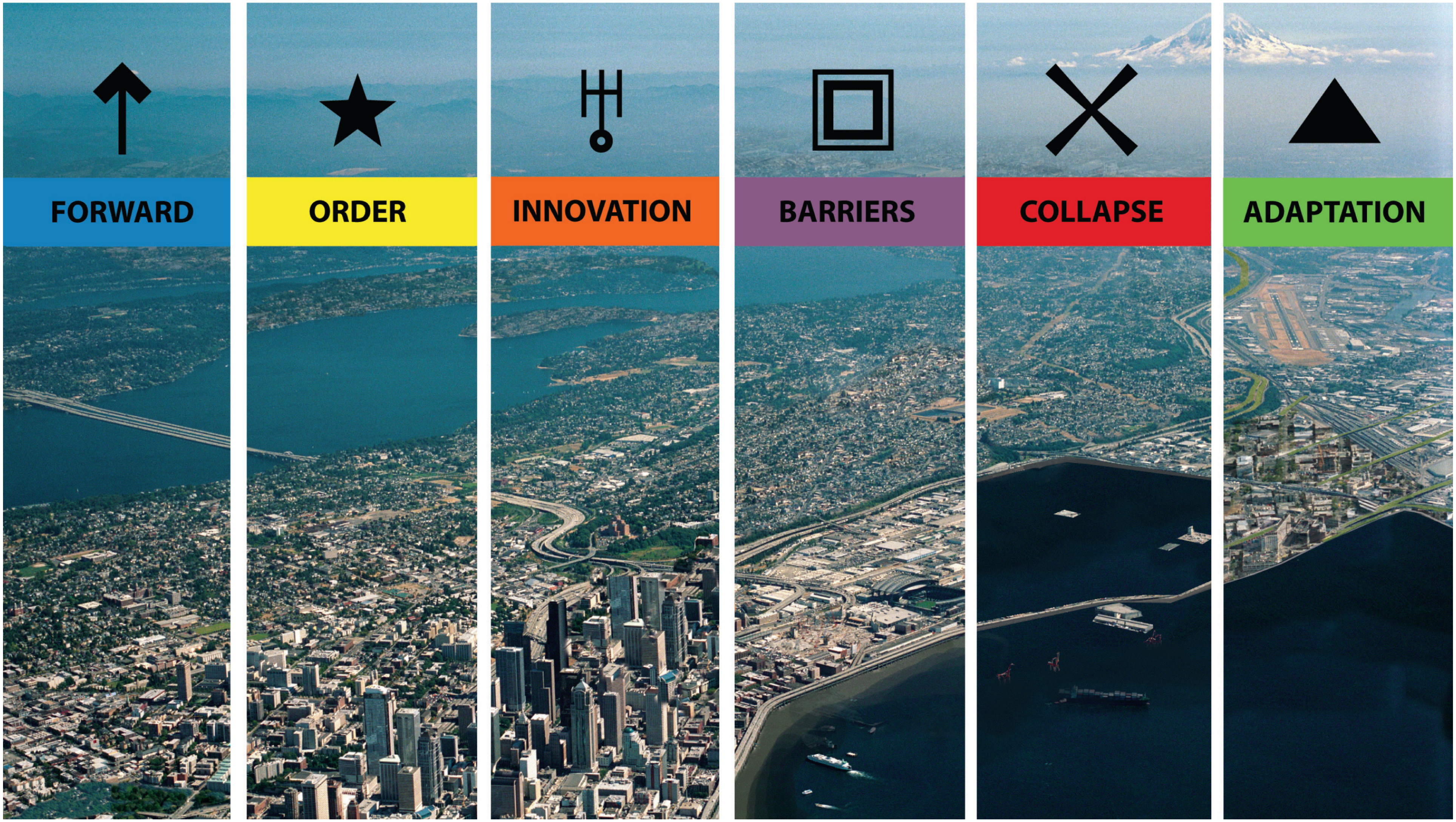
Puget Sound Future Scenarios



Puget Sound Nearshore Partnership

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Contents

1. Introduction

This report describes six alternative plausible futures for the Puget Sound region in 2050. The project, conducted as part of the Puget Sound Nearshore Partnership (PSNP)[1], aimed to develop future reference conditions for evaluating large-scale restoration[2] efforts by the Army Corps of Engineers. The scenarios explore trajectories of key drivers and regional conditions that will affect the nearshore ecosystem function. In future steps, these scenarios will be utilized as inputs into an integrated suite of models in order to assess the implications of the alternative future conditions on the nearshore ecosystem functions. This report reflects on the methods used to develop the scenarios and outcomes, and discusses the effectiveness of this approach for integrating uncertainty into a future ecological assessment.

Project scope and objectives

Investing Federal funding for restoring ecological conditions in our coastal areas is subject to a systematic assessment of the costs and benefits of alternative strategies, including taking "no action." Public agencies developing regional and local restoration plans are expected to provide an accurate account of such assessments in proposing any restoration project and recovery plan. However, assessing the cost and benefits of alternative restoration strategies including "no action" is challenging due to the uncertainty of key driving forces that can influence future conditions and their unpredictable interactions. What will be the future conditions of the Puget Sound nearshore ecosystem in fifty years without restoration? The Future Without Project defines the baseline future of the Puget Sound nearshore ecosystem assuming that a comprehensive, large scale ecosystem restoration strategy will not take place. Led by the UW Urban Ecology Research Laboratory, PSNP has developed multiple plausible futures for the Puget Sound's nearshore ecosystem.

The project aimed at:

- defining relevant, plausible, divergent and internally consistent scenarios for the Puget Sound region in 2050
- exploring potential risks and opportunities to inform the development of restoration strategies
- providing insight towards assessing the cost and benefits of alternative restoration strategies under plausible future conditions[3]

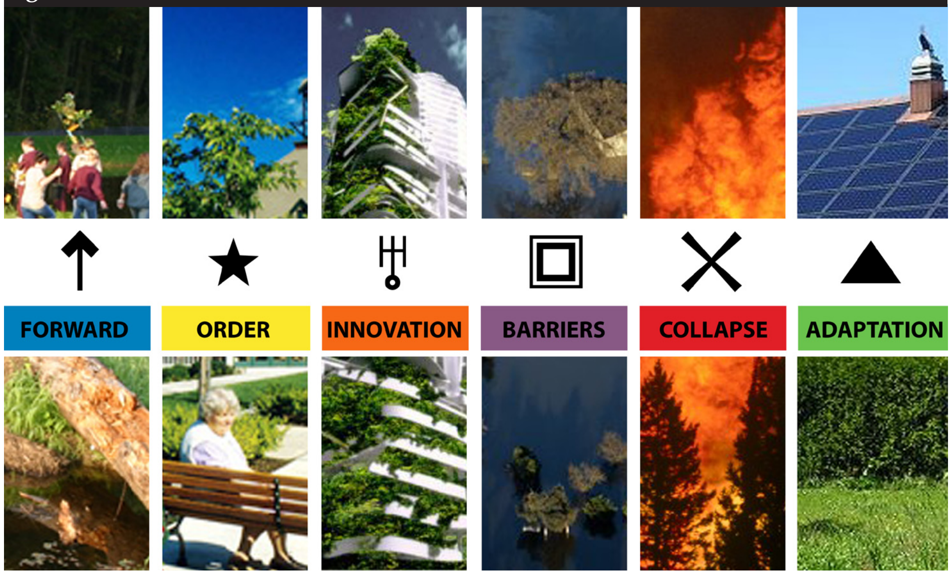
Scenario planning is a systematic method for exploring plausible alternative futures emerging from key uncertain factors affecting the relevant issues. Instead of focusing on a single prediction extrapolated from past trends, scenarios focus on uncertain drivers and expand the assumptions of predictive models to illuminate otherwise unforeseen interactions. Scenarios further highlight future risks and opportunities providing managers with the information needed to assess the effectiveness of alternative strategies.

Over the last two years the Puget Sound Nearshore Partnership's Future Without Workgroup and the Urban Ecology Research Laboratory have engaged more than 100 experts through a series of panel discussions and a workshop in order to develop the final scenarios. The scenarios in this report describe six alternative futures for this region, ranging from economic growth and social and ecological prosperity to economic downturn and ecological collapse when critical thresholds are surpassed and regional resources become heavily strained. The scenarios focus on alternative trajectories for climate change and human perceptions and behavior, and their consequent implications for this region's economy, demography, public health, infrastructure, knowledge base, natural hazards, governance and development patterns. Integrating scientific expertise and creative imagination, the scenarios describe plausible divergent future conditions (Figure 1.1). In a next phase of this project scenarios will be used to establish links between expected future conditions and nearshore ecosystem function.

1 In 2002, The Army Corps of Engineers and the Washington Department of Fish and Wildlife initiated the Puget Sound Nearshore Partnership to recommend a recovery plan for the Puget Sound nearshore (Puget Sound Nearshore Partnership [PSNP], 2004).
2 Restoration is the active alteration of disturbed land to a previous level of structure or function.

3 While the goal of the PSNP is to assess alternative strategies on nearshore ecosystem functions, the goal of this project is focused on the development of successful regional scenarios, which will ultimately lead to a strategic assessment.

Figure 1.1 The six scenarios



Problem definition

The Puget Sound nearshore, like other coastal areas around the world, is being degraded at an alarming rate. One of the main causes of coastal degradation is the concentration of people along the coast. Human activity has caused significant damage to the nearshore ecosystems, both through the direct destruction of nearshore habitat, and by transforming ecosystem functions such as sediment movement (armoring), infiltration (impervious surfaces) and nutrient regulation (sewer discharges). The implications of nearshore ecosystem degradation are great, not only to those aquatic species that reside in those waters, but for the overall ecosystem and human well-being. Salmon, a Pacific Northwest icon, is only one of nine regionally endangered or threatened species that inhabit the Puget Sound nearshore (Fresh, 2006). *E. coli* from human sewage and animal waste concentrates in shellfish and ends up in our food (Weiskel, 1996). The structures built along the shore to protect land properties and homes, over time, result in decreased drift sediment, reduced beach width (Griggs, 2005) and loss of habitat area (Johannessen, 2007). It is estimated that 73 percent of the original salt marshes of the Sound have been destroyed and 33 percent of its shoreline has been modified by development (Gelfenbaum, 2006).

In spite of the growing concerns for the state of nearshore ecosystems and the need for a science-based ecosystem management, there is a of lack agreement within the scientific and policy communities about which strategies to implement in order to restore nearshore ecosystem function (Linkov et al, 2006). Five elements of developing alternative restoration strategies for the Puget Sound nearshore estuaries and beaches help illustrate the applicable usage of scenario planning. First, the complexity of coupled human-natural systems (heterogeneity, non-linearity and emergent properties) make them highly unpredictable. Second, many of the processes underlying nearshore ecosystems are still poorly understood, further limiting the predictability of system response (Lynn, 1998). Third, restoration requires the integration of both social and natural sciences to address the interdependence between human and ecological systems across space and time (Rapport 1998). Fourth, restoration must incorporate an understanding of reflexive human decision-making and behavior into the evaluation of the strategies. And lastly, uncertainty increases the further out we look (Heijden, 1997). Scenario planning is a future assessment strategy specifically developed to integrate complexity and uncertainty into the decision making process. In this project we propose that scenario planning provides scientists with plausible future baseline conditions to adequately assess the implications of alternative restoration strategies.

Scenarios and their utility in future assessments

Scenario planning is an approach to future decision making that extends traditional strategic planning by developing multiple plausible futures. Each scenario represents an account of a plausible future (Peterson et al. 2003). Together, scenarios help direct our attention towards a "handful of plausible alternative directions that contain the most relevant uncertainty dimensions" (Lindgren et al, 2003, p.24). Perhaps what scenarios do best is help expand an organization's understanding of future risk by systematically exploring plausible futures whose risks the organization has not yet considered, let alone thought about strategically (Randall and Ertel, 2005). In many traditional strategic plans, a strategy is conceived before an assessment is conducted and the assessment is utilized to test that strategy. Scenarios assume the future is unknown, and therefore there are no predetermined answers (Hodgson, 2003). Further, scenarios presume that in highly uncertain and dynamic situations there is no singular 'best strategy' but rather a series of strategies which allow an organization to be prepared for different situations (Heijden, 1997). Just like a financial advisor may recommend building a portfolio of investments that is resilient under a changing economy, scenarios help decision makers create a robust portfolio of strategies that can be adapted to changing conditions.

The final scenarios describe region-wide, long term, baseline conditions, and can be utilized to evaluate alternative implementation strategies. While primarily used by the PSNP to evaluate restoration portfolios, the scenarios will allow a broad spectrum of public agencies to test their long range plans against the inherent uncertainty of the future. While the future is unlikely to turn out exactly like any single scenario, the suite of scenarios allows decision makers to explore a wider range of plausible circumstances than are traditionally integrated into long range planning.

For example, consider the following three long term decisions:

- ***Puget Sound Nearshore Partnership:*** Which bulkhead should be removed to reconnect nutrient, sediment and water flow without major damage to nearby residences or sensitive nearshore aquatic communities?
- ***Trust for Public Lands:*** Where should land be purchased to have the greatest benefit on ecological function?
- ***WA Department of Ecology:*** Where should we concentrate our cleanup efforts, to improve water quality without risk of recontamination?

Each decision benefits from exploring the range of plausible trajectories of key driving forces:

- How will the hydrological regime be influenced by climate change?
- Which areas are at greatest threat from flooding and shoreline movement?
- Where will the greatest development pressures be?
- How will public infrastructure for wastewater and runoff be transformed by innovative technology and a doubling population?
- Which forested patches will be critical to maintain for biodiversity?
- What value will society place on ecosystem functions such as clean water, shellfish health and shared public land?

The utility of scenarios comes both from how they address uncertainty of future trajectories and how they handle the interaction among key drivers. For example, the uncertainty of climatic implications on the hydrological regime by 2050 lies not only in the magnitude of change in precipitation, but on the direction of change (i.e.whether this region will experience more or less annual precipitation). Further, we cannot predict the impact of climate change on this region independently from human behavior. The interaction between the two drivers (climate change and human behavior) will create a significantly different outcome for this region than looking at each trajectory in isolation.

