ecosystems supports human fisheries. However, when the calculation is confined to parts of the ocean where most primary productivity and fish catches occur, the number approaches the productivity of terrestrial systems, 25-30% (Pauly and Christensen, 1995; Pimm, 2001). Again, if humans consume most ocean primary productivity in the form of fish and seafood, not much will be left to fuel the remainder of the food web and all the ecological processes that it drives (Pimm, 2001).

Terrestrial primary productivity comes mainly from forests, but ecosystem types such as grasslands and meadows also contribute, although at a much lower rate. Loss of forests to development decreases primary productivity. Such loss is an issue in the Puget Sound Basin, especially in the suburbanizing fringe.

Marine primary productivity comes from wetland plants, macroalgae and sea grasses in the coastal and near shore environment, and from phytoplankton in the continental shelf and deep-sea waters. Most marine primary productivity occurs in the coastal zone out to the farthest extent of the continental shelf. Due to changes in currents, upwelling and changes in water chemistry, which may affect the ability of diatomaceous phytoplankton to form calcerous shells, climate change has large implications for ocean productivity (Orr et al., 2005).

Cultural Services

Aesthetic
Aesthetic value, as an ecosystem service refers to the appreciation of, and attraction to, beautiful natural land and seascapes (De Groot et al., 2002). The existence of National Seashores, State and National Parks, Scenic Areas, and officially designated scenic roads and pullouts attest to the social importance of this service. There is also substantial evidence demonstrating the economic value of environmental aesthetics through analysis of data on housing markets, wages and relocation decisions (Palmquist, 2002). Puget Sound's islands, rocky beaches, and views of water, forests and mountains, are of major importance to the cultural and economic character of the region. There is also evidence substantiating the view that degraded landscapes are associated with economic decline and stagnation (Power, 1996).

Recreation and Tourism
Ecosystem features like biological diversity and clean water attract people to engage in recreational activities, and can also increase property values or attractiveness for business. Tourism and recreation are related to, but not totally encompassed by, aesthetic values. People travel to beautiful places for vacation, but they also engage in specific activities associated with the ecosystems in those places.

Recreational fishing, scuba diving, surfing, kayaking, whale and bird watching, hunting, enjoying local seafood and wines, and beachcombing are all activities that would not occur or be thoroughly enjoyed without intact shorelines, healthy fish and wildlife populations, and clean water.

Storm protection, shoreline stabilization and waste treatment are also important ecological services associated with recreation and tourism because they help keep tourists safe and protect both private and public infrastructure needed for the tourism industry.

Tourism and recreation, significant parts of nearly all coastal economies throughout the world, are both a blessing and a curse. Development designed to attract tourists has been a major source of degradation in coastal environments, causing water quality and habitat degradation. Too much recreational fishing pressure and too many whale-watching boats can also put excessive pressure on the species that attract people in the first place. The concept of ecotourism has arisen in part to deal with these issues. It is, however, an incomplete solution to date.

Recreation and tourism are, like aesthetics, an important part of the link between ecosystem services and the Puget Sound's economy. The Department of Ecology valued the tourism revenue generated annually in the Puget Sound region to be $9.5 billion (2008). More than half of recreational salmon that are caught in Washington State are from Puget Sound (Puget Sound Partnership, 2007).

Recreational fishing brings in substantial revenue to the state (approximately $854 million in 2001 according to the Washington Department of Fish and Wildlife (2002)), and thus to the Puget Sound area. Healthy, fishable salmon populations are therefore important to the tourism economy. Scuba diving, kayaking, bird watching, hiking, climbing and nature photography draw people, both residents and visitors, to the natural areas of the watershed.

The Washington Department of Fish and Wildlife calculated that wildlife watching in Washington State brought in $980 million in 2001 (WDFW, 2002). It is interesting to note that in the year for which these spending statistics were reported, non-consumptive wildlife viewing accounted for more than double the expenditures for hunting, and exceeded spending on recreational fishing by nearly $130 million. Although not all of this spending occurred in the Puget Sound Basin, statistics on the proportion of overall tourism revenue generated in Washington that comes from Puget Sound indicates that more than half of this was likely spent in the region.

The State of Washington has also invested in ensuring that people have public access to the 35 State Parks located in the region. Washington does not charge users fees for these parks, indicating that it is willing to spend considerable fiscal resources to support outdoor recreation.

While teasing out the direct monetary contribution of the ecosystems themselves to the recreation and tourism economy, there is no doubt that attractive landscapes, clean water, and healthy fish and wildlife populations provide a necessary underpinning to this sector of the economy. Several studies of nature-related recreation are included in the ecosystem service value analysis described below.

Aesthetic and Recreation Values in the Puget Sound Basin

The aesthetic value of the Snoqualmie Valley plays a big part in attracting and retaining residents, even in the face of regular flooding (Catchpole and Geggel, 2009b). Snoqualmie Falls alone is estimated to attract 2.2 million visitors each year, making it the second most-visited attraction in Washington State after Mount Rainier (City of Snoqualmie, 2009). People visit throughout the year, engaging in activities such as skiing, hiking, kayaking and fishing (Snoqualmie Valley CoC, 2010). The Valley's natural and social capital give it even greater potential as a tourist destination, and King County is eager to promote it more actively as a place to stay (Catchpole, 2010).

The population explosion in the City of Snoqualmie is a testament to this popularity. Between 2000 and 2009, thanks to an increase in available housing, the city's population grew by 496.6%, making it the fastest growing city in Washington State for that period (PSRC, 2009).

