6.1 INTRODUCTION

The ecological economics foundation for the Habitat Plan for the Green/Duwamish and Central Puget Sound Watershed (Water Resource Inventory Area 9 [WRIA 9]) is based on the fact that improvements in habitat conditions for Chinook salmon and other salmonids also restore a large basket of associated ecosystem services which are of significant financial value. These services include natural stormwater regulation, flood protection, drinking water production, recreational opportunities, aesthetic value, waste treatment, and a wide variety of other identified highly valuable ecological services. Thus, achieving the Habitat Plan goals and objectives (Chapter 4 – Section 4.3) both secures salmonid viability and contributes to economic prosperity and security for present and future generations. Salmon habitat actions enhance and restore economically productive natural capital providing services such as flood protection at least cost. The alternative is to replace self-maintaining ecosystems with capital-intensive infrastructure, such as flood control or stormwater facilities funded by taxpayers and which require ongoing maintenance. A healthy, efficient local economy depends on healthy ecosystems and the services they provide.

This chapter summarizes the relevant components of a study conducted for WRIA 9 titled Ecosystem Services Enhanced by Salmon Habitat Conservation in the Green/Duwamish and Central Puget Sound Watershed (Asia-Pacific Environmental Exchange 2005). The approach, guiding principles, and results of this work were reviewed, commented upon, and accepted by the Steering Committee.

The Seattle-based Asia-Pacific Environmental Exchange (since re-named Earth Economics), with the University of Vermont Gund Institute for Ecological Economics, worked with the WRIA 9 Watershed Coordination Services Team to estimate the value of ecosystem goods and services produced within the Green/Duwamish and Central Puget Sound Watershed. The consultant team also developed and analyzed case studies for two habitat restoration projects.

The ecological economics analysis included two parts: an overview of ecological services and benefits within WRIA 9 and an analysis of the enhancement of these services through restoration/rehabilitation actions. The first analysis included the identification of valuable ecological services produced within WRIA 9 and an estimate of high and low ranges in the dollar value of these ecosystem services in WRIA 9. As will be described later, these estimates probably understate the dollar value of ecosystem services. The second portion of the analysis examines the link between habitat conditions in WRIA 9, conservation hypotheses, and the enhanced value of ecological services. Specific habitat actions, the expected improvement in habitat conditions, and the dollar value of associated ecological services enhanced by the habitat actions are estimated in the second portion of the analysis.

This work was based on the conservation hypotheses and hypothesized necessary future conditions summarized in Chapter 4, Scientific Foundation, and the proposed actions (Chapter 7).

6.2 GUIDING PRINCIPLES FOR THE ECOLOGICAL ECONOMICS ANALYSIS

The guiding principles included the following:

- The framework and methodology for identifying and valuing ecosystem services (Daily, (Ed.)1997, and Boumans et al. 2004); and
- The conservation hypotheses, habitat information, and other socio-economic data specific to WRIA 9.

Ecosystem Services Valuation Framework and Methodology

The framework and methodology for conducting ecosystem service valuation have been widely discussed in the academic literature. In brief, taking the lowest and highest dollar value range per acre for each vegetation type (coniferous forest, woody wetland, etc.) established in the academic literature and multiplying it by the acreage provides rough low and high dollar estimates for the value of ecological services provided by an ecosystem.

More specifically, using Geographic Information System (GIS) data for WRIA 9, the acreages of forest, grass and shrublands, agriculture and pasturelands, wetlands, urban areas, lakes, ponds, rivers and streams, and ice and rock were multiplied by the estimated production per acre for each identified ecosystem services. Peer reviewed journal articles were reviewed for each GIS classification and the values associated with each of 23 ecological services. 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 WRIA 9.

This method is inexpensive. Though the range is large, indicating a lack of precision, the methodology does provide a broad picture of the value provided by the full range of ecosystems within WRIA 9. It also permits an examination of how habitat improvements for salmonids will reduce flood risk, produce higher water quality, and increase recreation among other services and thus contribute to the additional enhancement of economic value within WRIA 9.

The ecosystem valuation techniques developed within environmental and natural resource economics are widely accepted by the economics profession and in U.S. courts of law. All of the reference papers and valuation studies for the WRIA 9 study were peer reviewed and published in academic journals. A majority of the valuation techniques used in studies referenced in the study involve direct market pricing, replacement and avoided costs, and travel costs. In a few cases, contingent valuation figures are used.

Conservation Hypotheses and Scientific Information

The ecological economics analysis was based on the conservation hypotheses and habitat information developed for the WRIA 9 Habitat Plan. WRIA 9 Watershed Coordination Services Team selected the specific case studies to be examined. The conservation hypotheses and expected future conditions resulting from implementation of specific actions formed the basis for the ecological economics analysis and were directly drawn from the specific habitat actions proposed.

The Habitat Plan goals and objectives established by the Steering Committee were also adopted as guiding principles of the study (Chapter 4 - Section 4.3).