Project collaborators

The Puget Sound Future Scenarios is a collaborative project between the Future Without Team, a working group of the Puget Sound Nearshore Partnership (PSNP), and the Urban Ecology Research Laboratory (UERL) of the University of Washington. The Puget Sound Nearshore Partnership is a cooperative effort among U.S. Corps of Engineers and the Washington Department of Fish and Wildlife, working in conjunction with the U.S. Environmental Protection Agency, National Oceanic Atmospheric Administration, People for Puget Sound, U.S. Geological Survey, Washington Department of Ecology, the Salmon Recovery Fund, King County, Washington Department of Natural Resources, Northwest Straits Commission, U.S. Department of Energy, Northwest Indian Fisheries Commission, National Wildlife Federation, Pacific Northwest National Laboratories, Pierce County, Navy Region Northwest, the Nature Conservancy, Taylor Shellfish Company, the University of Washington, and the Puget Sound Action Team (PSNP, 2006A). The development of the Puget Sound Future Scenarios project has involved planners, scientists, and professionals from across the Puget Sound basin.

2. Nearshore Ecosystem Function in Puget Sound

The Puget Sound nearshore ecosystem

In 1988 The U.S. Environmental Protection Agency designated the Puget Sound as an 'Estuary of National Significance' (Goetz et al, 2004). The Puget Sound nearshore ecosystem supports the largest area of remaining estuaries on the West Coast, providing habitats for fish and invertebrates and representing one of the highest areas of primary productivity (Goetz et al, 2004; Gelfenbaum et al, 2006). In addition to its intrinsic values, the Puget Sound nearshore ecosystem provides important cultural, ecological and economic functions. Ecosystem functions supported by the Puget Sound include gas and climate regulation, nutrient cycling and biological regulation, sediment exchange and retention, seed dispersal and pollination, and disease and flood regulation (Leschine, 2007). Cultural values include aesthetics of the views, recreational interest, spiritual connection, and a source of scientific inquiry and knowledge. The Puget Sound Nearshore Partnership has selected Valued Ecosystem Components such as eelgrass, Olympia Oyster and Bluff back beaches to communicate the Puget Sound nearshore's ecosystem functions (PSNP, 2007). These values intentionally overlap human and ecosystem functions not intended to comprise the entire ecosystem network -rather, they are intended to provide examples of links between the focus of PSNP (ecosystem process, structure, function) and human values (i.e. salmon, orcas, shorebirds, etc.) Lastly and perhaps most easily measured, are the economic resources obtained from the Sound. These include direct consumptive goods such as oysters sold and salmon caught, as well as indirect economic gains such as tourism and international trade. While the valuation methods of the Puget Sound nearshore ecosystem are complex the overarching message is clear: Not only is the Puget Sound nearshore a great source of value to humans and nature alike, but behind each singular value stand dozens of critically interdependent values.

The nearshore ecosystem is the shallow water environment of estuaries and marine shorelines, and represents the aquatic interface between air, land and water (Fresh et al 2004) (Figure 2.1). The nearshore zone lies from the top of shoreline bluffs, across the beach, and into the water as deep as light penetrates to the bottom, extending upstream into estuaries encompassing the upper extent of tidal influence (PSNP, 2006). The Puget Sound nearshore ecosystem stretches across 2,500 miles of shoreline, from the Canadian border throughout the Puget Sound and Strait of Juan de Fuca to Neah (PSNP, 2006) (Figure 2.2). The Puget Sound basin is a glacial fjord carved out during the last glacial period about 10,000 to 14,000 years ago (Gelfenbaum, Mumford, Brennan et al, 2006). The basin covers 7,000 km2, fed by eleven major river systems and over 10,000 streams (Goetz, Tanner, Simenstad et al, 2004). The shoreline boasts 4,000 km of beaches making it one of the world's largest inland seas (Goetz et al, 2004).

Figure 2.1 The nearshore ecosystem (image from King County)

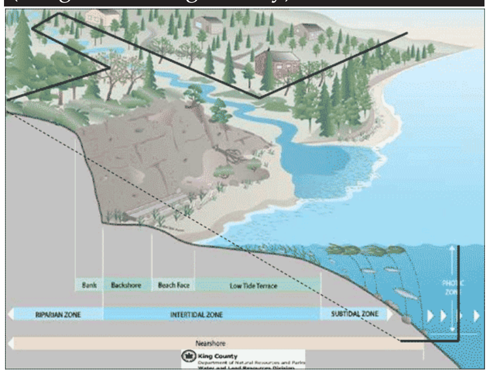
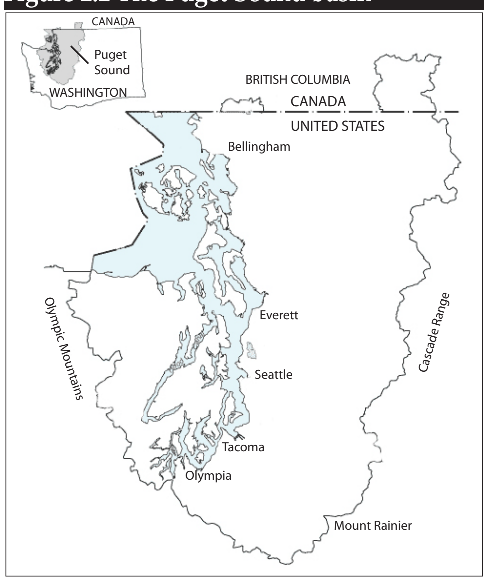


Figure 2.2 The Puget Sound basin



Restoring the Puget Sound nearshore ecosystem

In 1992, the Environmental Cooperation Council (ECC) created the Marine Science Panel to study the trans-boundary environmental problems of the coastal waters of the Puget Sound and Georgia Basin (Lynn, 1998). In the Panel's initial report the Panel identified the loss of nearshore habitat as the most important threat to the health of our marine waters (Lynn, 1998). Further, the Panel concluded that "surprisingly little is known about the quantity and quality of all major habitat types in the nearshore" (Lynn, 1998, p1). Multiple strategies are already in place to help protect the Puget Sound. In Washington State, the Shoreline Management Act regulates development along the shore, the Clean Water Act regulates effluent discharge into public water bodies, and land conservancies like the Trust for Public Lands are buying up land to preserve the current land cover. A more recent phenomenon is converting previously altered shorelines back into functioning habitat. In the United States current Federal initiatives are calling for the restoration of tens of thousands of kilometers of streams and wetlands (Simenstad, 2006). The Puget Sound Nearshore Partnership (PSNP), including more than a dozen state, regional and local agencies, was initiated in 2002 to recommend a restoration plan for the Puget Sound nearshore (PSNP, 2006). In addition, the restoration of Puget Sound nearshore ecosystem function is among the top priorities of a new government agency, the Puget Sound Partnership created in 2008 (PSP, 2007). The Partnership recognizes that such a plan will need to be based on sound science and strategic assessments.

Future assessments and nearshore ecosystem restoration

Developing the recovery plan for the Puget Sound nearshore ecosystem has revealed the complexity associated with restoration initiatives. Early restoration efforts frequently occurred on a very limited scale, altering and repairing specific sites. These efforts focused on recreating structures that were historically found within those sites. Ecological studies have since shown that approaches grounded on objectives of 'static' endpoints for ecosystem structures are ineffective in the long term, and restoration ecologists should instead focus on sustaining the functions of ecosystems (which are largely controlled by the interaction of both structures and processes) (Fresh, 2004). Recent restoration approaches incorporate dynamic goals through adaptive management and multiple trajectories (Simenstad et al, 2006). Further, these approaches focus on the entire landscape or basin, rather than isolated sites. For example, while the nearshore zone is defined by upland bluffs and low water lines, the study of the nearshore ecosystem encompasses the entire network of connections that influence the nearshore zone; an area much broader than the nearshore zone alone.

Ecological managers acknowledge that strategies based on repairing ecosystem functions require a new level of scientific understanding due to the complexity and uncertainty embedded in large scale and long term problems (Simenstad et al, 2006). While scientists have long studied both water and land, the interactions between these two systems are still relatively unknown (Graube, 2006). For one, long term and large area marine processes are poorly understood (UNEP, 2006). Scientists have limited knowledge of nutrient cycling, past and current coastal habitats, the biodiversity of marine life and major climatic patterns like the El Nino and Pacific Oscillation (UNEP, 2006; Snover et al, 2005; Gelfenbaum et al, 2006). While Geographic Information Systems (GIS) and remote sensing have facilitated extensive inventories, process based knowledge about how systems function and the extent of modifications remains lacking (Finlayson, 2006). Further, peer reviewed research on the Puget Sound nearshore ecosystem processes is limited (Gelfenbaum et al, 2006; Finalayson, 2006). At present, our scientific understanding of the processes and their interactions in nearshore ecosystems is insufficient to assess the potential success of ecosystem restoration (Gelfenbaum et al, 2006).

In addition to the complexity brought on by the dynamic interactions among structures, processes and functions, and the increased uncertainty due to a lack of information on nearshore ecosystems and the incorporation of large-scale landscapes and long term management horizons, the effectiveness of restoration is made more complex by the increasing interference of human activities. Most visibly, humans disturb natural systems, and therefore their interactions with ecosystem processes cannot be ignored. Over the next fifty years people will likely continue to build homes along the shore, build roads and infrastructure, and at the same time consume food from the nearshore zone and recreate in its waters. Restoration initiatives must integrate not only how human stressors influence nearshore processes, but how changes in ecosystem functions might conversely alter human activities. Currently, few peer-reviewed studies exist to document the relationship among social, cultural and economic values and their influence on nearshore ecosystems. While little data exists to describe these relationships, long term restoration projects cannot succeed without incorporating the human dimension in ecosystem health (Goetz, 2004).

3. Scenario Planning

Why scenarios?

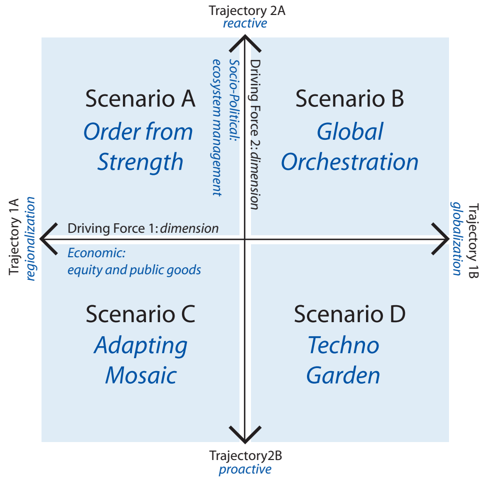
Our ability to predict future conditions is critical to inform management and planning decisions. However, long–range futures are difficult to predict due to the complex interactions and uncertainty of important driving forces. Thus our assumptions about predictability and uncertainty ultimately influence our ability to conduct effective future assessments. While past observations are important to inform our expectations of the future, the interactions among uncertain driving forces may create novel conditions that fall outside the expected uncertainty range. Scenarios provide an effective approach for planning and decision making by addressing the expanded range of uncertainty. Scenarios illuminate opportunities and risks by exploring the most divergent and relevant plausible future conditions that can emerge due to the interactions of multiple uncertain driving forces.

Visioning and forecasts are traditionally used in strategic planning as tools for envisioning desirable futures and projecting current trajectories. Scenarios go beyond visions and predictions by looking at a complete suite of plausible, divergent and compelling futures. Table 3.1 describes the main differences among forecasts, visions and scenarios in terms of their future views, assumptions and approaches. Scenarios are appropriate to tackle long time frames and complex environments. When the future is dominated by uncertainty, scenario planning allows decision makers to consider multiple plausible futures generated by the interactions of uncertain driving forces.

Future View	Their beliefs	Their Approach	Tool
Extrapolators	Believe that the future will represent a logical extension of the past.	Identify past trends and extrapolate them in a reasoned and logical manner.	Forecasts
Goal Analysts	'The future will be determined by the beliefs and actions of various individuals, organizations and institutions, and therefore the future is modifiable by these entities.	Project the future by examining the stated and implied goals of various decisions makers and trendsetters.	Visions
Scenario Planners	The uncertainty and complexity of future conditions is largely controlled by the interaction of the most important and uncertain key driving forces affecting a focal issue.	Develop multiple divergent, relevant and plausible scenarios to illustrate risk and opportunities of strategies	Scenarios

Table 3.1 Forecasts, visions, and scenarios

Figure 3.1 Anatomy of a scenario
(Millenium Ecosystem Assessment, 2003)



What is scenario planning?

Scenario Planning is a strategic planning approach for making long-term decisions. Rather than focusing on the predictions of a single outcome, scenarios examine the interactions of various key uncertain factors that may create alternative plausible futures (Figure 3.1). Scenarios are hypotheses of alternative plausible futures designed to highlight the risks and opportunities and assess the effectiveness of alternative strategies. The suite of scenarios incorporates the most divergent future conditions in order to rigorously and systematically test the efficacy of alternative strategies. Simply put, scenarios help us ask: If the future turns out differently than originally anticipated, will our strategy still work?

Scenarios are useful when the uncertainty is high and the risk associated with forecasting the wrong trajectory is great. Scenarios start by identifying the drivers of change influencing the issue of interest (focal issue), and providing insight about the direction for the assessment process, i.e. what questions should managers be asking. Then, by considering the uncertainty of key driving forces, scenarios reveal the implications of potential future trajectories. Scenarios challenge managers' assumptions about the future in a way that a single forecast cannot. Scenario planning is based on the premise that by exploring the most divergent plausible future conditions, managers can illuminate options and risks that would otherwise be hidden or dismissed. While the scenario development process is significantly more complex and resource intensive than a singular forecast, the benefit gained is the ability to assess the robustness of alternative strategies under plausible future conditions.

Scenario planning emerged in WWII when the US Air Force needed to anticipate what its opponents would do (Lindgren et al, 2003). A decade after the war, Herman Kahn brought scenario planning into the business world through the Hudson Institute (Schwartz, 1991). Perhaps the most well known use of scenarios comes from Pierre Wack's work with Royal Dutch Shell. Wack helped his managers believe and prepare for a world where oil prices would increase dramatically (Schwartz, 1991). Soon after Shell's success scenarios became a common strategic tool. However, while the free form process of early scenario planning led to original thinking, it kept the connections to decision making loose (Ringland, 1998). Only during the last two decades has a more structured approach emerged. The Puget Sound Future Scenarios are based on the Intuitive Logics School (ILS) method and practiced by the Stanford Research Institute, reflecting a structured approach to scenario writing true to the original intent (Ringland, 1998).