Scientific and Educational

Ecosystems are the subject of much scientific study for both basic knowledge and for understanding the contribution of functioning ecosystems to human wellbeing. The number of educational and research institutions devoted to studying marine and terrestrial environments shows the scientific and educational importance of ecosystems. Government, academic and private resources are all devoted to formal study of ecosystems in the Puget Sound Basin. Such pursuits benefit people through direct knowledge gained for subsistence, safety and commercial purposes. The study of natural systems is also an important intellectual pursuit for helping people understand how complex systems work. Scientific and educational institutions devoted to both marine and terrestrial environments also provide locally significant employment. These institutions include Batelle Northwest, University of Washington Biology and Forestry schools, The Pacific Northwest Research Station of the U.S. Forest Service and NOAA Pacific Fisheries Science Center.

Scientific and Educational Values in the Puget Sound Basin

The Snoqualmie Basin generates significant employment for scientific monitoring, research, educational and restoration activities. For example, salmon and stream restoration projects bring in federal, state, county and private funding, while educating the broader community in the science and value of healthy streams. The valley is also providing important insights into flood control management, as a part of the King County Flood Control District. The area is effectively a "living laboratory" for flood control measures, and the high frequency of flood disasters has forced King County to develop one of the nation's most progressive flood management strategies (King County DNRP, 2010). Insights gained here will not only save money for residents of the Snoqualmie Basin in the future, but will also gain statewide and international attention if they succeed, helping other jurisdictions to reduce the costs involved in flood protection.

Spiritual and Religious

Ecosystems and their components play a role in the spiritual beliefs of people. These values do not lend themselves well to economic quantification. Other aspects of the linkage between ecosystem and culture include the spiritual significance that individuals and societies place on nature, and the scientific and educational value derived from studying natural systems. The watershed is especially important to the Snoqualmie Tribe from a spiritual perspective, as evidenced by their traditions around salmon and other marine organisms, and by their art and stories. People of non-native American ancestry also often have spiritual values for nature expressed in many ways. There is no method for establishing a complete dollar value for spiritual value. The value for "my way of life" may be incommensurable with a dollar value. That is, these are two fundamentally different valuations, such as weight and length. They simply cannot be expressed in a common unit. However, partial valuation of some spiritual values may be possible and established through willingness to pay surveys for existence value for spiritual appreciation, ranking this spiritual value against material choices.

Spiritual and Religious Values in the Puget Sound Basin

A number of natural features within the Snoqualmie Basin are linked to the creation stories of Snoqualmie Tribe.

Ecological Economics

The field of economics was heavily influenced during the industrial revolution, and grew to focus on increasing the production of manufactured goods and built capital above all else. This approach has yielded a highly productive market system for manufactured capital, which we measure using Gross National Product (GNP). However, it is generally agreed that there are many things that we care about beyond manufactured products. In fact, a great deal of research suggests that things like leisure time, equality and healthy relationships with other people are much more important to happiness (Easterlin 1974; 1995; Graham 2005). Traditionally, economics has provided a poor measurement of human, social and natural capital productivity. Built capital and labor have been the primary "factors of production." Land and other resources are only occasionally included in economic analysis. Figure 1A provides a sketch of this perspective.

Figure 1A. Model of the Economy that Excludes Natural Capital

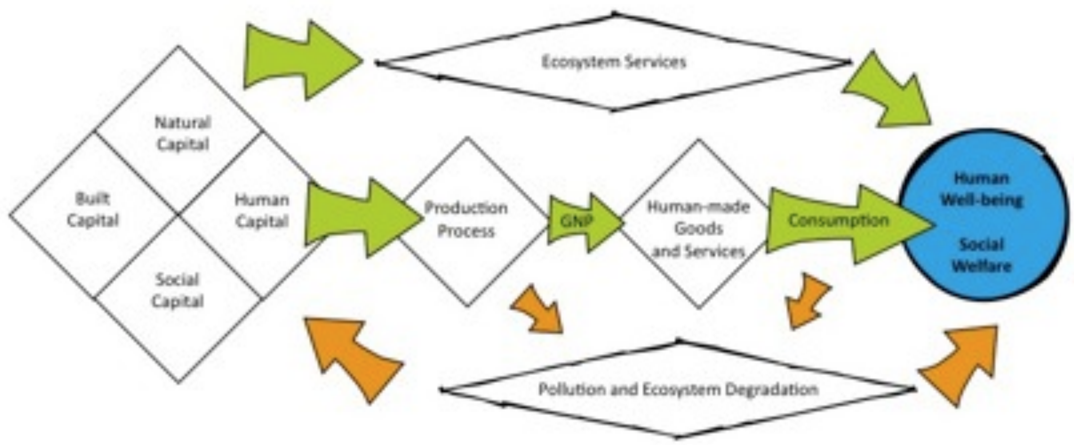
Adapted from Costanza et al. 1997a

As natural capital has become scarcer, increasing attention and research has been aimed at developing alternative economic approaches. In 2001 Joseph Stiglitz, George Akerlof and Michael Spence won the Nobel Prize in Economics for their work examining some of the imperfections in market economies, often overlooked by traditional economics.

One reason that natural capital is often ignored is the fact that it is often thought of as something that human-built alternatives can replace. In many cases, however, built capital cannot replace natural capital. When water becomes polluted and natural systems are not available to filter it, it is possible to build a water filtration plant. However, if diverse salmon populations become extinct, their genetic variance will be lost forever.

This report focuses on the contribution of natural capital to the Puget Sound economy. While we will discuss built, human and social capital assets in the watershed, we will not estimate their value. Figure 2A illustrates a more robust vision of the economy, which takes all four capitals into account.