6.3 VALUATION OF WRIA 9 ECOSYSTEM SERVICES

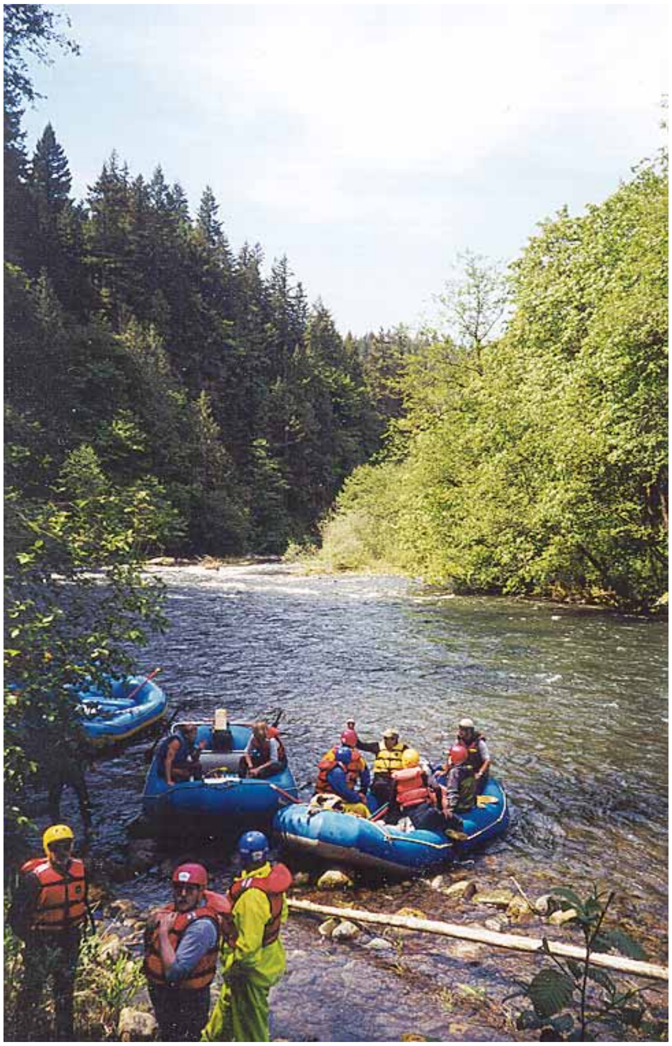
Habitat Plan actions to restore viable salmonid populations also will preserve and restore 23 categories of ecosystem goods and services identified in the Green/Duwamish and Central Puget Sound Watershed.

Healthy ecosystems produce goods and services for free and in perpetuity. They are essential to maintaining a healthy economy and livable communities within WRIA 9. Ecosystem goods and services enhanced by Habitat Plan actions include:

- Flood protection;
- Natural stormwater maintenance;
- Drinking water production and filtration;
- Reduction of pathogens and pollutants;
- Waste absorption;
- Storm protection;
- Biodiversity preservation;
- Nutrient regulation;
- Increased production of fish, shellfish, timber, and other food and raw materials;
- Nursery and refugia services;
- Erosion control;
- Biodiversity;
- Aesthetic value (beauty); and
- Recreational opportunities for fishing, hunting, boating, hiking, bird watching, and educational and scientific benefits.

The ecological economics analysis for the Habitat Plan is the first full valuation of the benefits provided by ecosystems within WRIA 9.

The ecological economics study gives a more complete picture of the results of implementing the Plan recommendations. People will receive many other benefits in addition to ensuring the viability of Chinook salmon, bull trout, and other salmonids. The purpose of valuing ecosystem services is to assist decision makers in recognizing all costs and benefits associated with alternative actions. The ecosystem infrastructure is a capital asset, and decisions about ecosystem services impact the maintenance of ecosystem infrastructure. Without valuing ecological services, vast amounts of benefits and the systems that produce them may be overlooked. This may result in significant losses and real financial costs born by taxpayers, governments, businesses, individuals, and communities over time. Often, economic analysis has omitted ecological goods and services, giving them an implicit value of zero. In turn, this error can lead to sub-optimal, if not very costly, outcomes in terms of land use patterns, infrastructure expenses, private property damage, or public safety hazards.



The Green River, shown here at river mile 47, is popular with boaters. May 2001 photo.

For example, New York City, confronted with declining drinking water quality, invested $1.5 billion in watershed restoration. While an enormous sum, this investment avoided the construction of a filtration plant that had a capital cost of $6 billion – four times greater — plus annual maintenance costs. This analogy is fitting: New York City, Seattle, and Tacoma are among the few cities in the U.S. that do not have to filter their municipal water because they own and/or manage their watersheds. (Filtration is different from treatment, which includes the addition of chlorine or the use of ozone or ultraviolet light to disinfect water supplies.) Because upland watershed ecosystems provide water filtration for free, these municipally-protected watersheds save local ratepayers money every time they turn on the tap.

The quality, quantity, reliability, and exact mix of goods and services provided by ecosystems within watersheds are highly dependent on the particular structure and health of those ecosystems. This is one of the most critical issues to understand about the production of goods and services by ecosystems within watersheds.

Degraded ecosystems require initial restoration investments to reestablish viability and ecosystem service production. Healthy, intact ecosystems are self-organizing and provide valuable ecological goods and services on an ongoing basis ("in perpetuity") at no cost to humans. This is very different than all forms of human-produced goods and services (cars, houses, energy, telecommunications, etc.), which have ongoing maintenance and end-of-life disposal costs. The delivery of ecosystem goods and services depends on the maintenance of a specific arrangement of ecosystem components that constitute a particular "structure." For example, the steel, glass, plastic, rubber, and gasoline that comprise a car must retain a very particular structure in order to provide the service of transportation. If the same car were simply a pile of constituent materials, it could not provide the service of transportation, though all the necessary parts are present. Healthy ecosystems require no "assembly" to produce goods and services, cutting out the costs of human-made capital and maintenance costs. Restoring ecosystems does, however, require initial investments.