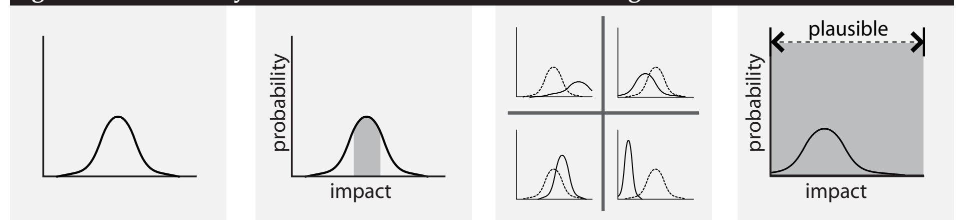
While scenarios have been most heavily used within the business environment, recent ecosystem management projects have been utilizing scenario planning's ability to portray complex information and an uncertain future. Some of the most impressive projects include the Millennium Ecosystem Assessment (MEA), the Intergovernmental Panel on Climate Change (IPCC), California's Water Plan 2005, and the Northern Highland Lakes District research (MEA 2003; IPCC 2000; Department of Water Resources 2005; Peterson et al 2003). Published reports point towards an intensive and demanding process, a collaboration with a diverse set of experts, and an ability to creatively see risks and opportunities that were not obvious at the onset of the study (MEA, 2003; Peterson et al, 2003).

How to develop scenarios

At first, scenarios may seem like stories that are creatively written, much like novels. But while there are several variations on how to conduct scenario planning, scenarios differ from fictional stories by being structurally and explicitly grounded in scientific knowledge. Scenarios focus on key drivers, complex interactions and irreducible uncertainties in order to generate the futures within which we can assess alternative strategies. According to the ILS method, scenario planning generally involves eight key steps (Schwartz 1991; Peterson et al 2003; Lindgren et al, 2003) (Appendix A: 8 Steps of Scenario Building):

1. Identify focal issue or decision
2. Identify driving forces
3. Rank importance & uncertainty
4. Select the scenario logics
5. Develop the scenarios
6. Select metrics for monitoring
7. Assess impacts for different scenarios
8. Evaluat alternative strategies

Figure 3.2 Probability distributions and scenario building



Probability distribution as predicted by past observations. | The probable impacts identified under predicted distribution. | hypothetical distributions of alternative scenarios. | all plausible impacts assessed by suite of scenarios.

Dealing with uncertainty

Scenarios allow planners and managers to fully consider the uncertainty associated with key drivers of change into the assessment process. The methodology for integrating uncertainty distinguishes scenarios from other future assessment approaches. The two main differences include the interactions among multiple uncertainties and the selection of drivers beyond the manager's control.

Predictive models are developed based on previous observations. Uncertainty is estimated based on known probability distributions of key drivers. Models work very well when the future's uncertainty can be described by past trajectories and associated fluctuations. Model predictions are limited when the future is highly uncertain and when driving forces exhibit non-linearities, discontinuities, thresholds and emergent properties. Forecasting future trajectories is further complicated when multiple driving forces simultaneously change in unpredictable ways. While we can estimate the uncertainty associated with one driver when we know its probability distribution, the way uncertain factors interact may generate unpredictable outcomes and surprises. Coupled human-natural systems are highly uncertain. Furthermore ecosystem functions are highly context driven, and the uncertainty associated with future trajectories can create future conditions that do not resemble past occurrences.

Scenarios expand the assumptions of forecasting by considering hypothetical boundary conditions generated by interactions of driving forces and their range of uncertainties, and testing these hypotheses with expert knowledge. For example, we can consider the full spectrum of future conditions under alternative climate change scenarios and their interactions with alternative technological futures. We may not be able to accurately predict what will happen when we simultaneously consider the full spectrum of alternative rates of technological change and magnitude of climate impact, but we can isolate alternative trajectories and ask experts to hypothesize about the potential outcomes of those interactions. Scenarios function by combining scientific knowledge with expert judgment to help decision makers look at novel interactions of uncertain drivers. The key benefit of the alternative scenarios comes from anticipating impacts that lie beyond the probable estimates based on past observations alone (Figure 3.2).

Scenarios look at a different type of uncertainty than looked at in traditional future assessments because they focus on drivers that lie outside the immediate control of decision makers. Several 'alternative futures' studies explore different projections by focusing on drivers that reflect the strategic decision being made. For example, many planning studies ask how the region may sprawl under alternative growth regulations (USGS, 2004; NASA, 2004). Scenarios instead focus on drivers that would alter the efficacy of the strategy. For example, global climate impacts, a collapsing economy or natural hazards could directly and indirectly affect the nearshore ecosystem condition, but cannot be controlled by the Puget Sound Nearshore Partnership. While other future assessments simplify uncertain outcomes of drivers outside their realm of influence, scenario planners specifically integrate this type of uncertainty in order to robustly test the efficacy of their decisions. The problem with simplifying these uncertainties is that it prevents decision makers from being able to test their strategies against factors that may be most influential in affecting the outcome of their plan. The trick is identifying the most relevant uncertainties to focus on.

The benefits and limitations of scenarios

Scenario planning is not an alternative to other planning approaches such as visioning and extrapolation. They each have different objectives. For example, when the future is relatively certain extrapolation can be a much more efficient method. Scenarios work best when the future is highly uncertain and are helpful when there are multiple key uncertain drivers simultaneously impacting the future. Scenarios can also be a useful communication tool, especially in bridging the gap between scientists, policy makers and the general public.

While the benefits of scenarios are great, so are the investments. In addition to a considerable investment of time and energy, scenarios pose challenges to managers who are more comfortable with traditional strategic planning. The amount of time required to conduct the various steps can be frustrating to experts who believe forecasting can provide a sufficient range of conditions in a more efficient manner. Further, scenarios combine facts with expert values (Schwartz, 1991). The incorporation of values can be uncomfortable to scientists who generally rely on verifiable facts. Finally, scenarios depend on knowledge that currently lies at the fringe, as their purpose is to transform our knowledge into new perspectives. This transformation requires planners to suspend their judgment long enough to appreciate new insights. When this transformation occurs it "often generates a heartfelt 'Aha'", but more often than not, scenarios fail at achieving this goal (Schwartz, 1991, p100).

Successful scenarios are easy to communicate, interpret and learn from: they're provocative, pushing the reader to think about the 'unthinkable'; they're plausible, making use of real world facts and models to construct futures that could actually happen; they're internally consistent, looking at the context and examining changes across a wide spectrum of concerns; they're divergent, acknowledging different possibilities; and they're open, allowing readers who are not widely involved with the issue to think about their own choices and plans within each future (Cascio, 2004).

Scenarios are particularly effective when they surprise and challenge participants in the scenario process, enabling them to 'think the unthinkable' (Schwartz, 1991, p100 quoting Herman Kahn, 1965). Scenarios have been developed for over fifty years, and numerous organizations and publications have attempted to define and refine the structure and process of scenario planning. Many have produced insightful alternatives that allowed practitioners to anticipate future uncertainties and plan accordingly. However, there have also been many scenarios that merely reconfirmed preconceptions and prejudices (Ratcliffe, 2000). Despite the structured methodology, the development of scenarios remains more an art than a science. In the end, the success of scenarios lies in the hands of its participants.

4. Scenario Methodology

Process[4]

Scenario development for the Puget Sound Future Scenarios has been an on-going process for the last two years. The steps identified in this process generally follow a classic 8-step scenario development technique developed by Stanford Research Institute and more recently applied by the Millennium Ecosystem Assessment. In the first year the UERL and PSNP teams focused on laying out the scenario parameters including the focal issue, time scale, driving forces and scenario logics. The second year has involved developing the final scenario narratives. The methodology presented below describes an integrative, iterative, and systematic process for ensuring the final scenarios are relevant, plausible, divergent and internally consistent.

Participating Experts

The development of scenarios requires the input and collaboration of a diverse set of expertise. It is our assumption that no one person or panel of scientists can effectively create scenarios on its own. The most fundamental emphasis of scenarios is to challenge initial assumptions formulated by past observation. Therefore the integration of different experts, representing a multitude of disciplines and backgrounds, and having the opportunity to both inform and reflect on the process is critical to the success of the final scenarios. Further, scenario development requires the active involvement of a specific type of expert--experts who have knowledge of key driving forces that are powerfully influencing this region's future; who are simultaneously comfortable with accurate scientific data and a high level of uncertainty associated with a long term outlook; and who are able to communicate across disciplinary boundaries in order to capture the interactions among key driving forces over a dynamic array of spatial and temporal scales.

To develop the Puget Sound Scenarios, the UERL has involved 152 experts (Appendix B: Expertise involved), representing more than 88 agencies and bringing together disciplines ranging from atmospheric science to economics and filmmaking. The final scenarios reflect three iterations of input, synthesis and feedback from this group of experts. Each expert has contributed hours of input, from preparing for and attending meetings to providing follow-up feedback on materials.

4 Developing the scenarios is one part of a larger nearshore assessment process. The final scenarios will work in concert with modeling and assessment to translate among qualitative narratives, integrated models, and metrics of nearshore ecosystem health. This report focuses only on the development of the scenarios and not the modeling and assessment.

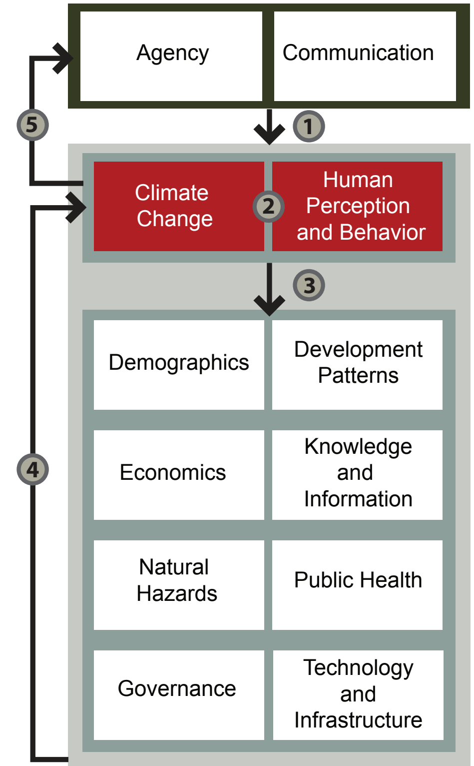
Interviews

The most intensive aspect of scenario development is conducting interviews, providing the chance to incorporate diverse scientific and policy backgrounds, and to test assumptions about the relationships among key drivers. Overall the scenario development process has involved 30 interviews, including phone interviews, individual meetings and panel discussions. Two phases of interviews with the experts allowed the UERL to formulate initial hypotheses about the trajectories of multiple drivers and their interactions, develop the scenarios and refine the hypotheses. The first phase of interviews identified the key drivers of change influencing this region's future with a focus on the nearshore ecosystem. The second phase of interviews, organized in panels of experts representing the final set of selected drivers, constituted the basis for developing the final scenarios by identifying key dimensions and trajectories for each driver and interactions between the drivers. The full details of the interviews are included in Appendix C: Handouts for participating experts.

The objective of the first phase of interviews was to capture the breadth of issues influencing the nearshore ecosystem. The final selection of experts was organized around their disciplinary background to ensure effective exchange of ideas and a focused discussion. Groups included physical scientists, biological scientists, social and behavioral scientists, planners, the private sector, non-profit organizations, public agencies and advocacy groups for minority populations. Interview questions primarily focused on drivers and changes affecting the state of the Puget Sound region in 50 years, and laying out the assumptions behind those relationships. Interview notes were coded to cluster keywords of changes and drivers into a manageable set of key driving forces, while still maintaining the multiple dimensions of each cluster.

The second phase of interviews was comprised of panel discussions intended to refine the scenario logics and finalize the scenario narratives. Overall the UERL identified over 200 experts, contacted over 100 different agencies, and personally interviewed 53 regional experts representing 12 expert panel teams. Expert teams represented the key driving forces identified by the first phase of interviews. Within this set, a 'core team' joined the two panels of the 'key driving forces' directing the scenario logics[5]. The core team met both at the beginning and end of the second phase. Their initial responsibilities included refining the scenario logics in order to depict the most relevant and divergent alternative futures and formulating the scenario hypotheses for each scenario. At the end of phase 2 the core team provided a final check to ensure the internal consistency of the scenarios narratives. Supporting panel discussions representing the remaining driving forces identified by the initial interviews met to define each driving force, identify critical dimensions of the driving force, and compare future trajectories of each dimension under the scenario hypotheses developed by the core team. In addition two panel discussion involved agency and communication experts whose objective was to ensure the final scenario's usability (Figure 4.1).

Figure 4.1 Panel disucssions



Workshop

In the fall of 2006 the Urban Ecology Research Lab led a one-day workshop to develop the initial scenario logics. Thirty-eight people attended the workshop, including representatives from academia, public agencies, the private sector and non-governmental organizations. Several academic disciplines were represented including geomorphology, geography, climatology, oceanography, ecology, biology, urban planning, business and economic development. The primary objective of the workshop was to select the most important and uncertain driving forces that would define the scenario logics. This step of the scenario process represents not only the most critical decision influencing the relevance and divergence of the final scenarios, but is also a decision that cannot be made independently by the diverse groups. The workshop provided a forum for participants to exchange knowledge about identified driving forces, to discuss potential merits of how the driving forces are ranked, to develop a shared agreement of which two drivers are the most important and uncertain, and to begin to develop hypotheses about the implications of alternative future trajectories.

5 Scenario logics consist of the two most uncertain and important driving forces identified within the workshop.

Synthesis

Between each step in the scenario development process, input from the experts was synthesized into communicable products leading to feedback from experts and a movement to the next step. The synthesis was largely conducted by the Urban Ecology Research Team including Dr. Marina Alberti and Michal Russo. The major synthesis tasks included coding and interpreting interview data. The first phase interviews were synthesized to identify the driving forces, clustering over 300 keywords into 10 aggregated drivers and developing a fact sheet to communicate the essential importance of each one. The second phase of interviews, or panel discussions, were synthesized to develop internally consistent scenario narratives integrating feedback from various teams. Based on expert input, a relational database was developed to summarize the relationships among selected dimensions of the key drivers, such that trajectories of indicators of each dimension could be developed under each scenario.

Scenario development

The ILS process generally includes eight steps. This report focuses on steps 1-5, which aim at the development of the scenarios[6].

Focal issue

The focal issue represents the question about the future that an organization is confronting. An effective focal issue must be collectively agreed upon by the leading organization and participating experts (Peterson et al 2003) and must include the articulation of both the temporal and spatial extent of the project (Schwartz, 1991). A common problem with large-scale assessments comes from losing sight of the objective of the project as the development of the analysis proceeds (Lingren et al 2003). Articulating the focal issue at the onset brings clarity to project goals and helps the process stays on track. The Future Without Workgroup (FWW) provided the initial focal issue for the project: The 'Future Without' focal issue is to assess the future of the Puget Sound nearshore ecosystem assuming a large scale restoration project does not occur. A series of roundtable discussion between the FWW and the UERL helped refine the focus of the project. The first phase of interviews with regional experts provided feedback on the focal issue, and helped refine the selection of relevant questions.