Figure 2A. Ecological Economic Model of the Economy



Adapted from Costanza et al. 1997a

When salmon were thought to be unlimited, rights to salmon seemed unimportant. However, as dams, overfishing, loss of nearshore habitat and other factors reduced salmon populations, and technology and human population increased, there was a shift from an empty world scenario to a full world scenario. Sustainability of salmon catches, something no one worried about in past decades, is now a crucial question. As salmon, water, timber, flood control and other ecosystem services become scarcer, they become more valuable.

Unlike a factory that produces a single product, like a car or toy, watersheds produce a full suite of goods and services. This is both highly productive and economically complex. Thus, it is important that the Snoqualmie Watershed has the right institutions to help guide responsible watershed planning.

Appendix B. Valuation of the Puget Sound Basin Ecosystem Services

The economy of the Puget Sound Basin cannot be understood without examining the contribution of natural capital and its associated flows of ecosystems services to the economy and well-being of people. Our economy and communities reside within the landscape as part of the environment. However, most decisions are made without considering the explicit contribution of functioning ecosystems to economic activity and output. Interest in identifying, describing and quantifying the economic value of ecosystem services has grown tremendously over the past 20 years, expressly for the purpose of improving environmental decision making (Daily 1997; Costanza et al. 1997b; Balmford et al. 2002). This is particularly relevant for coastal areas. Rough and preliminary estimates of the global economic value of coastal and nearshore marine ecosystems demonstrated that two-thirds of the total ecosystem service value of all systems on earth come from coastal and marine systems (Costanza et al., 1997b; Costanza, 1999). Understanding the nature of this economic value and how it changes with ecosystem restoration or degradation is also crucial because coastal systems are under great development and extraction pressure relative to other biomes (UNEP, 2005).

Ecosystems produce goods and services. Ecosystem goods like fish or trees can be excludable and amenable to market pricing while ecosystem services like the production of climate protection, or hurricane storm protection are public services, non-excludable, and not amenable to market pricing. Markets for fish and timber can exist because people can be excluded; once a fish is caught, nobody else can catch that same fish. Markets for breathable air cannot exist because people cannot be excluded from breathing air. In addition, breathing air is not rival; a person's breathing does not restrict another's breathing. Roads are rival; we all have equal access to roads, however, having too many people on the road restricts its effective use. Air is neither excludable (cannot be owned) nor rival (everyone can breathe the air). Every specific ecosystem good or service has special physical qualities which determine if it is an excludable or rival good or service and how well market valuation fits the nature of that service.

Ecosystem functions and the services they produce are diverse and operate across large landscapes (storm buffering) or, in some cases, the whole planet (carbon sequestration). Highly interdependent physical and biological systems make life, and economic life, on the planet possible – the operation of climate, oxygen production, nutrient cycles, water and energy flows, the movements of seeds, pollen, and pollinators, the distribution of different types of plants and soils, biodiversity, and the availability of decomposer organisms, such as bacteria, to clean up natural waste products. Oceans operate in a similar way with some organisms spanning large parts of the globe, and ocean nutrient cycles taking place over very large spaces and long time frames.

Because ecosystems provide a tremendously valuable, wide variety of common wealth, public goods and services at the lowest cost over long periods of time, they are the best systems for producing these goods and services. It would be impractical, and in some cases impossible and simply undesirable, to replace these economically valuable natural systems with more costly and less efficient built capital substitutes.

Valuing services which are "public goods" that are not excludable and thus unmarketable, but do contribute to our common wealth, is difficult. However, a number of techniques have been developed to derive economic values for ecosystem services.

Valuation Techniques

Ascribing economic value to these ecosystem services helps policy makers and the public decide how to allocate public funds for the common good upon which private wealth depends (Costanza, 2006). Ecosystem goods and services may be divided into two general categories: market and non-market. Measuring market values simply requires monitoring market data for prices and quantities sold. This production creates a flow of ecosystem goods that have a market-defined economic value over time.

Non-market values of goods and services are more difficult to measure. When there is no explicit market for services, more indirect means of assessing values must be used.

The valuation techniques that were used to derive the values in the database were developed within environmental and natural resource economics. As Table 1B indicates, these techniques include direct market pricing, replacement cost, avoided cost, factor income method, travel cost, hedonic pricing and contingent valuation.

Table 1B. Valuation Methodologies

Avoided Cost (AC): services allow society to avoid costs that would have been incurred in the absence of those services; storm protection provided by barrier islands avoids property damages along the coast.
Replacement Cost (RC): services can be replaced with man-made systems; nutrient cycling waste treatment provided by wetlands can be replaced with costly treatment systems.
Factor Income (FI): services provide for the enhancement of incomes; water quality improvements increase commercial fisheries catch and the incomes of fisherfolk.
Travel Cost (TC): service demand may require travel, which have costs that can reflect the implied value of the service; recreation areas can be valued at least by what visitors are willing to pay to travel to it, including the imputed value of their time
Hedonic Pricing (HP): service demand may be reflected in the prices people will pay for associated goods, for example housing prices along the coastline tend to exceed the prices of inland homes.
Marginal Product Estimation (MP): service demand is generated in a dynamic modeling environment using a production function (Cobb-Douglas) to estimate the change in the value of outputs in response to a change in material inputs.
Contingent Valuation (CV): service demand may be elicited by posing hypothetical scenarios that involve some valuation of alternatives; for instance, people generally state that they are willing to pay for increased preservation of beaches and shoreline.
Group Valuation (GV): this approach is based on principles of deliberative democracy and the assumption that public decision making should result, not from the aggregation of separately measured individual preferences, but from *open public debate.*