Until the extensive development associated with European settlement, the natural capital, goods, and services produced by ecosystems within WRIA 9, including wild salmon, were abundant and self-maintaining. They were so abundant and productive, in fact, that "natural capital" was simply taken for granted. Wild (natural origin) salmon are more than an indicator species. Salmon are a valuable economic asset in and of themselves. At one time, it was only a shortage of boats and nets that limited the catch of "unlimited" wild salmon. Today boats, nets, and fishing lures are abundant and a shortage of natural capital — wild salmon — is the limiting factor.

Healthy ecosystems, healthy economies, and healthy communities are all necessary to maintain and raise the high quality of life that citizens within WRIA 9 enjoy. As ecosystems are degraded, quality of life is degraded and citizens pay significant socio-economic costs. For example, either property owners suffer greater losses from increased flooding and other damage or cities and counties must replace previously free ecosystem services with increasingly expensive engineered solutions. Increased expenses from lost ecosystem services include increased water filtration costs, stormwater management, flood control, endangered species restoration, landslide damage, and other problems resulting from a degraded environment.

Ecosystems are the most economically efficient production systems for many critical public goods and services. For example, healthy riparian areas filter drinking water, move the vast majority of stormwater, recharge aquifers, and replenish surface waters at no cost. Replacing these services with engineered solutions requires costly capital projects such as levees, stormwater systems, and water filtration facilities.

Dollar Value Of WRIA 9 Ecosystem Goods and Services

The ecological economics study shows that WRIA 9 ecosystems produce $1.7-6.3 billion of value in goods and services every year for individuals, businesses, and governments within WRIA 9. These values are underestimates because not all services have been valued.

If ecological goods and services were like other goods and services (food, housing, transportation), each of the 630,000 persons in WRIA 9 (2004 estimate) would receive on average ecological goods and services worth $2,700-10,000 every year. However, the average value per person in WRIA 9 is in fact much larger because many ecological services are "non-consumable." Averaging value assumes that the value each person receives is like a piece of a pie – if one person eats the piece of pie, no one else can eat it. Some ecosystem goods and services are not consumed, however. Although the estimate of aesthetic value may be based on how much people actually pay for view property, in fact there is far more aesthetic value provided than the sum of differential view property prices paid, divided by the population. One person viewing the Green River from a public area and gaining aesthetic benefits does not preclude anyone else from enjoying the same view. Flood protection and biodiversity are an ecological service and good, respectively, that are not diminished by an increasing number of persons benefiting from them.

Table 6-1 provides dollar estimates for the acreages of land cover within WRIA 9.

Net Present Value of Ecosystem Services in WRIA 9

This continuous annual flow of benefits is worth a great deal. Economists calculate the total value of a flow of annual benefits to people today as the net present value. This is a measure in today's dollar value of this year's benefits plus today's estimated dollar value of the future "discounted" benefits. This calculation of net present value is widely used both business and government. Future benefits are "discounted" to reflect the view that most people value a dollar that will be received a year from now as worth less than one received today (because today's dollar can either be spent now'– providing immediate satisfaction – or saved, earning interest). Using the U.S. Army Corps of Engineers standard 3.5% discount rate, the net present value of WRIA 9 ecosystems is worth $48-180 billion. Improving the health of WRIA 9 ecosystems would increase this value and reduce public and private expenditures necessary to replace degraded ecosystem services.

Value Produced Over a 100 Year Period

Unlike human-produced capital investments, healthy ecosystems do not depreciate or require maintenance costs. Once healthy, they are self-maintaining. Thus, a restored watershed provides filtered water indefinitely for future generations, whereas a filtration plant requires capital expenditures, maintenance, and eventually depreciates requiring further capital expenditures. This difference in the nature of human-produced versus natural capital justifies treating the economic benefits of ecosystem restoration differently than traditional capital expenditures. Using a zero discount rate (rather than a 3.5% discount rate) over 100 years offers another view on value: the value to people today of today's flow of benefits *and* the value to someone in the future of that future flow of benefits. With a zero discount rate over 100 years, the value of WRIA 9 ecosystem services is $171-637 billion. A zero

TABLE 6-1. WRIA 9 Total Ecosystem Goods and Service Value Estimates ($ per year)

Ecosystem Category	Low Value	High Value
Forest	$1,295,829,783	$4,775,863,101
Grasslands and Shrub Lands	322,366,481	1,237,833,147
Agriculture and Pasture	6,405,977	23,135,736
Urban	7,208,896	38,084,051
Lakes, Rivers, Ponds and Reservoirs	4,200,049	26,156,494
Wetland	25,367,121	89,705,403
Coastal	5,472,559	29,444,372
Rock	24,599,206	84,280,699
Total Values	**$1,691,450,072**	**$6,304,503,003**

discount rate assumes that the value of a glass of clean water to a person today is equal to the value of a glass of clean water to a person a year from now or to another person in 100 years. Ideally, far more than 100 years of benefits will be garnered and thus this value still represents only a small slice of the potential value that healthy WRIA 9 ecosystems can produce for future generations.