6 Future phases of this project will address steps 6 and 7, selecting metrics for assessment and assessing the impact of different scenarios respectively. The 'Future Without' focal issue is to assess the future of the Puget Sound nearshore ecosystem assuming a large scale restoration project does not occur. The presupposition of 'no action' renders the last step of scenario planning, evaluating alternative strategies, irrelevant and was therefore removed from our process.

Driving forces

Driving forces represent key variables that influence a phenomenon or issue that constitutes the focus of a decision, the focal issue. Some common driving forces include demographics, economics, and science and technology. The final selection of driving forces ultimately defines the relevant parameters with which to describe the scenarios. Identifying the driving forces represents the most research-intensive aspect of scenario planning, requiring both a thorough investigation of the literature and dialogue with various experts. For the Puget Sound Scenarios, interviews with regional experts identified a wide spectrum of changes and drivers influencing this region's future. Interview notes were coded to cluster keywords into a final set of driving forces. For each driving force a definitional fact sheet was developed by the UERL team. At the workshop, participants received the factsheets and provided feedback on the selection and definition of the final set.

Uncertainty and importance

The final selection of driving forces is ranked in terms of each driver's level of uncertainty and importance in relation to the focal issue. This step formulates the direction of the final scenarios by identifying the most divergent and relevant conditions influencing alternative futures. Importance can be defined as the magnitude and extent of impact a driver has on the focal issue, or the cascading effect of the driving force on other drivers. The uncertainty of a driving force can be defined as having low predictability and a wide range of possible outcomes. Further, within the scenario-planning framework, uncertain driving forces generally represent drivers that are not readily controlled by the leading organization. The ultimate selection of 2 key driving forces in the Puget Sound scenarios relied on the ranking and agreement of workshop participants. Initially, interview experts discussed the importance and uncertainty of driving forces and their input was shared with workshop attendants. The final agreement over the selection of the two drivers came from individual, team and, lastly, a whole room ranking of each driving force. The driving forces with lower importance and uncertainty rankings continued to support the development of the final scenarios[7].

7 For consistency, the term 'key driving forces' represents the two most important and uncertain driving forces and the term 'supporting driving forces' represents the remaining driving forces with lower importance and uncertainty rankings.

Scenario logics
The interaction among the key driving forces creates the frame for the scenario logics. For each driving force scenario planners select one or more relevant dimension and identify the key uncertainties that characterize its trajectories. For example, assuming demography is one of the two most uncertain and important driving forces, a key dimension could be population growth, and two alternative trajectories could be fast or slow growth. The logics are initially defined by crossing the axes representing the selected dimensions such that four frames are created, each representing a divergent yet plausible scenario for which defining parameters are controlled by the interaction of the two drivers' future trajectories. However, if more than two key driving forces or more than one dimension of each driving force are identified as having a critical influence on isolating alternative future conditions, than the process ends up having more than four scenarios. In theory the scenario development process can produce a large number of scenarios. A key to a successful process is to iteratively refine the scenario logics in order to ensure that the final set of scenarios represents the most divergent and relevant alternative future conditions.

The final scenario logics for the Puget Sound scenarios underwent a series of iterations incorporating critical expert feedback. The initial logics were developed during the workshop. Nine teams developed nine sets of logics by crossing the same key driving forces. After the workshop the UERL looked for redundancy and inconsistencies within the logics and synthesized the 9 sets of into one set, incorporating two dimensions for each driver. Lastly, the core team, representing experts from the disciplinary fields of the key driving forces refined the synthesized set. This team of 14 regional experts re-defined each driver's dimensions, selected the most plausible interactions among the drivers, and identified divergent future trajectories of each dimension in order to develop the final scenario logics.

Scenario Narratives
The scenario narratives represent the final plot of the scenarios, containing detailed information on the future condition. Each scenario is developed by exploring the implications created by the interaction of the two key driving forces. Further, once the initial defining conditions are described, scenario planners can begin to articulate the trajectories of the other driving forces characterizing each scenario. The major goal of developing the scenario narratives is writing internally consistent and compelling stories that inform manager's view of future opportunities and challenges in relation to the focal issue. The Puget Sound scenarios relied on four main elements to develop the final narratives: key drivers, trajectories of the supporting drivers, storylines and alternative system states. The next section describes the objective and approach underlying each element.

The four elements used to synthesize the final scenarios
Key drivers
The key drivers represent the most important and uncertain driving forces influencing the focal issue. Scenario planners develop hypotheses about how each key driver (or more accurately a specific dimension of that driver) affects the future trajectory of each supporting key driving forces, either directly or indirectly. Key drivers were originally selected during the workshop and then refined by a core team of experts representing the two key driving forces.

Supporting Trajectories
Additional driving forces were used to describe the scenarios. Participating experts within panel discussions identified critical dimensions of their respective driving force, and a set of potential indicators to describe the trajectories of each diver under each scenario. Specifically, experts were asked to identify dimensions that have been previously analyzed (such that information is available to assess current status and future trends); that are relevant (to the scenarios and the nearshore ecosystem); that are uncertain (at least two alternative trajectories exist for this dimension for this region over the next fifty years); and that are not-highly correlated (such that the three dimensions measure very different attributes of the driving force).

The final future trajectory for each indicator under each alternative scenario was extrapolated from current trends. Overarching principles guiding the relationship among multiple future trajectories emerged from the panel discussion. These overarching trajectories formed a strong feedback loop to the original hypotheses, and helped shape the narratives of each scenario. Future trajectories are hypothesized based primarily on the influence of the key drivers, secondly by the trajectories of the other supporting indicators, and thirdly by the other dimensions of that driving force. These trajectories provide essential details filling the plot of each scenario, and ultimately leading to internally consistent and compelling scenarios.

Storylines

A third element of the scenario development came from the storylines. Scenario development is rooted in a common set of archetypal future worlds: worlds that evolve gradually, worlds influenced by a strong push for sustainability goals, worlds that exploit nature, and worlds where new human values and forms emerge (MEA, 2003). These archetypes represent the storylines for each scenario, i.e., the underlying theme or plot that synthesizes our assumptions about the future and reflects the basic premise behind each narrative. The Puget Sound Future Scenarios' storylines draw heavily from the past scenario precedence, including the Millennium Ecosystem Assessment, Peter Schwartz' The Art of the Long View (1993), Robert Costanza's Visions of Alternative Futures and their Use in Policy Analysis (2000) and the Northern Highland Lake District Scenarios (Peterson, 2003). The storylines are created by combining two essential pieces of the plot, our assumption about the worldview of society within the scenario and whether we are optimistic or skeptical about the validity of the particular worldview. Together, these pieces of the storyline help strengthen the linkages between the initial hypotheses of the key drivers and the assumptions of the supporting driver's future trajectories.

The storylines are described using four key elements: worldviews, societal emphasis, human-nature relationships, and future outlooks. Worldviews reflect the general beliefs of society about how the world works. Worldviews are dynamic, changing from one culture to another and from one time period to another. Some well known past and current worldviews are that the world is flat, that god will punish us if we sin, that humans evolved from apes, and that mass can neither be created nor destroyed. For these scenarios we combined global worldviews about the main emphasis in society (MEA, 2003) with specific human to nature relationships (Holling et al, 2002). The main societal emphasis reflects the approach society relies on more heavily in order to solve problems, including technological innovation, free market enterprise, collaborations, policy and regulations or new knowledge. The human-nature relationship can be described as how society (in aggregate) views humans' relationship to nature, whether functions are interdependent or independent, whether humans can (re)produce nature, whether nature is there for humans to consume, or humans are intended to steward nature. Future outlook on the other hand is the implicit decision in scenario building about whether or not that worldview is actually 'true'. If the optimists are right, and the worldview is correct, the scenario will reflect a future where society will prevail and positive changes are on the horizon. If the skeptics are right, and the worldview is incorrect, the scenario will likely reach a crisis.

System State

The last element, the system state, communicates the level of resilience and types of pressure within each scenario. This element helps assess the extent to which the final scenarios are divergent in terms of the opportunities and challenges they pose for nearshore ecosystem restoration. Resilience[8] is defined as the capacity of an ecosystem to withstand disturbances without shifting to a qualitatively different state (Carpenter, 2001). The more resilient a system, the easier it can bounce back and rebuild itself after a perturbation. Sources of pressures refer to the magnitude and type of pressures that the region may experience under the conditions of each scenario. A pressure is generally a form of distress that focuses the attention and consequent financial investment and regulatory emphasis within a society. Some examples of pressure can include natural or man-made hazards, economic decline and wealth distribution, health and resource availability, corrupt governance, inadequate reform and infrastructure failure. Each type of pressure will inevitably have a different influence on the regulatory emphasis and financial investments, and thereby each may have significantly different implications for restoration management in this region. For example, an economic recession may distract political attention from ecological issues, and may actually lead to loosened regulations attempting to draw in economic growth. On the other hand a public health epidemic may heighten societal awareness of ecological implications on human welfare and lead to larger investments in ecological restoration efforts. System state variables were gathered from interviews with participating experts (in both phases of the project) and from relevant research publications.

5. Driving Forces

Overview

Driving forces are the main ingredients for scenario planning, describing factors or phenomena which alter the future trajectory in significant ways. Assumptions we make about the future often reflect changes we see within our environment, though these changes represent only the tip of an iceberg. A driving force represents the whole iceberg. By identifying and discussing the driving forces significantly influencing future conditions, scenario planners can make explicit the assumptions behind the scenario narratives. This section describes ten driving forces identified by participating experts, including two key driv-

8 In this report resilience is specifically referring to ecosystem as opposed to engineering resilience as described by Carpenter, 2001)

ers: climate change and human perceptions and behavior, and eight supporting driving forces: demography, development patterns, economy, governance, public health, natural hazards, knowledge and information, and infrastructure and technology.

Each of the ten driving forces combines the input from the first phase of interviews into a multi-faceted compendium, containing a clustering of similar drivers and the changes associated with them. In the second phase of panel discussion each driving force was further refined by selecting three to four critical dimensions and consequent indicators of that driver (Table 5.1). The following section includes the definition of each driving force and its relevancy to the focal issue as well as descriptions for each of its dimensions in terms of the selected indicator (in parenthesis), its current status and projected future trend.

	Driving Force	Dimension	Indicator
Key Drivers	Climate change	Temperature	Temperature
		Precipitation	Precipitation
		Fluctuation	Fluctuation
	Human Perceptions and Behavior	Individualism / Collectivism	Group scale of sharing
			Level of congruence
		Future Valuation	Discount rate
			Long-term public investments
Supporting Drivers	Demography	Population growth	Rate of growth
		Age Structure	Age distribution at 5-year intervals
		Migration	In-migration as % of pop
	Development Patterns	Intensity of Development	Number of people per impervious area
		Configuration	Forest Aggregation Index
		Diversity and Fit	Walkability
		New Development Growth Rate	Number of housing permits added each year
	Economy	Economic Growth	GDP growth rate
		Economic Inequality	Gini index and Lorenz curve
		Stability of Economy	Percentage of industry sector contribution
		Trade Dependence	Import / Export Dollars
	Governance	Leadership (Strength & Effectiveness)	Number of bills introduced and passed into law
		Locus of Power	Number of decision makers; type of interactions
		Types of Partnerships	Influence of public, private, non-profit, academia partnerships
	Knowledge and Information	Educational Attainment	% of population 25+ with a high school (HS) degree; a Bachelors or higher (BA+)
		Investment in Education	Spending per capita for K-12 and higher
		Accessibility	Access to knowledge and information
	Natural Hazards	Vulnerability	Spatial distribution of natural hazards
		Magnitude of Events	Cost of Natural Hazards
		Frequency	# of hydrologic disasters per year
	Public Health	Health Status	%self assessed poor or fair health
		Resource Distribution	% without health insurance
		Resource Abundance	Acres of shellfish growing area and farmland
	Technology and Infrastructure	Connectivity	Connectivity of transportation, energy, waste (water and solid), and water (drinking and storm) infrastructure
		Investments	Expenditure on highways, transit, electric, gas, waste, sewer, and water
		Type of Infrastructure	Dominance of rigid vs. adaptive technology

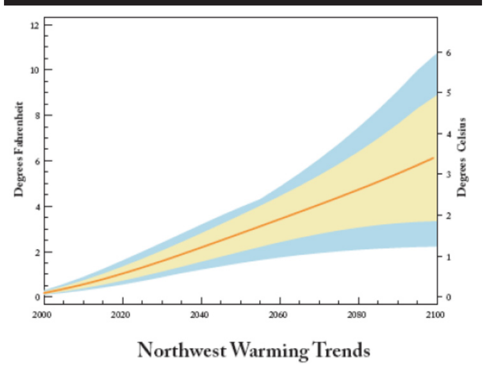
Table 5.1 Driving forces dimensions and indicators

CLIMATE CHANGE[9]

Climate variability in the Puget Sound basin is regulated by interactions between seasonally varying atmospheric circulation and the region's mountain ranges (CIG, 2007). For example, two thirds of the region's precipitation is captured during six months of the year and falls west of the Cascades (CIG, 2006). Over the last century scientists have observed increasing changes in this region's (and global) climate. Some climate variability can be attributed to natural fluctuations including both El Niño/Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) phenomena. In addition to, but not independent of this natural climate variability, is human influenced climate change. During the 20th century the average annual temperature of the Puget Sound region warmed by 2.3degF (a rate substantially greater than the global warming trend, 1.1degF)(Ibid). One third of the observed Pacific Northwest warming trend in winter (1900-2000) seems to be a result of natural climate variability; the rest is attributed to human influenced climate change.

Even if we stop emitting CO2 today, greenhouse gases currently in the atmosphere have locked in future warming into the global system far into the future. The Climate Impacts Group has downscaled global climate models to help predict temperature and precipitation trajectories for the Pacific Northwest until 2100. In general, models project an increase in average annual temperature on the order of 0.2-1.0degF per decade with increases across all seasons (Figure 5.1). While there is less certainty around precipitation changes, most models project decreases in summer precipitation and increases in winter precipitation. In addition, much of the winter precipitation will occur as rain as opposed to snow.