Adapted from Farber et al 2006

Table 2B. Appropriateness of Valuation Methodologies for Ecosystem Service Type

Ecosystem Service	Amenability to Economic Valuation	Most Appropriate Method for Valuation	Transferability Across Sites
Gas regulation	Medium	CV, AC, RC	High
Climate regulation	Low	CV, AC, RC	High
Disturbance regulation	High	AC	Medium
Biological regulation	Medium	AC, P	High
Water regulation	High	M, AC, RC, H, P, CV	Medium
Soil retention	Medium	AC, RC, H	Medium
Waste regulation	High	RC, AC, CV	Medium to high
Nutrient regulation	Medium	AC, RC, CV	Medium
Water supply	High	AC, RC, M, TC	Medium
Food	High	MP	High
Raw materials	High	MP	High
Genetic resources	Low	M, AC	Low
Medicinal resources	High	AC, RC, P	High
Ornamental resources	High	AC, RC, H	Medium
Recreation	High	TC, CV, ranking	Low
Aesthetics	High	H, TC, CV, ranking	Low
Science and education	Low	Ranking	High
Spiritual and historic	Low	CV, ranking	Low

Tables 1B and 2B show that each valuation methodology has its own strengths and limitations; often restricting its use to a select range of ecosystem goods and services within a given landscape. For instance, the value generated by a naturally functioning ecological system in the treatment of wastewater can be estimated by using the replacement cost (RC) method which is based on the price of the cheapest alternative for obtaining that service (the cost of chemical or mechanical alternatives). Avoided cost (AC), which is a related method, can be used to estimate value based on the cost of damages due to lost services. This method was used to value the flood protection services provided by restored habitats and functions within the flood plain. Travel cost (TC) and contingent valuation (CV) surveys are useful for estimating recreation values while hedonic pricing (HP) is used for estimating property values associated with aesthetic qualities of natural ecosystems. Contingent valuation surveys and conjoint analysis can be used to measure existence value of ecosystems and charismatic animals. Marginal product estimation (MP) has generally been used in a dynamic modeling context and aids in examining how ecosystem service values change over time. Finally, group valuation (GV), a more recent addition to the valuation literature, directly addresses the need to measure social values in a group context. In many applications, the full suite of ecosystem valuation techniques will be required to account for the economic value of goods and services that a natural landscape provides. Note from the tables above that not all ecosystem services are readily valued and that some services have no valuation studies. Very important services such as climate regulation, genetic resources, and spiritual and historical significance, are of great value but have low valuation amenability. In addition, nutrient cycling as a basic supporting service usually receives relatively low values even though life on the planet would not be possible without it (UNEP, 2005). Because traditional economic valuation is based on marginal market values, valuation methodologies are not well suited to the valuation of natural systems that provision essential goods and services freely.

Conducting an "Appraisal" of our Natural Capital

While original studies are desirable for context and accuracy, such data are often simply not available within the desired time frame. Conducting original empirical work for all services and all ecosystem types in a study area would entail over 100 primary ecosystem service valuation studies and would be cost prohibitive. This study is intended to emphasize the importance of filling critical informational gaps in ecosystem service valuation. Greater primary research over the next few years will enable a sharper understanding of Puget Sound ecosystem services.

To address the difficulty of conducting primary evaluations for each study area, economists use a methodology that is similar to a house appraisal and is called value or benefit transfer (see below for a more detailed discussion of this method). The market value of a house before it is sold is not known. To estimate the value, an appraisal is conducted to determine a likely range of values. Appraisals are based on established values of other houses that are close by and share similar attributes. The particular aspects of the house, such as a good roof, the number of bedrooms, a finished basement, and a mountain view, are also considered in the appraisal. These attributes comprise additive values for estimating the appraised value of the house.

Similarly, a value transfer study uses values derived from studies of similar ecosystem types; the closer to the study site in location and attributes the better. However, studies from other parts of the country or world can be used to estimate the values in the target study area. More studies from distant areas broaden the low-high range estimate of values. Called the benefit transfer method, this is done by conducting a careful analysis of economic values for the appropriate ecosystem type, determining applicability to the target area, converting values to common units – usually dollars per acre per year – then applying them to acres of ecosystem type based on GIS analysis.

The wide ranges of value that can emerge from these studies and other issues involving incommensurability have resulted in a vigorous discussion in the academic literature on the use of benefit-transfer methods (see e.g., Wilson and Hoehn, 2006; and Spash and Vatn, 2006). While these studies have limitations, they provide valuable information in the appropriate context. The purpose of estimating ecosystem services is to provide a better valuation than the implicit value of zero. Estimates from value transfer studies have inherent uncertainty. By using the lowest estimates and the highest in the literature, a range of values are provided that should capture the value of the ecosystem services examined in the study area. The low valuation boundary, as in this case, are underestimates of actual value; they can demonstrate that ecological services in an area are worth at least a certain dollar amount which is usually sufficient to inform policy decisions such as restoring or maintaining those systems.

In addition, economic values are not the sole decision-making criteria. Techniques called multi-criteria decision analysis are 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.