Value in the Short Run and the Long Run

In the short run, ecosystems provide critical and highly valuable services. In the long run, they are even more valuable. Human-built capital, such as a car, requires maintenance and depreciates over time. After providing valuable service a car becomes garbage or recycling. The great-grandchildren of current generations will likely obtain little use from the cars now being driven. However, they will unquestionably benefit from the drinking water, flood protection, salmon, and recreation provided by healthy ecosystems. Ecosystem services are rising in value (increasing in scarcity and economic importance) relative to built capital. Preserved and restored ecosystems are self-maintaining and produce value into perpetuity.

Clean water is critical for human enjoyment of the marine nearshore, shown here at Redondo Beach in Des Moines. July 2003 photo.

Difficulties In Dollar Valuation And Service Identification

Although easily identified as valuable, many ecological services are difficult to value in dollars. For example, dollar values can be established for water filtration services provided by a forest, whereas it is very difficult to fully capture the dollar value of aesthetic pleasure that humans gain from looking at the forest, nor every aspect of the forest's role in supporting the intricate web of life. Part of aesthetic value can be captured by measuring the difference in property values where people have "view" property or live next to healthy ecosystems compared to properties that do not provide these aesthetic benefits. In this case, stream-side property owners pay a measurable premium price for aesthetic value. However, many others benefit from this aesthetic amenity without having to pay for it and thereby provide a transaction that can be measured. Similarly, the cultural value of salmon — especially for Indian people — obviously exists and is significant. However, a dollar valuation of non-market "cultural value" is difficult to estimate. Finally, many valuable ecological services may not be identified yet. For example, the full importance of the stratospheric ozone layer was not known until the 1970s, while chemicals that harmed it had been produced since the 1930s. There may yet be significant ecological benefits from healthy WRIA 9 ecosystems that are unidentified.

Healthy watershed ecosystems incur less damaging flooding. February 1996 photo.

Value Ranges are Underestimates

The dollar estimates of the value produced by natural systems are inherently underestimates. Not all benefits identifiable are valued or fully valued, as explained above. In some cases, there are few valuation studies for particular goods or services and some are outdated. In recent decades, the values of ecosystem services have risen faster than inflation. In addition, these are renewable goods and services where most of the value is held in the future. For these reasons, the high and low estimates in value are underestimates of the true range in value of ecosystem services. Ecological service valuations are not intended to capture all value but rather to serve as markers somewhere below the minimum value of the true social, ecological, and economic value of an ecological service.

Return on Investments in Salmon Habitat Protection and Restoration

This analysis demonstrates the tremendous value that accrues to people in WRIA 9 from existing ecosystem goods and services. The money spent to protect and restore salmonid habitat is an investment that pays many financial dividends. Dollars spent for salmon restoration also buy benefits in flood protection, stormwater management, recreation, and other services with clear dollar values. This information can improve the economic efficiency of the conventional economy.

WRIA 9 ecosystems have always provided vast amounts of value at zero or low cost. This changed once these ecosystems began to be degraded and it became necessary to replace some of these ecosystem services with human built infrastructure. This value, though previously unaccounted for, lays a foundation for a healthy economy within WRIA 9. Without clean water, air, flood protection, natural stormwater maintenance, etc., the conventional economy could not function as efficiently. Investing in the restoration of this natural capital improves the economic efficiency of the conventional economy. Individuals and businesses will spend less on taxes, utility fees, or damage repair if healthy ecosystems within WRIA 9 can provide significant services for free. This perspective may result in the determination that ecosystem maintenance is in fact a "least cost" approach to providing many crucial services, such as flood protection. Ecosystem restoration avoids significant infrastructure capital and operations and maintenance costs and provides benefits through self-maintaining ecosystems. Salmon habitat restoration is a least cost investment that meets several objectives:

- Achieves the requirements of the Endangered Species Act by restoring viable salmonid populations. Doing so should reduce the likelihood of federal regulations and provide certainty to businesses, local governments, and individual citizens. This greater certainty will improve the environment for private and public investment. (The extent to which the Puget Sound Salmon Recovery Plan will meet the requirements of the Endangered Species Act is yet to be determined. NOAA Fisheries will make this determination and may decide whether to provide assurances that Habitat Plan partners will be protected from third-party lawsuits. See Chapter 8 for further discussion on assurances.);
- Maintains the value of the existing stream of goods and services that flow from the land and water ecosystems of the watershed in their present condition. From this perspective, the costs of protecting and restoring ecosystems are similar to the regularly-scheduled maintenance and periodic repair of an automobile. Prudent owners undertake these costs (which are avoidable in the short term) to maintain the long-term reliability and use of their vehicle and avoid catastrophic and expensive failures (e.g., engine failure due to lack of regular oil changes). While illuminating, however, this analogy nonetheless understates the value of ecosystem goods and services over time. Unlike an automobile, which almost always depreciates even with regular care, maintenance of current ecosystem health would result in an increase in value over time as the human population of the watershed increases, driving up demand for the same basket of goods and services;
- Avoids the necessity of further replacements of human capital for natural capital (e.g., the construction and operation of flood prevention levees, stormwater management systems, etc. to replace natural "water management systems" of mature forests, highly porous soils, wetlands, streams, and rivers). Ecosystem maintenance can thus be viewed as a least cost means of obtaining a vital set of economic goods and services within WRIA 9; and
- Enhances the value of the ecosystem goods and services by creating net improvements in the quantity and quality of watershed ecosystems. Investments in ecosystems are often superior to traditional capital investment because they provide a higher rate of return, do not depreciate, and the returns involve far less uncertainty. Investments in ecosystem health yield large benefits in the near and distant future.