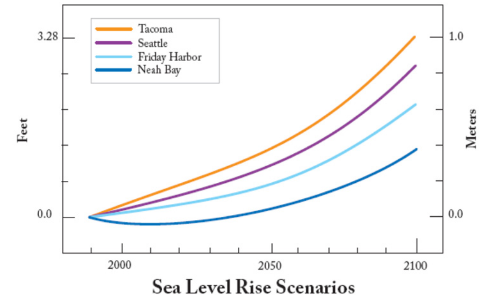
Figure 5.1 Warming trends
(Snover et al, 2005)



Changes in temperature and precipitation have cascading impacts on numerous Puget Sound resources including sea level rise, snowpack, streamflow, water quality, forests, agriculture and fisheries, hydropower production, water supply systems and flood and storm management. There is still great uncertainty around these impacts especially in regards to their magnitude, their interactions, and their temporal and spatial distribution. The following are general hypotheses developed by the Climate Impact Group about potential impacts:

Sea level rise

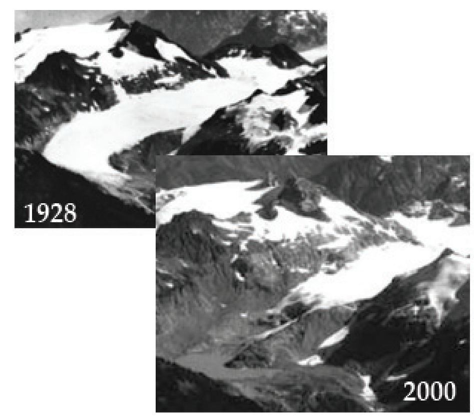
Figure 5.2 Sea level scenarios
(Snover et al, 2005)



- Sea level rise will cause permanent inundation in low-lying areas of the Northwest coast, accelerated erosion at base of bluffs and shrinking wetlands.
- Freshwater ecosystems will be increasingly vulnerable to saltwater intrusion and eventual conversion to saltwater ecosystems. Saltmarsh habitats are predicted to increase under all CIG scenarios.
- Sea level rise impacts different regions differently due to vertical land movements (subsidence, uplift, sedimentation, and marsh accretion). Within the Puget Sound, the southern areas are subsiding more than northern areas. In Seattle, for example, the land is subsiding at 1.4mm per year, roughly doubling global sea level rise projections[10] (Figure 5.2).
- Increased landslides are associated with wetter winters
- Wind patterns may accelerate impacts of sea level rise by as much as 8".

Snowpack

Figure 5.3 Snowpack change
(Snover et al, 2005)



- Rising temperature will reduce mountain snowpack (Figure 5.3)
- Snowpack functions as a wintertime freshwater storage, increasing snowmelt will decrease summertime water availability.

Streamflow

- Rivers that derive flow from snowmelt will see reduced summer flows, increased winter flows and earlier peak flows.
- Rain-fed stream may see increased wintertime flow due to increases in winter precipitation

9 This section has been written based on information provided on the Climate Impact Groups' website (CIG, 2007).

10 There are currently questions about whether subsidence and uplift rates are linear in time and space (Canning, 2007).

- Transient (snow/rain) watershed zones are most vulnerable to temperature influenced flow changes.

Water quality

- Warmer summer water temperatures may exceed critical thresholds
- Lower summer streamflows may increase juvenile salmon mortality rates
- Salinity regimes and stratification will be effected by saltwater intrusion from seal level rise
- Nutrient levels will be affected by changing temperature regimes, increased peak flows, and changes in dissolved oxygen.
- Dissolved oxygen levels at depth could decrease, increasing hypoxic conditions in bottom water.

Forests

- High altitude forests will expand upward into meadows while low altitude forests may come under increased drought stress.
- Tree growth and regeneration will likely improve at high (currently snowy) elevations and diminish at low elevations.
- The risk of forest fires may increase due to effects on vegetation structure and soil moisture.

Hydropower

- Hydropower production capacity will increase in the winter and decrease in the summer.

Agriculture and Fisheries

- Management of fisheries and agriculture are predicated on observed historical patterns of temperature and precipitation. Each sector has adapted to the timing, length, range, amount and frequency of these regimes as experienced in the past. Changes in both the temperature and precipitation regime may alter the optimal management strategies for these resources.
- Many crops will grow better with higher CO2 and longer growing seasons provided there is sufficient water.
- Pest and invasive species will be similarly advantaged. Higher crop vulnerability due to water stress coupled with increasing pests may lead to a decline in yields.

Water Supply Systems

- Increased competition over summertime water resources, making it harder to reliably fulfill present commitments to both in-stream and out-of-stream uses.
- During the summer increasing demands and decreasing supply may force a reliance on storage in the form of reservoirs, snowpack and groundwater.

Flood and storm management

- Combinations of higher winter temperatures and increased precipitation will increase frequency and magnitude of flooding in the Puget Sound.
- While many areas are protected by dykes and reservoirs, increase in flows could overwhelm these managed systems.

Human Perceptions and Behavior

The key driving force of 'human perceptions and behavior' is a clustering of social drivers that influence the actions and beliefs of the population at large. These drivers are intricately linked to both economic drivers that control the exchange of goods and the political institutions, which govern human behavior. The social norms and values that motivate a population have implications on resource consumption, obligations and aspirations. Experts interviewed for the Puget Sound scenario development have identified the social constructs of individualism and collectivism and societal perspective towards future valuation as the critically uncertain dimensions of human behavior affecting this region's future. The trajectories of these dimensions are dependent on a diverse set of interacting variables making them difficult to predict with any accuracy.

Individualism and Collectivism

The terms individualism and collectivism have been given various meanings and are difficult to measure (Table 5.2). Social psychologists have discovered considerable complexity when assessing these constructs, theorizing about their causes and consequences. They have found that people are typically both individualist and collectivist and that a balance of both tendencies generally achieves the optimal state for societal health. Further, in every community there are individuals who act very differently from one another, and any generalization is simply a statistical tendency.

Four arguments help define the attributes of the constructs:

1. Among individualists, the self is defined independently of the specific collective. Among collectivists the self includes the associations the individual belongs to (i.e. mother, Seattleite) This flows into various aspects of life, including the extent to which individualists share resources with group members and conform to the norms of the group.
2. Collectivist cultures share a promotive interdependence (i.e. the goals of the self and group are compatible). Individualists, on the other hand, may have personal goals that are inconsistent with the goals of the larger collective.
3. Collectivists carry out their obligations despite personal sacrifice. Individualists focus on attitudes, personal needs, rights and contracts.

4. Individualists place emphasis on rational analysis of advantages and disadvantages. Collectivists emphasize relationships and value based decision-making.

While American individualism has been widely discussed (Tocqueville, 1835; Bellah et al, 1985; Inkeles 1983) levels of individualism have been different at various historical periods (Triandis, 1995). The Great Depression and the Vietnam protests are considered periods of shift towards collectivist behavior. The Puget Sound region can be considered individualistic in respects to a competitive economic market, great mobility, affluence of choices, and relatively minor investments in public goods in comparison to income levels. On the other hand many sub-areas take pride in civic engagement and high levels of volunteering. Though it is difficult place the Puget Sound society along a continuum from collectivist to individualistic, our assumption within this document is that we are somewhat off-balance, leaning more towards individualistic behavior.

Measures of Individualism and Collectivism

Unlike climate change, measures of changes in human perception and behavior are harder to pin down. The following four measures represent qualitative means to assess changes along the individualistic / collectivist continuum. There is vast debate and disagreement among social scientists on quantitative indicators associated with these measures.

1. Share of household income devoted to expenditure on public goods and services as well as charitable contributions.
2. Voting record on bills supporting private provision of services (i.e. user fees, levees and turnpikes) compared to bills passed that support public provision of services (progressive taxation and redistribution). For example, voting for or against universal health care or school levee measures.
3. Number of hours spent volunteering for regional or sub-regional benefits.
4. Social cohesion, a measure of an individual's relationship to the region's people and places can be indicated by trust, reciprocity and the concern for the well being of other members in one's community. Social cohesion can be measured by mobility, or the length of time an individual or household has staying in the same region.

The following ten external drivers have been identified as influencing social behavior towards either collectivist or individualistic ends (Triandis, 1995).

1. Affluence, exposure to mass media, increased mobility, globalization, urbanization, and modernization -> individualism.
2. Increasing societal complexity and differentiation -> individualism.
3. Great heterogeneity in culture generally -> individualism.
4. Stability in culture -> collectivism.
5. Increased density -> collectivism (although urbanized region with great affluence of choices -> individualism).
6. External threats, vulnerability and resource scarcity -> collectivism
7. A time pressure required for quick action -> collectivism.
8. When resources are obtained via individual action -> individualism.
9. Strong leadership -> collectivism
10. When goals are better achieved through cooperation -> collectivism; when goals are better achieved towards competition -> individualism.

Future Valuation

Future valuation refers to the value society places on the quality of the future condition. A society with a high future valuation is willing to sacrifice more now to have more resources in the future. A basic tenement of this dimension is the discount rate[11], or the interest rate at which an agent discounts future cash flows. The discount rate can be quantitatively defined as (Heylighen, 2008):

present value = future value / (1+discount rate * time)

As the discount rate increases, the present value of the long term investment decreases. For example, if asked the question, would you rather have $20 today or $100 at the end of the year, an individual personal discount rate would determine which option an individual chooses. It would depend on current resource scarcity (i.e. how much he/she needs $20 today) and risk perception (i.e. how certain he/she is of the future resource scarcity). A high discount rate or short term future valuation would push the individual towards taking the $20 today, and vice a versa. The assumption made within this document is that a high future valuation will increase emphasis on long-term regional investments such as improved infrastructure, education spending and health care provision. On the other hand, a low future valuation may increase current demand and exploitation of current resources.

11In this document discount rate is defined as the overall concept in general and not specifically to the national discount rate used by banks when burrowing money directly from the Federal Reserve Bank.

As with the social constructs of individualism and collectivism there is no predefined measure of future valuation (Table 5.2). In practice discount rates from 2% to 10% are used widely in economics. Roughly speaking, a discount rate of 10% means if an investment doesn't show a return in 10 years, it is not profitable. A 2% discount rate is predicated on a longer future valuation (50 years) while a 20% discount rate predicated on a shorter-term future valuation (5 years). It is difficult to define one discount rate for all values because valuation is heavily context driven.

Measures of Future Valuation

1. Investment towards resource conservation (i.e. money spend on land conservancies, nature preserves)
2. Voting record for long term investments (i.e. mass-transit infrastructure or new wastewater facilities).
3. Actively reduced current resource distribution (i.e. shortened harvesting seasons and increased regulations on new developments).
4. Higher taxation on consumption (i.e. increased water and energy costs) and income (i.e. school and park levees).

Table 5.2 Human perceptions and behavior definitions

Individualism and Collectivism: *(Triandis, 1995, p 2)*
Collectivism may be defined as a social pattern consisting of closely linked individuals who see themselves as part of one or more collectives; are primarily motivated by the norms of, and duties imposed by, those collectives; are willing to give priority to the goals of these collectives over their own personal goals; and emphasize their connectedness to members of these collectives.

Individualism is a social pattern that consists of loosely linked individuals who view themselves as independent of collectives; are primarily motivated by their own preferences, needs, rights, and the contracts they have established with others; give priority to their personal goals over the goals of others; and emphasize rational analyses of the advantages and disadvantages of associating with others.

Short and Long Term Future Valuation
Short term future valuation is associated with high future discount rates due to the perception that resources should be applied towards present events. Decisions that require high inputs of capitol but do not emerge as a benefit for a long are seen less favorably than short-term investments.

Long term future valuation is associated with a preference to conserve resources for future use. A low discount rate allows individuals to maintain a high valuation for investments that don't emerge for very long time periods.

Future valuation is affected by multiple variables and can be highly dependent on the resource in question and risk propensity. In general society is risk averse and tries to eliminate uncertainty. This tendency pushes us towards conserving some resources for the future, whether in the form of bank savings or sending our children to college. On the other hand, rapid growth and competition has generally pushed society towards increased consumption and short-term decision making. Instability in the form of economic recessions or natural disasters may increase discount rates (shorter future valuation) as resources are more heavily relied upon in the current contexts. However, great affluence is not necessarily associated with a longer term perspective in decision making, and may conversely increase risk propensity as the future seems more 'certain'. High educational attainment within a population has been previously correlated to longer-term future valuation (Wolff, 2004). Knowledge of future hardships may increase our future valuation. For example, the more we lean about declining fish stocks and the potential for over harvesting the higher the value we place on consuming current yields through more restrictive permits.

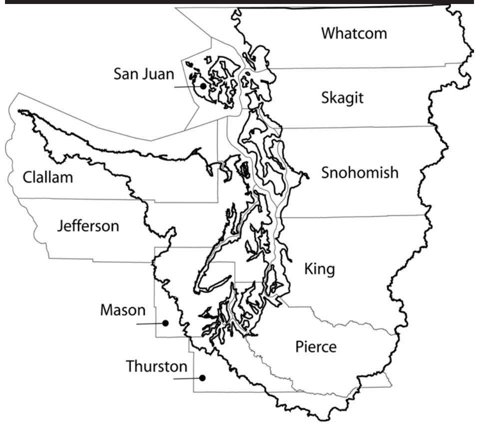
Demographics

Demography is the study of the primal forces that leads to change in a population including fertility, mortality and migrations. The size of a population has direct implications for resource and service consumption: the amount of housing, water demand, traffic, employment, waste disposal, etc. In addition, the way a population is distributed across age groups, geographic regions, living arrangements and ethnicity affects consumption patterns and impacts on ecosystems.

Population Growth (*Rate of population increase*): The rate at which the number of residents within the Puget Sound Basin increase per year. While the total size of a population can provide us with information about the magnitude of resource and service consumption, the rate of growth determines the potential pressure associated with the growth. A fast rate may signal a growing economy, increasing housing demand, and pressure on local resources, a declining rate can conversely reflect an economic downturn or a natural disaster and a corresponding decrease in housing value.