There are also social issues involved with the entire exercise of assigning monetary values to nature. Discussions of the economic value of ecosystem services are often laden with concerns of privatizing nature (e.g., McCauley, 2006) or worries that the act of putting dollar values on what ecosystems do will lead private landowners to demand payments for the services their lands provide without regard for wider social or legal obligations. It is important to frame the discussion of ecosystems and their services with an analysis of both the ecological economic and legal underpinnings of ecosystem services as public and/or common property resources (Barnes, 2006). Understanding that ecosystems have economic value does not mean that ecosystem services can or should be privatized. In fact, because most ecosystem services are non-excludable, public goods by nature (or by definition), they simply cannot be privatized and must fall under the remit of public institutions.

Perhaps most importantly, financial and investment decisions that are denominated in dollars are constantly being made, thereby allocating public and private money and resulting in a profound impact on natural capital systems and ecological and economic productivity. Establishing a range of value with the best available valuation methodology allows for the more effective inclusion of natural capital in budgetary, financial, and investment decisions.

Valuation of ecosystem services in Washington State is a relatively new field. There are few studies. Individual valuation studies are the basis for understanding how value is provided from a land cover type to people. These studies give a glimpse of value and are not comprehensive. The valuation of flood protection provided by wetlands, for example, (Leschine et al., 1997) examines the value of wetlands in urban and rural areas. In Lynnwood, WA a community just north of Seattle, only 2% of wetlands are left; they are scarce and those left provide important services and are of greater value per acre than more abundant wetlands in upland areas. Leschine et al. assess the value these urban wetlands at between $36,000 in Lynnwood and $51,000 in Renton, a community just south of Seattle. Wetlands in North Scriber Creek, a more rural area, range from $8,000 to $12,000/acre. This study describes one vegetation type and one ecosystem service. A compilation of studies across different vegetation types and ecosystem services is required to understand the value of flood protection provided in a watershed composed of forests, grasslands, agricultural areas, urban land and wetlands. This is only representative of a number of studies that have been conducted in the Northwest on ecosystem services.

Currently, benefit transfer offers an imperfect but workable methodology for deriving an “appraisal” of the value of natural capital. This is a static approach, a snapshot of valuation at a specific time, with a set of GIS data and valuation studies. A dynamic systems analysis, such as that being developed by the University of Vermont Gund Institute (MIMES Project), in partnership with Earth Economics, promises to provide dynamic modeling directly connected to physical data. This allows an examination of change in physical conditions and changes in value over time. Scenarios with or without restoration can be examined. It also allows spatially explicit mapping of ecosystem services, the mechanics of their provisioning and the systems delivering these services to beneficiaries.

In the development of another methodology, Earth Economics is currently co-principle with the University of Vermont Gund Institute For Ecological Economics (ARIES Project) on a National Science Foundation Grant. The ARIES Project examines methodologies for linking studies that show the differences in the provisioning of flood services spatially across the landscape, and how to utilize the diversity of information provided by valuation studies in conjunction with GIS information systems and an "ontology" or understanding of how these ecosystem services are provisioned.

Another project, the Natural Capital Project, also seeks to map the provisioning of ecosystem services and the beneficiaries across the landscape.

The Puget Sound Nearshore Partnership produced several reports outlining benefits Puget Sound ecosystems provide. Leschine and Petersen (2007) provide a discussion of "valued ecosystem components" which incorporate aspects of social, cultural, spiritual, ecological and economic values. They also provide a discussion of ecosystem services and valuation techniques.

The fact remains, that there is a dearth of data (Plummer, 2007), analysis and methodology for accurately calculating the value of most natural capital, particularly services for which there are no markets.

Value Transfer Methodology

This study used the value transfer methodology which takes the results of previous studies, screens them for appropriate fit, then applies them to a target site which has very little or no coverage from original empirical studies (Devouges et al. 1998; Loomis, 1992). It is often the only feasible approach to a comprehensive valuation of ecosystem services in an area, due to limitations of time and funds. Conducting all new empirical research for all ecosystem types and services in a particular region, especially an area as large and as diverse as the Puget Sound Basin, would take millions of dollars and many years to complete. Since it can be used to reliably estimate a range of economic values associated with a particular landscape, based on existing research, for considerably less time and expense than a new primary study, the value transfer method has become a very important tool for policy makers in the US and other countries.

Value transfer studies of large landscapes like the entire Puget Sound Basin by necessity aggregate peer reviewed valuation estimates using all or most of the techniques described in Tables 1B and 2B. This is because such a large landscape will encompass many types of ecosystem services and not all services can be ascribed economic value using the same techniques or even family of techniques.

Using Geographic Information System (GIS) data for the Puget Sound Basin, the acreages of forest, grass and shrub, agriculture and pasturelands, wetlands, urban areas, lakes, ponds, rivers and streams, marine and estuarine waters, eel grass, and ice and rock were multiplied by the estimated value production per acre, where reasonable values could be found, for each identified ecosystem services. Peer reviewed journal articles were reviewed for each GIS classification and the values associated with each ecological service. The high and low values for each ecosystem type and ecological service were selected to provide the high and low range estimates. A benefit transfer methodology was applied to the GIS data to calculate a range of dollar values of ecosystem services provided annually within the Puget Sound Basin.

One of the most comprehensive value transfer studies in the United States was recently conducted for the State of New Jersey (Costanza et al., 2007). The authors conducted a thorough literature review of valuation studies, screened them for appropriate demographic and economic variables, and converted all values to 2004 dollars per acre per year. They focused on 10 ecosystem services for which empirical studies were available and that are non-market in nature (as data is readily available for ecosystem goods which are sold in markets).