It was beyond the scope of the study to demonstrate the full dollar value of all ecosystem services associated strictly with salmon restoration actions. However, it is clear that supporting salmonids will increase the annual value of ecosystem goods and services produced within the watershed and could significantly reduce other infrastructure costs. Failure to protect and restore salmonid habitat would incur significant ecosystem service losses and require larger investments to meet endangered species requirements should additional salmonids be listed under the Endangered Species Act.

Further ecological economic analysis to examine the benefits and avoided costs associated with salmonid habitat improvements would be helpful.

6.4 ANALYSIS OF HABITAT PLAN ACTIONS: TWO CASE STUDIES

Two case studies were examined based on the conservation hypotheses and specific habitat protection/restoration/rehabilitation projects recommended. Depending on the action, some subset of associated ecological services would be affected by these salmonid habitat recovery actions.

The WRIA 9 conservation hypotheses identify the habitat conditions that are important or critical for salmon recovery based on best available science. To establish the ecosystem services enhanced by specific projects, two habitat projects were examined with respect to each of the 23 identified ecological services. Each measure associated with a project will enhance, reduce, or have no effect on each ecological service. For example, one measure identified in the North Wind's Weir project (see below) is increasing vegetated shallow water and marsh habitats and intertidal zone access. This specific habitat measure improves 15 ecological services including water filtration, waste treatment, and refugium services. Minimizing impervious surfaces improves six identified ecological services. With the latest science as a basis and providing information on the area and habitat type changes expected, economic methods can be used to estimate the change in economic value. The valuation of ecological services enhanced was further complemented with other economic analyses including examining potential loss of investments and other methods.

Case Study 1: North Wind's Weir Shallow Water Habitat Rehabilitation Analysis

North Wind's Weir, looking downstream at low tide. Project site is to right. July 2000 photo.

In coastal river systems, the confluence between fresh water flowing downstream and salt water pushed inland by the tides creates an estuarine transition zone. Transition zone wetlands and off- channel areas are a critical ecosystem in the life history of salmonids, especially Chinook salmon. Transition zone habitat is where juvenile salmonids adapt from fresh to salt water.

Sufficient habitat space, shelter, and food must be available in the transition zone for salmon to linger, osmoregulate (physically change to adapt to salt water), and grow to survive for salt water conditions. Due to habitat improvements upstream, increasing numbers of juvenile salmon may survive the fresh water journey downstream only to find inadequate habitat in the transition zone.

In the Duwamish Estuary Subwatershed, the transition zone has been significantly altered for human use, leading to considerable losses in critical transition zone salmon habitat. (See Chapter 4, Scientific Foundation, for additional description of current Duwamish transition zone habitat and the factors that have decreased, degraded, and shifted its location. Figure 4-1 shows the location of the known transition zone.)

Fresh water flowing into the Duwamish Estuary has been reduced by 70% owing to the diversion of the White and Cedar/Black Rivers. With reduced fresh water flow and channel dredging, salt water has intruded, effectively pushing the transition zone upstream from its historical location. The establishment of heavy industrial uses in the transition zone has replaced riverine-tidal, estuarine, and palustrine wetlands with impervious surfaces. The original stream edge has been replaced by levees, revetments, and other armoring, turning slow-moving edge habitat into unrestrained downstream flows. In addition, the Duwamish estuary riparian vegetation is of low habitat quality and has been mostly replaced by non-native weeds such as Himalayan blackberry. With these changes, transition zone habitat has been degraded and confined. Spatial structure, residence time, and the habitat available for refugia and rearing functions in the Duwamish estuary have therefore been reduced and constrained (WRIA 9 and King County Department of Natural Resources and Parks 2004). High densities of fish have been observed utilizing what is left of this specific habitat.

Current conditions in the transition zone suggest it is a critical threshold point. Overall increases in salmonid survival rates in the watershed are dependent on the availability of sufficient transition zone habitat to accommodate fish while they adjust from fresh to salt water. Under the present conditions of greatly reduced transition habitat, the benefits of increased salmon productivity upstream may be lost in the transition zone. Viewed alternatively, improvements in the quality and quantity of transition zone habitat will ensure that investments in spawning and rearing habitat upstream (and rearing habitat in the marine nearshore) are realized in terms of improvements to the viable salmonid population parameters of abundance, productivity, diversity, and spatial structure.

The Shallow Water Habitat Creation at North Wind's Weir at River Mile 6.3 (Chapter 7 – Section 7.4, Project Duw-10), located in the Duwamish estuary transition zone, is one project that will address the need to expand transitional zone habitat. By excavating shallow water habitat on two acres and adding emergent and upland native vegetation, the project will increase off channel wetlands and sloughs and in-stream shallow and slow water habitat in the transition zone. This restoration will enhance the quantity and quality of habitat in the transition zone, ameliorating some problems described above. The expected combined acquisition and construction costs for this project total $3.8 million.