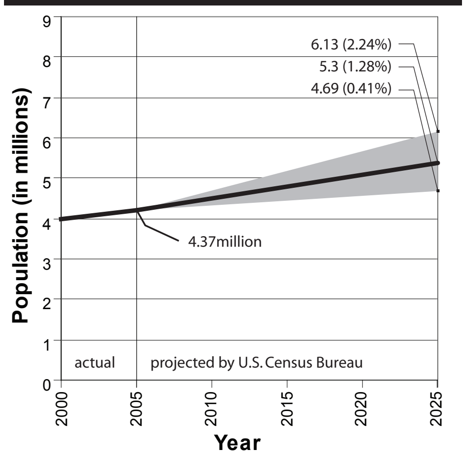
The US Census Bureau conducts a census count every decade, with the last one occurring in 2000. The Office of Financial Management (OFM, 2005) re-assesses the population every year and develops long-term projections for 25 years out on a county-wide level every five years. Since the Puget Sound Basin does not follow county borders there is no accurate account of the basin's population, instead we rely on a twelve county synthesis (Figure 5.4). In 2000, the basin's population was 3.98 million; by 2007 it was estimated at 4.37 million residents. Wthin this time period the rate of growth fluctuated from 0.76% to 1.91% with an average annual growth rate of 1.28%.

Figure 5.4 Puget Sound counties



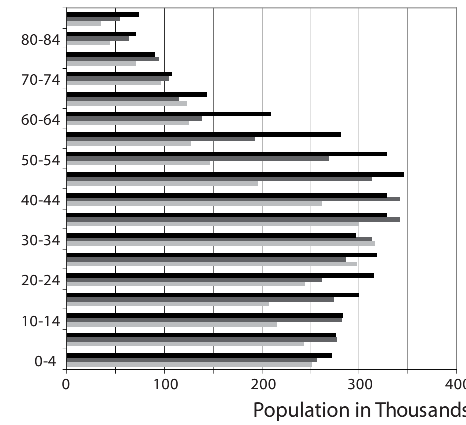
OFM forecasts population growth in the State of Washington by looking at economic trends, migrations, and natural growth (fertility and mortality). Long-term projections maintain current trends while short-term (annual) forecasts look at economic and migration fluctuations. At an annual growth rate of 1.28% the Puget Sound Basin is forecasted to exceed 5.3 million residents by 2025. OFM provides each county with a high and low projection for allocating growth within their Urban Growth Boundary. An annual low growth rate for the Puget Sound is forecasted at 0.41% and a high rate is 2.24% (Figure 5.5).

Figure 5.5 Population growth (OFM, 2005)



Age Structure (*Age distribution at 5-year intervals*): Changes in the age structure can be attributed to three factors: natural changes in fertility and mortality, in/out migrations and social norms. We are currently seeing the impacts of the "baby boom" population aging. As this large segment of the population retires this region is forecasted to experience a significant change in service demands, housing patterns and traffic problems. Migration patterns will influence which age groups are attracted to this region; skilled young adults, elderly in their retirement years, or parents of small children. Lastly, changes in social norms and socio-economic conditions will influence the average childbearing age, number of unwanted pregnancies, desirable family size and life expectancy.

Figure 5.6 Age distribution (OFM, 2005)



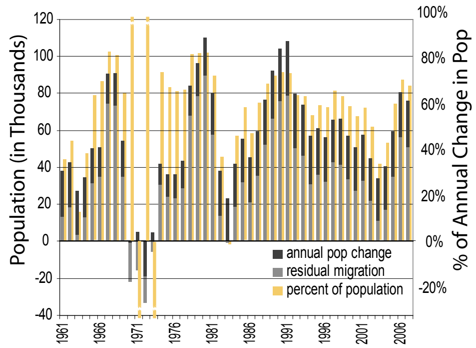
As with the population growth rate, data is provided at the U.S. Census Bureau with finer time intervals synthesized by the OFM. In 2000, the largest segment of the Puget Sound population was in their late twenties to mid-forties. In 2007 the largest segment is in their mid-forties to late fifties. Between 1990 and 2007, the percentage of the population under the age of 20 dropped by 2% (from 28% to 26%) while the percentage over the age of 50 rose by 7% (from 23% to 30%). Adding to the aging of the population, between 1960 and 2000 the fertility rate in Washington dropped from 3.67 to 1.95 while the life expectancy rose from 77 to 80, further affecting the age pyramid (Figure 5.6).

Forecasts of the region's population are available at the state level. According to OFM forecasts, by 2030 the largest segment of the population will be over the age of 50 (accounting for 36% of the population) while the number of residents under the age of 20 will remain at 26%. This will generally signify a decrease in the percentage of the state that partakes in the workforce.

Migration (*In-migration as percentage of total population*): Short-term social, economic and political trends determine changes in migration rates. While these trends are hard to predict, their influence on this region's population growth is significant. Generally, the relative attractiveness of the area depicted by an increase in jobs, median-income, quality of life and political stability pulls people into a region. Migration trends are also controlled by migration policy and global turmoil. The characteristic of incoming migrants is dependent on targeted jobs; whether unskilled manual labor of agriculture, manufacturing or construction, or high income skilled high tech jobs primarily in urban areas. The Puget Sound area is also an attractive draw for retired people, especially San Juan and Jefferson Counties.

Migration rates fluctuate widely from year to year. The OFM provides migration estimates by county from 1961 to the present. While natural increase from births and deaths was maintained at 37% (St Dev 2.4) Puget Sound migration rates fluctuated with an average of 58% (St dev 17.7%[12]) (Figure 5.7). In the last decade, in-migration accounted for over 2/3 of the state's population. According to the Puget Sound Region Council in the Central Puget Sound (including the counties of King, Snohomish, Pierce and Kitsap) between 1995 and 2000 in-migrants tended to be younger, better educated, and with a higher income compared to out-migrations (PSRC, 2006). In fact, over half of Washington's population aged 25-34 holding advanced degrees were in-migratory.

Figure 5.7 Migration into the Puget Sound (OFM, 2005)



OFM provides annual migration assessments that look at past trends and economic projections. Over the long term forecast OFM assumes a steady migration rate of 50,000 in-coming residents per year into Washington State. This projection assumes a continuance of the current economic growth rates, which are outperforming the nation as a whole.

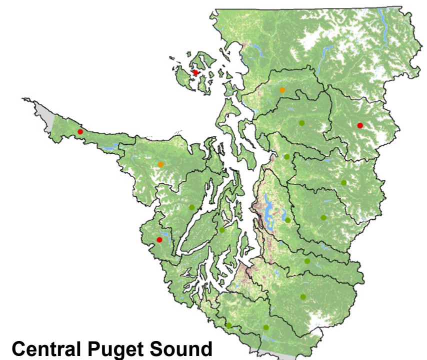
Development Patterns

Development patterns comprise any human modification to the landscape. Modifications generally consist of structures and land alterations created for economic, cultural or ecological use. Depending on the spatial extent and resolution patterns of development can appear strikingly different on the landscape. From different perspectives, alterations to the landscape can be viewed as either valued improvements to the land through provision of human shelter and amenities or negative disturbances to ecological systems, or both.

Intensity of Development (*Number of people per impervious area (PIA)*): The number of people per impervious area (PIA) can serve as a good proxy to measure the impact of each additional individual to the overall development pattern through alteration to natural land cover. Further, the total amount of impervious surface within a watershed has been shown to affect water quality (Boothe, 1991). The more roads, more driveways, and greater housing footprint that are added per person, the smaller the value becomes. In general, the higher the intensity of development the higher the value while the lower the intensity (often characterized as 'sprawl') the lower the number.

The Urban Ecology Research Laboratory has utilized satellite imagery for 1991 and 2001 for the entire Puget Sound basin (UERL, 2006). The percentage of impervious surface is assessed for each 30m-grid. Used in conjunction with the 1990 and 2000 census UERL has assessed the number of people per impervious square km. Over the last decade, while King County has increased the number of PIA, Pierce County has decreased its PIA. Since the inception of the GMA, the PIA value within the UGB has increased (Alberti, 2005); however the PIA outside of the UBG has decreased (Liu et al, 2007) (Figure 5.8).

Figure 5.8 Percent impervious area (Alberti, 2005)



Central Puget Sound

	1990	2000
Inside the UGA	2783	2810
Outside the UGA	1542	1379

The net change in people per impervious area for the entire Puget Sound Basin will likely increase as development increases and greenfield development continues to be more economically feasible. But the relationship may vary across a gradient of urbanization and inside and outside the UGB. If growth trends continue, we are likely to see a simultaneous increase in people per impervious area within the UGB and a decrease outside of the UGB.

Configuration: (*Forest Aggregation Index*): As residential development encroaches on forestlands we see increasing fragmentation. This has implications not only for biotic integrity (through decreasing interior habitat and habitat connectivity) and increased disturbance, but also for lowered water quality, reduced carbon sequestration, and a reduction in the long-term viability of the timber industry (Turner et al, 2001). Configuration refers to the arrangement and extent of a land cover and can be measured through the aggregation index. The aggregation index (AI) measures the level of fragmentation within the same land cover (Figure 5.9). The lower the aggregation index, the higher the

12 Excluding extreme fluctuations from the 1970-73 economic recession.

fragmentation of that particular land cover class. In this region, forestland connectivity is largely determined by the relationship among development pressure, timberland industry, and regulatory forces.

According to the Regional Geographic Initiative (RGI) study, conducted by the UERL, between 1991 and 2001 the majority of HUC sub-watersheds of the Puget Sound saw a significant decline in their forest aggregation index (Figure 5.10).

According to the Cascade Land Conservancy the business as usual trends for this region will result in increased forest fragmentation (lower AI). According the Rural Forest Initiative western Washington has been losing forestland at increasing rates of the last two decades (Erickson, 2007) (Figure 5.11).

Figure 5.9 Aggregation Index metric

Aggregation Index (AI)

$$AI = \left[\frac{g_{ii}}{\max \rightarrow g_{ii}}\right](100)$$

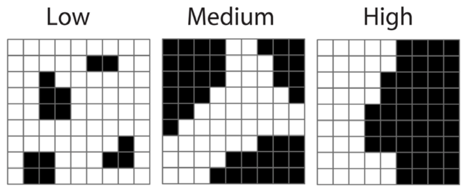


Figure 5.10 Forest aggregation (Landsat, 1999)

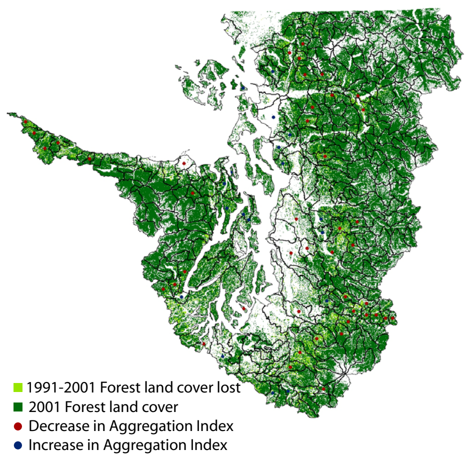


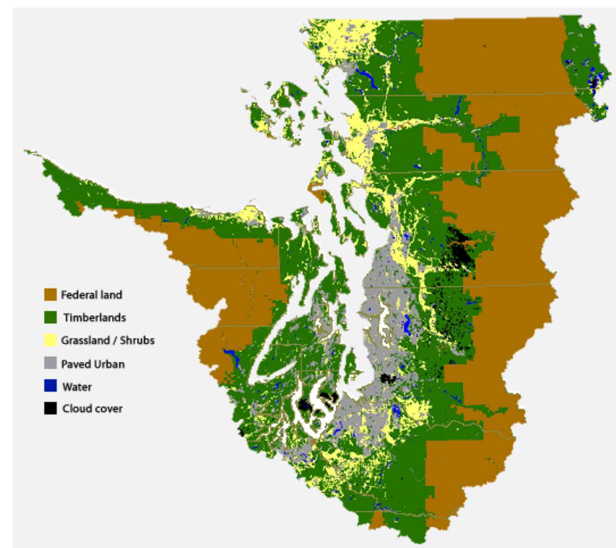
Figure 5.11 Timberlands (Erickson, 2007)

Puget Sound timberlands, development patterns and regulations

The Puget Sound's timberlands represent our history, our economic resources and our way of life. As development encroaches on these resource lands we increase the risk of permanently eliminating the economic viability of logging in this region and further reducing ecosystem functions such as upland water retention and habitat provision.

Timberlands represent forestlands actively harvested for yields. Historically, Washington timberlands were owned by a few very large industries including Weyerhauser, Simpson and Plum Creek. While planning regulations control the conversion of farmland and timberlands, a stronger driving force influencing land cover change is the Highest & Best Use, or real estate value of these lands. When the value of real estate increases such that it is greater than the value of the timber yields, we generally see a conversion into residential development. Confounding these pressures are social changes such as an increasing rate of retirement, generational disinterest, increasing state taxes, and an overall exhaustion of the land owners.

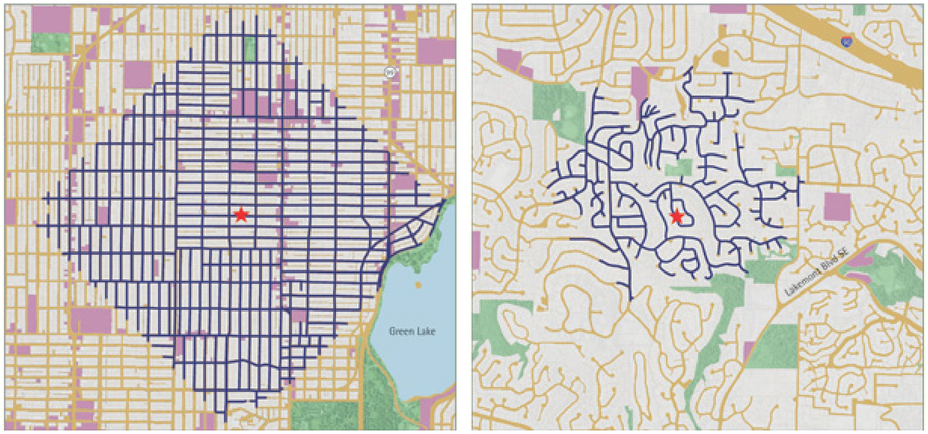
Timberlands generally don't transition into development in one step, several indicators foreshadow their conversion. Changes in timber industry structure serve as a strong indicator. Many lands are sold into Real Estate Investment Trusts, criticized as holding lands for future developments. Many land holders are selling their mills, with Weyerhauser representing the last Washington timberland industry that remains vertically integrated. One growing trend is the conversion of large parcels into smaller parcels (20-80 acres) sold to individual land owners. These plots are generally considered to be less economically stable and face larger development pressures.