This study of the Puget Sound ecosystem services also applied the approach used by Costanza et al. (2007) and used the values published therein as a base point (in dollars per acre per year). Studies specific to ecosystems of the Pacific Northwest and Puget Sound that were not included in the New Jersey study were added here. Studies that were not appropriate to the Puget Sound were screened out. Low and high estimates are provided to give the range of variation on estimates for each ecosystem cover type and service combination. While this low and high range in estimates of ecosystem service values reflects the innate uncertainty in applying value transfer, it also provides a reasonably robust result.

Because this is a meta-study, utilizing many valuation studies, we do not know the cumulative shape of the error. However, both the low and high values established are likely underestimates of the full value of ecosystem services provided within the Puget Sound basin because values for most ecosystem services have not been estimated. In addition, for those ecosystem services for which we estimate a value, most have not been estimated across all vegetation types. Omission is still the greatest hurdle, and likely the greatest source of error in the valuation of ecosystem services.

The lower value boundary represents a “below the floor” value for natural capital and carries a great deal of confidence. It can be an important guidepost for policy.

To calculate the entire range of estimated values, the full list of estimated values available in the literature for a particular cover type/ecosystem service combination was reviewed. Many individual valuation studies include low and high estimates. All the lowest estimates from each list of studies for each ecosystem service within a cover type were totaled to provide a low estimate with the same procedure to establish the high estimates. The estimates were not averaged. This approach results in a larger range than would be the case if all low (high) estimates within a cover type ecosystem service combination were first averaged prior to aggregating across ecosystem services within a cover type, however it better reflects the underlying uncertainty.

All studies from which estimates are derived were from temperate zone ecosystems and high-income countries. In this way, estimates from ecosystem types with very different ecological parameters (e.g., tropical versus temperate forests) or from countries with very different income demographics (industrialized versus non-industrialized) were excluded. Almost all of the studies were conducted in the United States. Appendix C lists the studies used for the value transfer estimates. All values were standardized to 2006 dollars using the Bureau of Economic Statistics Consumer Price Index Inflation Calculator.

Appendix C. Low and High Values of Ecosystem Services

Ecosystem Service	Land Cover	Author(s)	Minimum	Maximum
Gas & Climate Regulation	Wetland	Dodds, W.K., et al. 2008	$121.79	$121.79
		Roel calculation for LA	$31.32	$284.58
	Grasslands	Copeland et al. (in press) (Calculated 1994)	$0.06	$0.06
		Costanza et al. 1997	$4.10	$4.10
		Fankhauser and Pearce (1994)	$4.05	$4.05
	Shrub	In house calculation	$6.60	$66.30
		local estimate	$7.77	$78.00
	Urban green space	Birdsey, R.A.	$216.49	$216.49
		McPherson, E. G. 1992	$186.62	$930.90
		McPherson, E. G., Scott, K. I. and Simpson, J. R. 1998	$28.53	$28.53
	Pole Forest	In house calculation	$24.04	$464.33
	Mid Forest	In house calculation	$34.34	$663.37
	Late/Old Forest	In house calculation	$46.35	$895.47
	Riparian Forest (pole)	In house calculation	$24.04	$464.33
	Riparian Forest (mid to late)	In house calculation	$46.35	$895.47
Water Regulation	Wetland	Thibodeau, F. R. and Ostro, B. D.	$6,765.49	$6,765.49
	Grasslands	Costanza et al. 1997	$1.76	$1.76

		Jones et al. (1985) (Calculated 1992)	$2.16	$2.16
	Urban green space	Birdsey, R.A.	$181.85	$181.85
		McPherson, E. G. 1992	$6.09	$6.09
	Pole Forest	In house calculation	$10.23	$10.23
	Mid Forest	In house calculation	$10.23	$10.23
	Late/Old Forest	In house calculation	$10.23	$10.23
	Riparian Forest (pole)	In house calculation	$10.23	$10.23
	Riparian Forest (mid to late)	In house calculation	$10.23	$10.23
Genetic Resources	Grasslands	Perrings (1995) (Calculated 1992)	$0.01	$0.01
Aesthetic & Recreational	Wetland	Allen, J. 1992	$109.98	$9,946.87
		Dodds, W.K., et al. 2008	$1,662.36	$1,662.36
		Doss, C. R. and Taff, S. J.	$4,456.50	$4,923.49
		Hayes, K. M., Tyrrell, T. J. and Anderson, G. 1992	$1,290.63	$2,466.77
		Mahan, B. L., Polasky, S. and Adams, R. M.	$36.98	$36.98
		Thibodeau, F. R. and Ostro, B. D.	$33.49	$698.43
		Whitehead, J. C.	$1,111.66	$2,235.11
	Salt Marsh	Anderson, G. D. and Edwards, S. F. 1986	$22.19	$103.82
		Bergstrom, J. C., et. al. 1990	$15.66	$25.31
		Farber, S. 1987	$5.19	$5.19
	Shrub	Bennett, R., et. al.	$179.98	$179.98
		Bishop, K.	$605.51	$678.72
		Boxall, P. C., McFarlane, B. L. and Gartrell, M.	$0.19	$0.19
		Haener, M. K. and Adamowicz, W. L.	$0.21	$0.21
		Maxwell, S.	$12.54	$12.54
		Prince, R. and Ahmed, E.	$1.59	$2.02
		Shafer, E. L., et. al.	$573.56	$573.56
		Willis, K. G.	$0.45	$202.89
		Willis, K. G. and Garrod, G. D.	$4.37	$4.37