Though economic methods are based on marginal analyses and not well suited for measuring a threshold for extinction, four different approaches to valuing the expansion of transition zone habitat were applied and are summarized below. These analyses justify significant expenditures on actions to reclaim transition zone habitat:

- Expenditures for salmon protection and restoration within WRIA 9 to date are in the tens of millions of dollars. Total expenditures over the next 10 years could be $272-389 million if all projects were implemented (the cost of the highest priority projects is expected to be $198 to $291 million). The value of these investments could be lost or markedly diminished without securing sufficient transition zone habitat for the increased numbers of juvenile salmonids produced upstream;
- Scientific analysis suggests that continued salmonid declines are likely without improvements to transition zone habitat to boost productivity. As a result, if increased transition zone habitat is not created now, the federal government may require the creation of transition zone habitat at a future date as it responds to the Endangered Species Act. If salmonid populations decline further in the meantime, it may require a larger restoration of transition zone habitat to restore viable salmonid populations;
- Ecosystem services also would be enhanced with increased transition zone habitat. The valuation of a subset of ecosystem service values produced by the North Wind's Weir project provides a net present value for the project of $384,000 to $1.4 million (using a 3.5% discount rate). A zero discount rate (giving equal value to the goods and service benefits enjoyed by future generations) provides values of $1.35-23.72 million in net value for the project, depending on the time horizon considered. This partial analysis does not account for the value of securing a viable Chinook population, which has both intrinsic benefits (having the fish) as well as benefits in terms of legal certainty; and
- The fourth economic methodology applied to the North Wind's Weir project was experimental and is based on assumptions about allocating a limited budget to produce the desired future conditions identified in the Habitat Plan. Given a constrained budget and the scientific knowledge of habitat functions, current constraints, and desired future conditions, where should scarce public dollars be allocated to create the greatest benefit for salmonid restoration? This approach also assumes that relieving the most constraining limiting habitat factors on salmonid populations will provide the highest initial returns. Assuming for analytical purposes a budget of $100 million over the next decade for salmon restoration in WRIA 9, an expenditure of over $19 million for the recovery of the first two acres of transition zone would be justified. This is far higher than the actual cost of the project. It also indicates that the restoration/rehabilitation of at least several additional acres is justified. (The North Wind's Weir project is one of several projects to improve transition zone habitat; an additional 30 acres of transition zone habitat creation is proposed [projects Duw-7 and Duw-11].) This analysis needs further refinement but holds promise as a tool to assist decision making. As noted in Chapter 5 – Section 5.7, improvements to transition zone habitat are given greater emphasis (40% of overall funding over the first 10 years of the Plan) than improvements to rearing (30%) and spawning (30%) habitats.

Overall, these four analyses underestimate the value of salmon habitat restoration associated with the North Wind's Weir project because the transition zone is critical natural capital, improvements here are unavoidable in achieving viable salmonid populations, and the lack of transition zone habitat is placing natural origin estuarine-dependent salmonids such as Chinook in threat of extinction. Natural origin Chinook face a state of crisis in ecological terms. Values under crisis conditions rise rapidly. This subtlety is not captured in traditional economic analysis, which is based on marginal changes and marginal values. Meeting the goals of this Plan should protect and restore enough of the critical natural capital in each critical habitat type to eliminate this state of crisis.

Case Study 2: Armoring in the Marine Nearshore Analysis

The marine nearshore is critical to salmonids. It provides habitat for juvenile salmon as they leave the Green/Duwamish River and enter the oceanic phase of their lives. Nearshore ecosystems where terrestrial and aquatic ecosystems meet (to a depth where light penetrates) are tremendously productive. In general, they are the most biologically productive ecosystems (in terms of annual biomass production) on a per acre basis in the world. They provide food and materials, oxygen, waste treatment, storm protection, recreation, high aesthetic and recreation value, and many other services. Globally, coastal ecosystems were estimated to provide over $12.5 trillion in benefits in 1997 (Costanza et. al. 1997).

Despite the great amount of value identified, there are still a large number of benefits the nearshore provides that are clearly valuable but have not yet been valued. Thus, any benefit transfer valuation of nearshore ecosystem services is necessarily significantly below the true value. Peer-reviewed valuation studies representing 25 ecosystem services associated with particular land forms and habitats in the nearshore have been conducted. However, there are over 150 other identified ecosystem service/habitat/landform associations for which no valuation studies exist. The value of ecosystem services produced in the nearshore is high and consequently any benefit transfer valuation of nearshore ecosystem services is necessarily significantly below the true value.

Another critical factor in this analysis is the lack of understanding of the dynamic oceanographic and biological processes that relate structure, function, process, and value in the nearshore.

WRIA 9 conservation hypotheses in the nearshore, as throughout WRIA 9, support the strengthening of healthy ecosystem processes and resulting habitat features. This produces a corresponding rise in the value of enhanced ecosystem goods and services. With these considerations, the ecological economics study authors identified ecosystem services of two conservation hypotheses associated with the restoration of the nearshore environment.