Diversity and Fit (*Walkability*): This indicator calculates what percentage of the residents of the Puget Sound basin live within a neighborhood that is walkable. Walkability can be related to multiple factors including sidewalk width and presence of shade trees (Frank, 2007), however, within this report walkability refers to a much broader description including proximity to nearby services, parks and open space, to the diversity of residents in age, income and race, high density, public transit and a pedestrian centric design (Sightline, 2007). This indicator is therefore used as a proxy for both diversity of land use and fit, evaluating how well developments fit the needs of their residents and workers.

Walk Score.com has developed an on the fly mapping system for assessing neighborhood walkabiltiy based on a distances to nearby services, density and street network (Walkscore, 2007) (Figure 5.12). We are currently awaiting a zonal analysis for the Puget Sound Region. Since the current status is largely unknown it is difficult to predict future trends. However, a successful implementation of the GMA should result in increased walkability, however current trends in low-density development are not necessarily congruent with this objective.

Figure 5.12 Walkability (Walkscore, 2007)

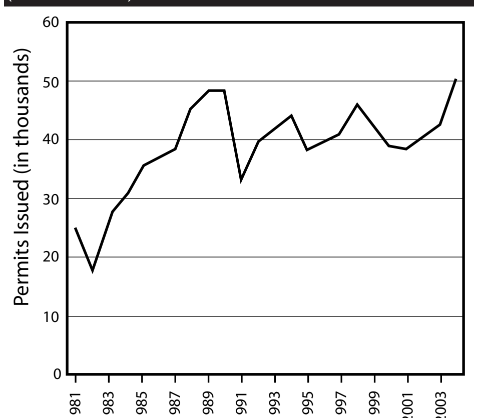


1 mile walk in a compact neighborhood | 1 mile walk in a sprawling suburb

New Development Growth Rate (*number of housing permits added per year*): The change in urbanization of the Puget Sound has come largely from new housing development. Building permits provide a useful measure of housing construction activity (Housing Partnership, 1998). The rate of growth, represented by the number of new housing permits divided by the existing housing stock can reflect population growth (OFM, 2006). This indicator further combines social norms such as household size and frequency of second home construction.

Housing unit estimates for counties are developed by the Office of Financial Management, Forecasting Division. Their estimates are based on the most recent decennial census count and moved forward in time using building permits, demolitions, and other administrative records obtained directly from local governments. Since the 1990 Census housing estimates have remained relatively stable with a mean of 1.82% growth (max 3.21% min 1.21%, St Dev 0.4%). At this rate an additional ~28,000 houses are added into the Basin each year (Figure 5.13).

Figure 5.13 Building permits
(OFM, 2006)



While we have outpaced the national growth rate over the last 5 years, most projections presume a slowing down, if not decline, in the annual housing growth rate in the next decade. The Economic and Revenue Forecast for Washington State predicts that while higher interest rates will have adverse impacts on the Washington housing market, this will be offset by strong population growth. The strength in housing has been mostly in the single-family market, which continues to benefit from low mortgage rates.

Economy

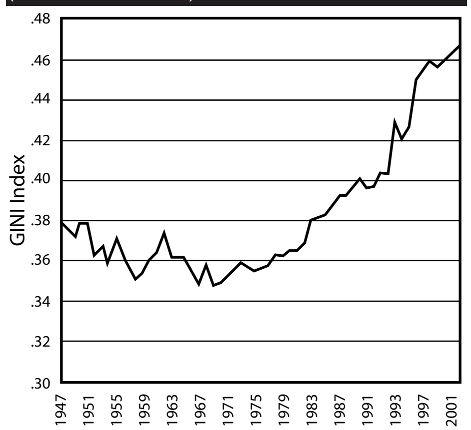
The economy influences human activities in pursuit of systems for the production, consumption and distribution of goods and services. Although the relationship between the economy and other socio-political drivers is well documented, the impact of economic growth on the environment is still highly debated (Grossman 1995). Capitalism, as an institutional structure, has been theorized to inflate the levels of demand of the population (Sack, 1990) On the other hand, there is also empirical evidence to suggest that higher per capita income levels increases policies and regulations that help protect the environment (Arrow et al, 1996).

Economic Growth (*Gross Domestic Product (GDP) Growth Rate*): GDP is the Bureau of Economic Analysis' (BEA) featured and most comprehensive measure of U.S. economic activity (BEA, 2007). GDP is calculated as the sum of what consumers, businesses, and government spend on final goods and services, plus investment and net foreign trade. Economic growth has impacts on lifestyles, housing development, technological innovation, and even knowledge transfer (OFM, 2005). There is generally a positive feedback loop between GDP and population growth: a strong economy attracts more people into this region, and consequently population growth can boost the economy (OFM, 2005). Many ecologists argue that GDP has been used inappropriately to measure prosperity. In the past, positive GDP growth has been correlated with ecological decline as populations increase their use of resources and energy, which consequently produce pollution and waste (Meadows 1972; Daly, 1991).

Between 1977 and 2006 Washington's GDP has steadily risen, with our current state product valued at more than eight times its value three decades ago. In 2005, the Bureau of Economic Analysis (BEA) began to assess GDP by Metropolitan Statistical Area as well. BEA has hind cast the GDP for the Seattle-Tacoma-Bellevue Metropolitan Area to 2001. In 2005, Washington's GDP equaled $ 271,381 million, with the Seattle-Tacoma-Bellevue -MSA producing 67% of that amount. The average rate of growth for the State GDP over the last decade is 6.25% (with a high of 10.23% and a low of 1.71%). The STB-MSA GDP growth rate has increased significantly over the last 5 years, with the most recent expansion coming in at 7.3%.

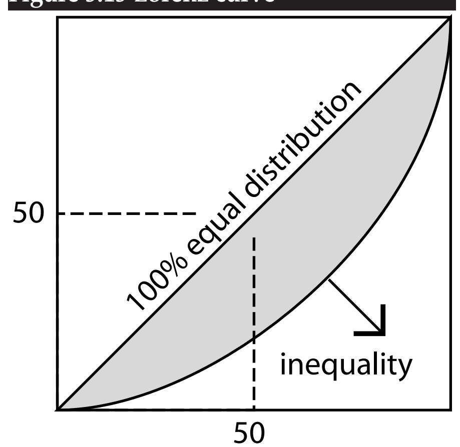
According to the BEA, Washington is among the four fastest growing states (in terms of GDP) both in 2005 and 2006. It is projected that the GDP will continue to rise, but the rate is uncertain. According to International Financial Statistics the National GDP is projected to increase at a 3% rate out to 2012.

Figure 5.14 Gini index
(US Census, 2007)



Economic Inequality (*Gini Index and Lorenz Curve*): The Gini index measures how the total income of a geographical area is distributed among its citizens (Cowell, 2000). The GINI index is a measure of statistical dispersion most prominently used as a measure of inequality of income distribution or inequality of wealth distribution (Figure 5.14). It is defined as a ratio of income to with values between 0 and 1: with the numerator depicted as the area between the Lorenz curve of the distribution and the uniform distribution line; the denominator is the area under the uniform distribution line (Figure 5.15). The lower the Gini Index, the more equally distributed the income, the closer the curve becomes to the even distribution line.

Figure 5.15 Lorenz curve

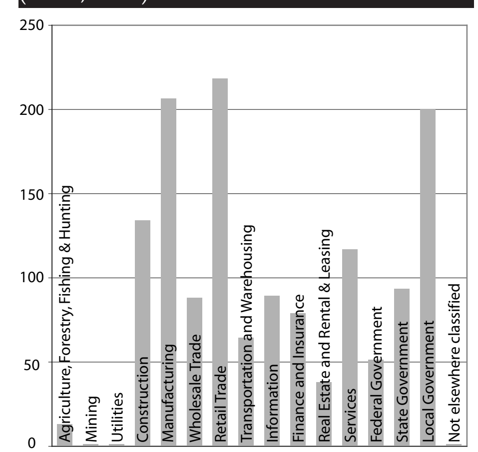


While the GINI index for the Puget Sound is currently unavailable, Census county statistics on household income is available for 1990 and 2000. In 2000 the median household income within the Puget Sound (12 county area) was $49,583. In 2000 more than 6.6% of the households were making under $10,000 a year, while over %14.6 households were making more than 10 times that amount (>$100,000 annual income). Past trends have shown that a fast paced economy and tight labor markets lead to increasing economic disparity (Ryscavage, 1999). A shift towards higher equality would require a fundamental change in the way society deals with income distribution and current economic condition.

Stability of the Economy (*Percentage of Industry Sector Contribution*): The strength of the economy in this region has been largely attributed to its diversity. Among the Region's largest companies (in terms of market value) are Microsoft, Washington Mutual, Starbucks, Weyerhaeuser, Amazon, Costco, Paccar, Nordstrom, Safeco, Expedia, and Getty Images. Supporting these larger firms are hundreds of smaller industries. The economic crash of the early 1980's was blamed largely on the heavy reliance on one industry, namely Boeing (OFM, 2005). An economy made of a diverse constituency of firms in varying industries is considered more resilient to market perturbations. Different employers allow us to keep growing in time of crises.

The Puget Sound economy has diversified significantly since the 1970's. Over the last 3 years the stability of the Puget Sound's economy has been applauded as national economic status declines while local industry remains unencumbered. One mechanism to account for the sector contribution is capital production; another is number of employees employed. According to Washington's State Employment Security Department in the first quarter of 2007 the retail trade industry represented the largest of 16 sectors, employing 15.7% of the region's employees. Manufacturing (particularly aerospace manufacturing for Boeing was a close second at 14.8% (Figure 5.16).

Figure 5.16 Economic stability
(OFM, 2005)



The Puget Sound economy is projected to remain highly diverse at least until 2030 (OFM). However, if major industries like Boeing, Microsoft and Amazon leave it will still devastate this region economically.

Trade Dependence (*Export / Import Dollars*): In the last few decades the trends towards globalization have been accelerating which has intensified the trade of goods and services among countries (OFM). Politically, exports are generally seen as a positive 'good' creating an inflow of capital from abroad, while imports are often seen as requiring an outflow of capital to foreigners. Economically, a global balance between exports and imports has been shown to be advantageous to currency and wage stabilization (Chase, 1999) Environmentally, international trade has been shown to degrade local environmental quality through unsustainable resource extraction. Critiques of increasing globalization have made arguments for the benefit of 'buying local' (Danson, 1998).

The Puget Sound region's geographic location gives it the advantage of serving as the major North American gateway for trade with Pacific Rim countries. "The ports of Seattle and Tacoma are the second largest container cargo load center in the Western Hemisphere" (Chase, 1997, p5). Washington leads the nation in exports per capita making international trade a major economic engine for Washington State. In fact it has been shown that one in four jobs in the State are directly or indirectly tied to export trade (Ibid). The ports in Puget Sound handle exports originating both from Washington and from other states, but a significant contribution comes form international imports destined for purchase within Washington State.

Over the last decade we have shifted from a trade focused on agricultural products and lumber to high tech industrial machinery and computer equipment. Despite this major shift, aircraft parts still dominate more than 63% of the State's total exports (OFM Trends, 2006). Washington is a trade dependent state, and the falling dollar has been a great asset to increasing exports. As our goods become cheaper relative to the global marker, we can increase our exports. On the other hand this leads to an increase in the price of imports. While a wide variation exists in the ratio of dollars spent on imports versus exports (from 20% return with China, who we import good from, to 259% with Netherlands, who we export goods to). The overall ratio in the Washington is 71% return on exports per dollar of imports (CTED, 2004)(Figure 5.17).

Figure 5.17 International trade
(OFM, 2005)

Trade is controlled at the national and state level. Nationally, political relationships, trade agreement and exports bans largely control the amount and type of trade coming through Washington's borders. Further, changes in accessibility due to technological innovation, whether through cost of transportation or advancements in communication can affect the relative importance of the trade industry. Locally, the Ports of Seattle, Tacoma and Bellingham can directly influence trade by investing in 'human capital, transportation and communication infrastructure' (OFM). Indirectly, changes in industry concentration towards high-tech exports as opposed to natural resources (timber and agriculture) will not only significantly impact our trading partners, but also the trajectory of economic growth in this region.

Governance

Governance refers to the process and institutions that guide and constrain human activity (Thomas, 2007). Governmental interference with human activity is generally constrained to improving the health, safety and welfare of its citizens. Different views of the effectiveness of the current approach and outcome as well as potential future utility of governance in this region are largely value laden. The three dimensions indicated below may appear biased towards certain approaches and outcomes; however, there is still a large divergence in published literature about the real implications of these trajectories.

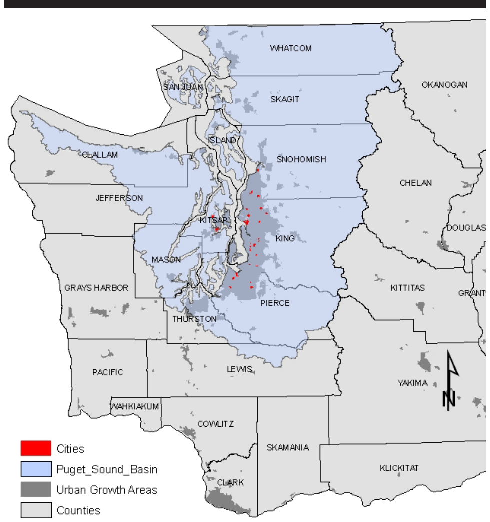
Strength and Effectiveness of Leadership (*Number of bills introduced and passed into law*): Political leadership can be conceptualized as the leadership through elected representatives (and their appointees) and the political will of citizens and residents. The outcomes of elections at all levels of government affect who is in charge of policy and budget decisions, which can impact regulatory and socio-economic conditions. The strength and effectiveness of regional leadership is a politically debatable issue and ultimately no one measure accurately defines it. Legislation, referring to a single statute or a collective body of laws, is an action taken on behalf of the governing body to guide or constrain human activity. This indicator focuses on the number of pieces of legislation introduced and passed into law as a measure of the strength of leadership. The highly debatable assumption made is that the strength of leadership is positively correlated with the number of passed and effective pieces of legislation.

In 2007 the house and senate introduced 2,591 bills, of which 20% (522) were passed (Washington State Legislature, 2008). At this time no information on future trends has been collected for this report. In order to generalize trends we have isolated three potential trajectories; a strong and effective government, a weak and ineffective government, and a strong and ineffective government. Strength is correlated to how much power they are administered by their constituency. Effectiveness corresponds to their ability to create change.