	Agricultural lands	Bergstrom, J., Dillman, B. L. and Stoll, J. R. 1985	$29.26	$29.26
	Urban green space	Tyrvainen, L.	$1,342.21	$3,934.57
	Lakes/Rivers	Burt, O. R. and Brewer, D.	$461.82	$461.82
		Cordell, H. K. and Bergstrom, J. C.	$135.37	$1,419.65
		Kealy, M. J. and Bishop, R. C.	$12.93	$12.93
		Kreutzwiser, R.	$181.25	$181.25
		Loomis J.B. 2002	$11,131.00	$19,699.00
		Patrick, R.,et. al.	$1.69	$25.56
		Piper, S.	$240.20	$240.20
		Shafer, E. L. et. al.	$551.74	$1,101.41
		Ward, F. A., Roach, B. A. and Henderson, J. E.	$20.48	$1,918.61
		Young, C. E. and Shortle, J. S.	$81.85	$81.85
	Pasture	Boxall, P. C.	$0.03	$0.03
	Beach	Edwards, S. F. and Gable, F. J. 1991	$149.20	$149.20
		Kline, J. D. and Swallow, S. K.	$37,535.93	$48,441.03
		Silberman, J., Gerlowski, D. A. and Williams, N. A.	$23,486.04	$23,486.04
		Taylor, L. O. and Smith, V. K.	$445.46	$445.46
	Mid Forest	In house calculation	$5.20	$339.36
	Late/Old Forest	In house calculation	$10.41	$678.72
	Riparian Forest (pole)	In house calculation	$1,109.90	$11,305.57
	Riparian Forest (mid to late)	In house calculation	$1,109.90	$11,305.57
	Open Water Estuary	New Jersey Type A-C studies	$11.51	$1,381.50
Habitat Refugium & Nursery	Wetland	Allen, J. et. al. 1992	$5,477.34	$13,341.27
		Knowler, D. J. et. al.	$62.67	$287.22
		Streiner and Loomis 1996	$1,574.76	$1,574.76
		Vankooten, G. C. and Schmitz, A.	$6.30	$6.30
	Salt Marsh	Batie, S. S. and Wilson, J. R.	$6.66	$6.66
		Bell, F. W. 1997	$164.08	$1,082.32

		Farber, S. and Costanza, R. 1987	$1.42	$1.42
		Lynne, G. D., Conroy, P. and Prochaska, F. J.	$1.25	$1.25
	Shrub	Haener, M. K. and Adamowicz, W. L. 2000	$1.31	$9.00
		Kenyon, W. and Nevin, C.	$532.33	$532.33
		Shafer, E. L. et. al.	$3.17	$3.17
	Lakes/Rivers	Loomis 1996	$17.13	$17.13
		Streiner and Loomis 1996	$1,479.84	$1,479.84
	Late/Old Forest	In house calculation	$287.16	$532.33
	Riparian Forest (mid to late)	In house calculation	$287.16	$532.33
	Open Water Estuary	Woodward and Wui, 2001 (low value); New Jersey from A-C studies (for high value)	$92.75	$354.14
Water Supply	Wetland	Allen, J. et. al. 1992	$11,160.70	$33,418.85
		Creel, M. and Loomis, J.	$577.46	$577.46
		Dodds, W.K., et al. 2008	$1,357.64	$1,357.64
		Hayes, K. M., Tyrrell, T. J. and Anderson, G. 1992	$1,370.43	$2,130.25
		Lant, C. L. and Tobin, G.	$211.88	$2,333.31
		Lant? - IL water qual study 1989	$193.92	$193.92
		Pate, J. and Loomis, J.	$3,829.07	$3,829.07
	Lakes/Rivers	Bouwes, N. W. and Scheider, R.	$617.46	$617.46
		Croke, K., Fabian, R. and Brenniman, G.	$565.91	$565.91
		Henry, R., Ley, R. and Welle, P.	$429.30	$429.30
		Knowler, D. J. et. al.	$58.89	$269.91
		Ribaudo, M. and Epp, D. J.	$843.44	$843.44
	Marine	Hanley, N., Bell, D. and Alvarez-Farizo, B. 2003	$822.24	$822.24
		Nunes, P and Van den Bergh, J. 2004	$587.15	$587.15
		Soderqvist, T. and Scharin, H.	$275.97	$458.81
	Riparian Forest (mid to late)	In house calculation	$2,240.01	$13,849.87

	Open Water Estuary	New Jersey Type A-C studies	$5.88	$127.47
Disturbance Regulation	Salt Marsh	Costanza et al. 2007	$258.49	$102,105.30
	Beach	Parsons, G. R. and Powell, M.	$23,637.86	$23,637.86
		Pompe, J. J. and Rinehart, J. R.	$38,316.19	$38,316.19
	Riparian Forest (mid to late)	In house calculation	$8.04	$250.85
Waste treatment	Salt Marsh	Breaux, A., Farber, S. and Day, J. 1995	$116.82	$18,807.44
	Grasslands	Pimentel et al. 1997	$50.98	$50.98
Soil Formation	Grasslands	Costanza et al. 1997	$0.59	$0.59
		Sala and Paruelo (1997) (Calculated 1994)	$0.52	$0.52
	Pasture	Pimentel, D. 1998	$6.62	$6.62
Nutrient Cycling	Wetland	Dodds, W.K., et al. 2008	$7,346.62	$7,346.62
	Eel grass beds	Costanza et al. 1997	$5,860.22	$16,410.10
Biological Control	Grasslands	Pimentel et al. 1995	$9.74	$9.74
		Pimentel et al. 1997	$13.47	$13.47
Soil Erosion Control	Grasslands	Barrow (1991) (Calculated 1992)	$19.04	$19.04
		Costanza et al. 1997	$16.99	$16.99
Pollination	Grasslands	Pimentel et al. 1995	$10.77	$10.77
		Pimentel et al. 1997	$14.65	$14.65
	Agricultural lands	Robinson, W. S., Nowogrodzki, R. and Morse, R. A. 1989	$12.88	$12.88
		Southwick, E. E. and Southwick, L. 1992	$2.55	$2.55
	Mid Forest	In house calculation	$33.51	$150.48
	Late/Old Forest	In house calculation	$67.01	$300.96
Medicinal Value	Late/Old Forest	In house calculation	$5.01	$160.49