WRIA 9 has a diverse range of marine nearshore landscape and habitat features: from mud flats to bluffs to beaches and from grass to kelp and other submerged aquatic vegetation. On the other hand, this stretch of Puget Sound shoreline has also been heavily impacted by filling, bulkheads, riprap, vegetation clearing, and other modifications.

Several programmatic and project actions in Chapter 7 would contribute to the removal of shoreline armoring. These actions would have two primary effects:

- Restoration of erosion and sedimentation processes that create habitat; and
- Restoration of estuarine floodplains, salt marshes, mudflats, deltas, spits, and brackish side channels.

Table 6-2 shows the ecosystem services enhanced by the restoration of sediment processes and creation of floodplains, marshes, flats, estuaries and deltas, spits, and side channels. The double star indicates a great increase in value.

To provide an example of the interaction between the disruption of coastal processes and critical salmon habitat, a regression model was run examining the quantity of submerged aquatic vegetation and shoreline disturbance due to boat access and shoreline armoring. (Regression models are statistical tools that measure the change in one variable with changes in other variables.) An initial and partial estimate of the total value of ecosystem services provided by submerged aquatic vegetation alone shows that armoring, docks, and boat launches have contributed to the loss of $44 million annually in Puget Sound. The marine nearshore of WRIA 9 is one of the most heavily armored and developed areas along Puget Sound and accounts for a large portion of Puget Sound-wide losses. Removal of armoring also supports two salmon conservation hypotheses that would increase the quantity and value of ecological services provided. Depending on the site, oceanographic effects on sediment transport, submerged aquatic vegetation, and other dynamics, these salmon restoration actions in the nearshore would likely produce high economic benefits.

This analysis gives an idea of the value of a relatively small subset of ecological services in the nearshore, yet many landscape and ecosystem services have not been considered and are not included in this analysis. Because barriers such as riprap, bulkheads and fill disrupt or change natural wave action and sediment transport, they have an influence far beyond the immediate area affected. Eelgrass beds naturally shift as sediments shift. However, if sediment supply is cut

TABLE 6-2: Ecosystem Services Enhanced By Habitat Restoration Measures in the Nearshore

Ecosystem Service Enhanced	Restore Sediment Processes	Creation of estuarine floodplains, salt marshes, mudflats, deltas, spits, and brackish side channels
Gas regulation		*
Disturbance prevention	*	*
Nutrient regulation		*
Waste treatment		*
Refugium function	**	**
Nursery function	**	**
Food	*	*
Ornamental resources	*	*
Aesthetic	**	**
Recreation	**	**
Cultural and artistic information	*	*
Spiritual and historic information	*	*
Science and education	*	*
	* *Increase in Value*	** *Great Increase in Value*

off (e.g., by a bulkhead) or severely disrupted in movement by a barrier (e.g., a jetty), there may be great cumulative effects and the losses of ecosystem services. Alternatively, the benefits from restoration may be several magnitudes larger than estimated within a static analysis.

To fully understand the value of these ecosystem services requires a dynamic analysis beyond the scope of this analysis. This would provide a much clearer understanding of the full ecosystem service effects of disrupting coastal processes and restoring them.

WRIA 9 includes 90 miles of marine shoreline, shown here off Normandy Park. May 2003 photo.

6.5 NECESSARY FUTURE CHINOOK SALMON POPULATION CONDITIONS AND ECONOMIC EFFICIENCY GAINS WITHIN WRIA 9

The hypothesized necessary future conditions for viable salmonid populations (Chapter 4 – Section 4.5) can enhance economic efficiency within WRIA 9. The WRIA 9 ecological economics analysis demonstrates the vast amount of value provided by the WRIA 9 watershed to its citizens ($1.7-6.3 billion annually with a net present value of $48-180 billion). Salmonid habitat restoration also protects and enhances a full basket of 23 valuable ecosystem services.

The provision of watershed-related services including stormwater management, public drinking water, flood protection, recreation, and other benefits, or the replacement of these watershed services with built infrastructure has been split among a variety of general and special-purpose governments. This diffusion of costs has hidden the true impact of the degradation of ecosystem goods and services. Greater cooperation between these governments across WRIA 9 could both further enhance salmonid recovery and reduce the costs of flood damage, stormwater management, and other services. This would increase the overall economic efficiency of providing watershed-related services.

WRIA 9 presently provides a formal venue for cooperation between King County, 15 cities, and Tacoma Public Utilities and it provides an informal opportunity for exchange of information and coordination with a larger group of entities including the King Conservation District, Port of Seattle, Boeing, and citizen restoration groups. As this coordination is strengthened and efficiencies identified, its members can reduce the overall cost burden of salmon habitat protection and restoration and watershed ecosystem maintenance. Each of the Habitat Plan goals, objectives, policies, and actions are associated with the health of the watershed. The health of the watershed also influences potential costs or benefits in other areas where local governments, businesses, and other institutions experience either costs or benefits. If the watershed continues to be degraded, citizens, businesses, and governments must either pay more to replace lost ecosystem services, or suffer economic damage from greater flood damage or stormwater pollution. The costs to various governments to build levees, water filtration plants, stormwater systems, and other capital replacing natural processes should be reduced with greater ecosystem restoration and health. Because many ecological services are produced at the watershed level, WRIA 9 is the right scale for managing these watershed-related services.