Appendix D. List of Value-Transfer Studies Used

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Appendix E. Limitations of Approach and Results

The results of this first attempt to assign monetary value to the ecosystem services rendered by the Puget Sound Basin have important and significant implications on the restoration and management of this natural capital. Valuation exercises have limitations that must be noted. However, these limitations do not detract from the core finding that ecosystems produce significant economic value to society.

Transferred value analysis estimates the economic value of a given ecosystem (e.g., wetlands) from prior studies of that ecosystem. Like any economic analysis, this methodology has strengths and weaknesses. Because this is a meta-study, it has greater opportunity for error, and as the numbers show, a very wide range between low and high estimates. Some have objected to this approach on the grounds that:

1. Every ecosystem is unique; per acre values derived from another part of the world may be irrelevant to the ecosystems being studied.
2. 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). This remains an important issue even though this was partly addressed in the spatial modelling component of this project.
3. 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.
4. 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 accounts 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 (see below).

Proponents of the above arguments recommend an alternative that amounts to limiting valuation to a single ecosystem in a single location and only using data developed expressly for the unique ecosystem being studied, with no attempt to extrapolate from other ecosystems in other locations. An area with the size and landscape complexity of the Puget Sound Basin will make this approach to valuation extremely difficult and costly.

Responses to these critiques can be summarized as follows (See Costanza et al., 1998; and Howarth and Farber, 2002 for more detailed discussion):

1. 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 and no less justified than their use in other "macroeconomic" contexts, for instance, developing economic statistics such as Gross Domestic or Gross State Product. This study's estimate of the aggregate value of the Puget Sound Basin'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.

2. The results of the spatial modeling analysis that were 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, a major indicator of ecosystem health – and 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 patch 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) seems appropriate as a first approximation.

3. As employed here, the prior studies we analyzed (most of which were peer-reviewed) 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 performed. The approach is similar to determining an asking price for a piece of land based on the prices for "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.

4. 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 in fact conceive of an exchange transaction in which all or a large portion of, for example, a watershed were sold for development so that the basic technical requirement that economic value reflect exchange values could in principle be satisfied. Even this is not necessary if one recognizes the different purpose of valuation at this scale – a purpose more analogous to national income accounting than to estimating exchange values (Howarth and Farber 2002).

In the last analysis, this report takes the position that "the proof of the pudding is in the eating", i.e., estimating the value of an area's ecosystem services is best demonstrated by presenting the results of an attempt to do so. In this report we have tried to display our 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) 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. That the value ecosystems provide to people exceeds the gross world product should, with some reflection, not be so surprising. Costanza's estimate of the work that ecosystem do is an underestimate of the "infinity" value of priceless systems because that is not what he sought to estimate. Consider the value of one ecosystem service, 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 stuff is unanimous. This indicates that the value of photosynthesis and atmospheric oxygen to people exceeds the value of the gross world product. That is only a single ecosystem service and good.

In terms of more specific concerns, the value transfer methodology introduces an unknown level of error because with the exception of some studies that were conducted in this area, we usually do not know how well the original study site approximates conditions in the Puget Sound Basin. Other potential sources of error in this type of analysis have been identified (Costanza et al. 1997) as follows:

1. Incomplete coverage – not all ecosystems have been valued or studied well – is perhaps the most serious issue since 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.

2. Distortions in 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.

3. 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.

4. The valuations probably underestimate shifts in the relevant demand curves as the sources of ecosystem services become more limited. If the Puget Sound Basin'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.

5. 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).

6. As noted above, the method used here assumes spatial homogeneity of services within ecosystems. The spatial modeling component of the project was intended to address this issue and showed that, indeed, the physical quantities of some services vary significantly with spatial patterns of land use and land cover. Whether this fact would increase or decrease value is unclear, and depends on the specific spatial patterns and services involved.

7. Our analysis uses a static, partial equilibrium framework that ignores interdependencies and dynamics. More elaborate systems dynamics 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.

8. 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.

9. 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.

10. There are great difficulties and imprecision in making inter-country comparisons on a global level. This problem was of limited relevance to the current project, since the majority of value transfer estimates were from the U.S. or other developed countries.

11. In the few cases where we needed to convert from stock values to annual flow values, the amortization procedure also creates significant uncertainty, both as to the method chosen and the specific amortization rate used. (In this context, amortization is the converse of discounting.)

12. All of these valuation methods use static snapshots of ecosystems with no dynamic interactions. The effect of this omission on valuations is difficult to assess.

13. Because the transferred value 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.

The result would most likely be significantly higher values if these problems and limitations were addressed. Unfortunately, it is impossible to know how much higher the values would be if these limitations were addressed. One example may be worth mentioning, however. Boumans et al. (2002) produced a dynamic global simulation model that estimated the value of global ecosystem services in a general equilibrium framework to be roughly twice of what Costanza et al. (1997) estimated using a static, partial equilibrium analysis. It is impossible to say whether a similar result would be obtained for the Nisqually Basin, but it does give an indication of the potential range of values.

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