6.6 RESULTS AND CONCLUSION

The implementation of WRIA 9 Habitat Plan policies and actions will enhance and increase the value of ecosystem goods and services provided in the watershed. The most significant goods and services are flood protection, natural stormwater management, drinking water production and filtration, reduction of pathogens and pollutants, waste absorption, storm protection, biodiversity preservation, nutrient regulation, increased production of fish, shellfish, and other food and raw materials, erosion control, aesthetic value, and recreational fishing, hunting, boating, hiking, bird watching, and educational and scientific benefits.

WRIA 9 investments in ecosystem protection and restoration (natural capital) will enhance a great number of highly valuable goods and services. These ecosystem services are rising in value (increasing in scarcity and economic importance) relative to built capital. Preserved and restored ecosystems are self-maintaining and produce value into perpetuity.

The alternative to habitat protection/restoration is further degradation of natural capital in WRIA 9. Watershed citizens will then have to choose between one of two options:

- Replacing lost ecosystem services with engineered solutions (e.g., flood control facilities, increased stormwater infrastructure) that require large capital investments and maintenance; or
- Forgoing the lost services and suffering an increasing risk of damage (e.g., from flooding), which requires reconstruction costs and higher insurance costs.

A partial estimate of the value of ecosystem goods and services within WRIA 9 is $1.7-6.3 billion annually with a net present value of $48-180 billion over 100 years at a 3.5% discount rate. The $1.7-6.3 billion figure yields annual benefits per capita of $2,700-10,000. However, this figure captures only the value to today's generations. People living in 2100 will value clean water produced in 2100 much more highly than today's people value clean water in 2100 because today's people probably will not be alive in 100 years. Using no discount rate, the value is $171-637 billion over 100 years. The value to future generations beyond 100 years in the future is far greater.

As markers of social capital, the population, educational level, employment levels and distribution of labor between sectors were examined. The WRIA 9 planning process and initial protection/restoration projects have brought governments, communities and individuals together, strengthening this social capital.

Markers of built capital examined include roads, buildings, industries and businesses, and other property. The total value of taxed property within WRIA 9 is $71.5 billion. Of this, $43.9 billion consists of improvements on property (built capital) and $27.6 billion of land value (social and natural capital). It has taken about 150 years to accumulate the $43.9 billion of taxed built capital stock in WRIA 9.

The costs of restoration and benefits of habitat improvements are not necessarily born equally by everyone within the watershed. Equity issues are increasingly important considerations in salmon protection and restoration. While an analysis of equity issues was beyond the scope of the ecological economics study, decision makers are encouraged to consider patterns of costs and benefits as the recommendations of the Habitat Plan are implemented.

The Shallow Water Habitat Creation at North Wind's Weir at River Mile 6.3 project was evaluated with four methodologies and found to be economically justified based on the protection of current and future investments; the risk of future Endangered Species Act requirements for transition zone acquisition; the (underestimated) value of ecosystem services provided by the North Wind's Weir project ($384,000 to $23.7 million, depending on the discount rate and time horizon); and the analysis of expenditure priorities based on a limited budget ($19 million in expenditures on the transition zone were justified). The Duwamish transition zone meets the criterion of critical ecological capital in crisis. No current marginal valuation methodology alone can gauge the value of critical natural capital at a threshold of nearly total loss. A policy objective throughout WRIA 9 should be to keep all ecosystems healthy enough to remain outside crisis status.

Removal of armoring in the marine nearshore will increase the quantity, quality, and total value of habitat in the nearshore ecosystem. Valuation studies for some ecosystem service/habitat/landform associations for the nearshore exist, but over 160 nearshore systems identified as valuable are lacking peer-reviewed valuation studies. Despite this, the value of ecosystem services produced per acre in the nearshore is believed to be among the highest of any ecosystem type. Habitat Plan measures related to removal of armoring were examined and the ecosystem services enhanced identified. Some land cover types produce over $140,000/year/hectare considering two categories of ecological services. A regression analysis of armoring, boat launches, and docks in relation to submerged aquatic vegetation shows that one foot of armoring reduces submerged aquatic vegetation coverage/hectare by .003 percent, based on Puget Sound coastal Geographic Information System data. Submerged aquatic vegetation is valued at producing $46,950/acre (1997 dollars). Consequently, armoring results in losses of $29.75/foot, which means a loss of over $43.9 million annually across Puget Sound from the loss of submerged aquatic vegetation ecosystem services alone. The costs of armoring for perhaps one hundred other services/habitat/landform associations are as yet unmeasured.

The bottom line is that the greatest socio-economic implication of salmon habitat recovery is securing healthy ecosystems, which provide vast public and private benefits. Understanding the value that flows to the people of the watershed from healthy ecosystems provides important context for making decisions about where and when to make investments in salmon habitat and how to share those costs. This analysis shows that making expenditures on habitat in areas where costs are high are justified in terms of the high value of ecosystem goods and services produced in areas where those services are scarce (e.g., the Duwamish Estuary transition habitat). Implementation of the WRIA 9 Habitat Plan will enhance the economy and quality of life for citizens in WRIA 9 by enhancing natural capital and the stream of ecosystem goods and services generated by that capital. All three forms of capital — natural capital, human-built capital, and social capital — must be healthy to maintain a healthy economy and high quality of life.