Locus of Power (*Number of decision makers; type of interactions*): The Puget Sound region is governed by numerous overlapping jurisdictions: federal government (i.e. the Clean Water Act), state government (i.e. Growth Management Act) city and county municipalities (i.e. zoning), as well as local groups (i.e. neighborhood associations). Over the last few decades the number of decision makers influencing the future of this region has grown significantly, effectively fragmenting our regional government. In response many regulations and informal relationships have been forged to handle cross-jurisdictional issues. For example, the Growth Management Act's cooperation requirement is intended to ensure that municipalities take into account the implications of new development and infrastructure on adjacent municipalities. This indicator focuses on both the number of decision makers and their form of relationships. Two interdependent continuums are discussed, the number of units of government from a single unit of governance (unified) to many units (fragmented) and from high levels of cooperation among those units (networked) to very low levels of cooperation (autocratic).

Currently there are 700 electives and 30 jurisdictions within King County Alone. The Puget Sound currently includes 12 counties and over 100 cities and 23 tribes (Figure 5.18). As new areas become developed and incorporated into new municipalities the numbers of decision makers continues to grow. One source of fragmentation is the relationship between rural and urban municipalities. Most often both the goals and resources of these regions are inconsistent. Both regions generally want local resources to be spent on local investments. However, while the majority of the population, and thereby funds, are located within the urban area much of environmental implications (from sprawling developments, increase in impervious surfaces and infrastructure extensions) come form rural counties. Thereby urban municipalities are often found trying to control change in rural municipalities without the willingness to pay for those rights (i.e. purchasing the development rights).

Figure 5.18 Units of government



Nationally we have seen increasing fragmentation due to an increase in the number of units of government. In the last decade we have seen an increase in specialized and narrow interests associated with local municipalities (i.e. each county has its own plan and works in isolation from one another). Some critiques say that only in response to a major crisis will we see a reverse trend towards unification. On the other hand, we have seen increasing attempts at networking among local units as municipalities try to share resources and coordinate plans.

Types of Partnerships (*Influence of public, private, non-profit and academia partnerships on regional governance*): In addition to partnerships among municipalities governmental units also forge partnerships with local businesses, non-profits and academia. Business partnerships are generally intended to support economic growth within a municipality. For example, a local unit may allow for specific permits or provide for new infrastructure if a business agrees to locate within the municipality, and thereby boost the local economy. These types of partnerships are generally common and are considered important in ensuring the economic vitality of the region. However, in excess residents often argue that private firms are controlling politicians and creating unfair treatment policies. Other forms of partnerships including those with academia and non-profit firms are generally less controversial. Public agencies often partner with academia to link research with new policies. Many agencies partner with local non-profits to improve conditions for minority populations and ecosystems.

The number of partnerships as a whole have been increasing over the past few decades. Specific information on the number and type of partnerships has not been identified for this report. Since the number of current partnerships has not been identified, no future trends have been developed.

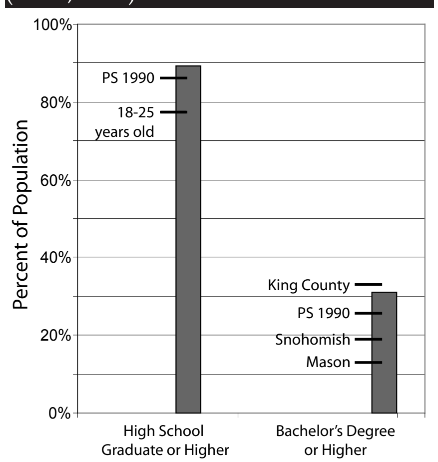
Knowledge and Information

Knowledge refers to the awareness or cognition of science, art or technique. Knowledge generally applies to facts or ideas acquired by study, investigation, observation or experience (Merriam-Webster, 2007). Information is the communication or reception of knowledge. Knowledge and information play critical roles in shaping human behavior and perception and thereby indirectly influence the direction and capability of new innovations and policies. Our strength as a region is derived from the coupling of gaining new knowledge and our ability to transfer this information within and beyond this region. While knowledge can be, and often is, gained outside of the classroom, our educational institutions are a good indicator of how equipped the next generation will be to handle this region's challenges and opportunities.

Educational Attainment (*% of population over the age of 25 with a high school degree or higher; with a bachelors degree or higher*): Education attainment refers to the highest level of schooling achieved by an individual. This indicator reflects both the value society places on education and the freedom provided to citizens to attend academic institutions. Educational attainment levels have been correlated with numerous socio-political factors including (but not limited to) voting trends, income levels, crime rates, health and future valuation.

In 2000 27.7% of Washington residents over the age of 25 carried a bachelors degree or higher. This percentage is more than double the percentage in 1970, where only 12.7% received this level of educational attainment. The Puget Sound region has higher levels of educational attainment than the state as a whole, with 31% holding a BA or higher in 2000 (up from 25% in 1990). Within the Puget Sound there is still significant variation in educational attainment among counties. King and San Juan counties have the highest educational attainment levels at 33%. Mason and Snohomish have the lowest attainment levels in the Puget Sound at 13% and 19% respectively. The large majority of 25 year old or older Puget Sound residents hold a high school degree or higher, 89% in 2000 (up from 86% in 1990)(Figre 5.19). In 2000, Washington ranked 9th nationally for the percentage of persons holding a bachelors degree or higher. In addition to the percentage of 25+ residents, a measure of 18-24 can be a better indicator of the current performance of higher education system. Measures for 25+ attainments are influenced by migration, past performance and age structure of population (Kirschner, 2004). In 2000 only 77% of the Puget Sound population of 18-24 year olds held a high school degree or higher.

Figure 5.19 Educational attainment
(OFM, 2005)

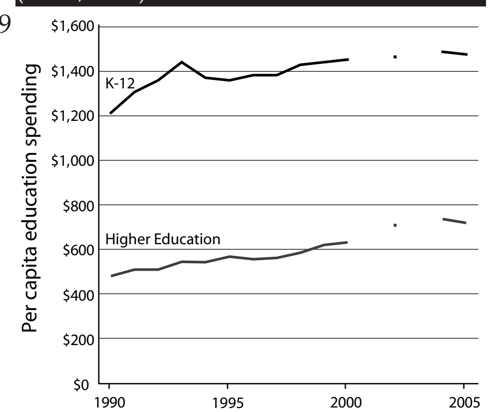


If past trends continue the percentage of the population with higher educational levels will continue to rise. However, an economic downturn can lead persons with higher education degrees to migrate out (or not migrate in) in search of higher incomes, thereby affectively lowering the region's educational attainment levels.

Investment in Education (*$ spent per capita on K-12 and Higher Education in the State*): Higher investment in education is correlated with higher achievement levels (Washington Education Association, 2006). Higher spending in K-12 may lead to higher test scores of students and potentially greater contribution to future knowledge in this region. Investment in higher education may be correlated with greater levels of innovation and new knowledge creation. Higher investments in education may also lead to economic growth (Fisher, 1997).

In 2006 Washington was ranked 42nd in the nation for average funding per student (Bhatt, 2005). This information has alarmed politicians and residents alike. Further exacerbating this situation are very large class sizes, in fact Washington has the 4th largest average classroom size in the Nation. Over the last 25 years Washington has slipped from having higher than the national average K-12 education expenditure per capita to falling far below the national average. In 2005 Washington spent $1,467 per student (OFM, WA trends)(Figure 5.20); the top four states spent more than $2,000 per student, that's over 36% more (US Census). On the other hand Washington's higher education spending has consistently remained above the national average. In 2005 WA ranked 16th among the 15 states with over $719 per capita (up form $482 in 1990).

Figure 5.20 Spending per capita
(OFM, 2005)



Following past trends Washington will continue to fall in terms of K-12 education spending. A significant impact of this trend may be that students education under the Washington system will need to migrate out of the state to find low-skilled jobs while highly educated migrants fulfill the skilled labor currently provided within the Puget Sound region. Extrapolating this trend further, employment sectors for highly skilled jobs might out-migrate seeking high quality life for their employees.

Accessibility to Knowledge and Information (*indicator not yet defined*): At the time of this writing a suitable indicator to assess how accessible knowledge and information are to the general populace has not been identified. In general, accessibility leads to a more informed public who may be able to make better informed decisions about behavior and new policies. No information on the current status or future trends of accessibility to knowledge and information has been collected at the time of this writing.

Natural Hazards

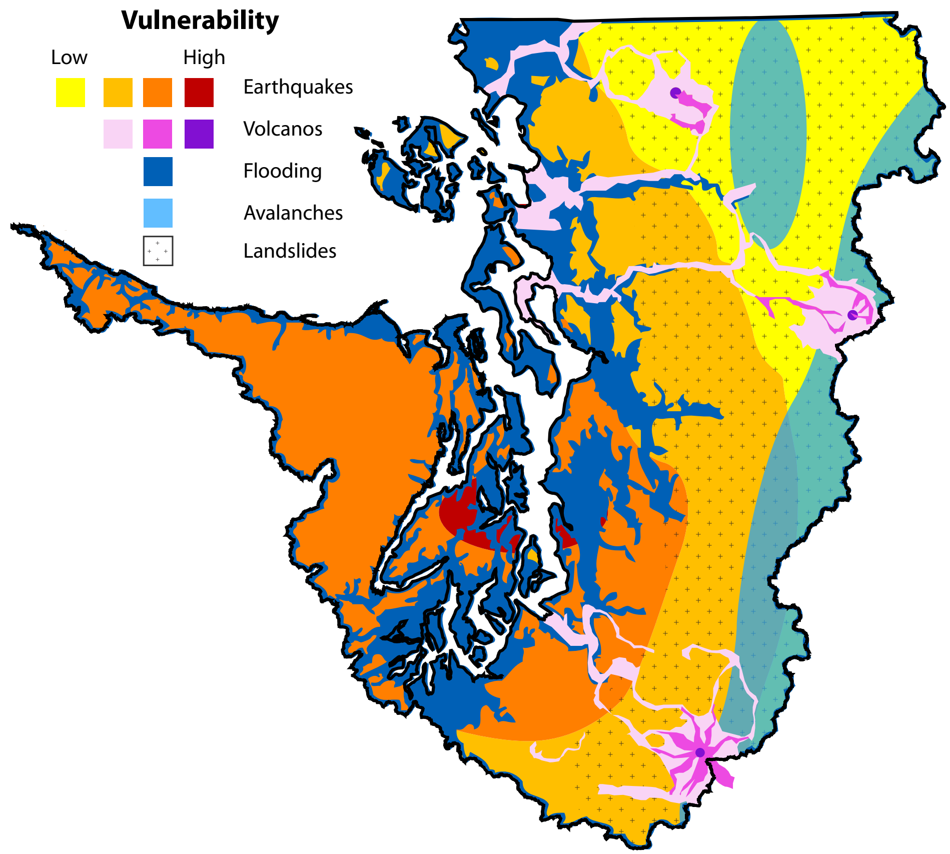
Natural hazards refer to a natural agent altering the landscape in a significant manner. There are still arguments among experts on how to perceive this change agent. Mainly, does the change necessarily constitute negative implications in terms of a disaster or can it be re-assessed as a surmountable challenge and even an opportunity for a change in human behavior? The means, by which society perceives a hazard, whether reactively or proactively, may be critical in identifying the form of future development, infrastructure investments and governance. However, for the purpose of identifying specific change causing events this driving force focuses on hazards which have in the past caused a negative affect on humans and their environment.

Spatial Vulnerability (*Distribution of Natural Hazards*): Hazards are generally correlated to specific locations: flooding is associated with lower elevations and stream corridors; volcanic eruptions are tied to specific mountains; earthquakes lie within subduction zones; etc (WA EMD, 2007). The map below identifies the spatial vulnerability of the Puget Sound's major hazards.

Within the Puget Sound the coastal area and high elevations are generally more vulnerable to natural hazards than areas within the middle belt (WA EMD, 2007)(Figure 5.21). Higher elevations are vulnerable to avalanches, landslides and in some cases volcanic eruptions. The coastal area is generally vulnerable to windstorms, flooding, erosion, and seismic activity including both earthquakes and tsunamis (Ibid).

Climate impacts may increase the vulnerability of both the coastal areas and higher elevations. Coastal elevations will be influenced by sea level rise and

Figure 5.21 Spatial vulnerability (WA EMD, 2007)

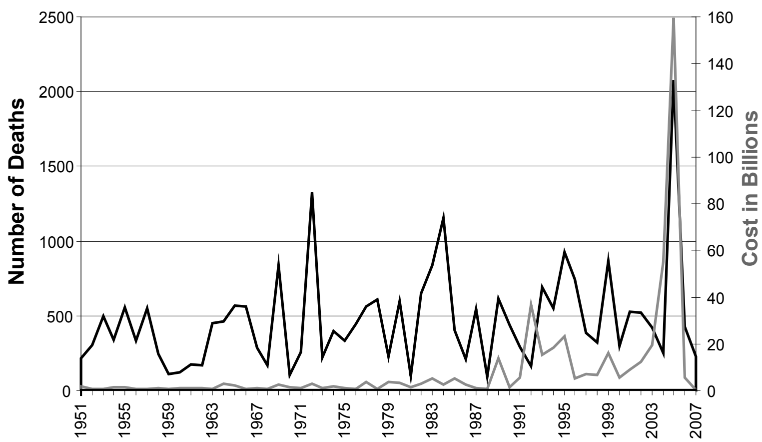


potentially stronger windstorms. Higher elevations may experience increased avalanches and landslides due to increasing temperatures and increasing precipitation coming down as rain as opposed to snow. In addition to climate impacts, development patterns can influence the pattern of hazards. For example, hillside developments can increase the vulnerability to landslides while lowland development can increase the vulnerability to flooding.

Magnitude of Events (*Cost of Natural Hazards*): The magnitude of an event describes the relative size, significance or influence. The magnitude of an earthquake is measured on the Richter scale, drought by the number of days where the water supply is 75% below normal, windstorms by their speed. In general, the more severe the event is, the more costly the response, in terms of both casualties and economic impacts. This indicator specifically looks at the annual cost of emergency preparedness and response within Washington State. The relationship between the magnitude of a natural disaster and the cost of repair is influenced by new technological innovation, the level of preparedness, and the type of damages incurred.

At the time of this writing we do not have estimated costs of hazards for the Puget Sound or Washington States and have relied on national estimates. The International Disaster Database (EM-DAT) has synthesized information on disasters of the last century, by nation, disaster type of impacts incurred. Over the last century the United States have spent over $ 449 billion on disasters. Over $280 billion was spent over the last decade (Figure 5.22). While the cost of hazards has increased exponentially the cost in human lives has fluctuated with no upward trend (this trend is not true for other countries).

Figure 5.22 Cost of hazards (CRED, 2008)

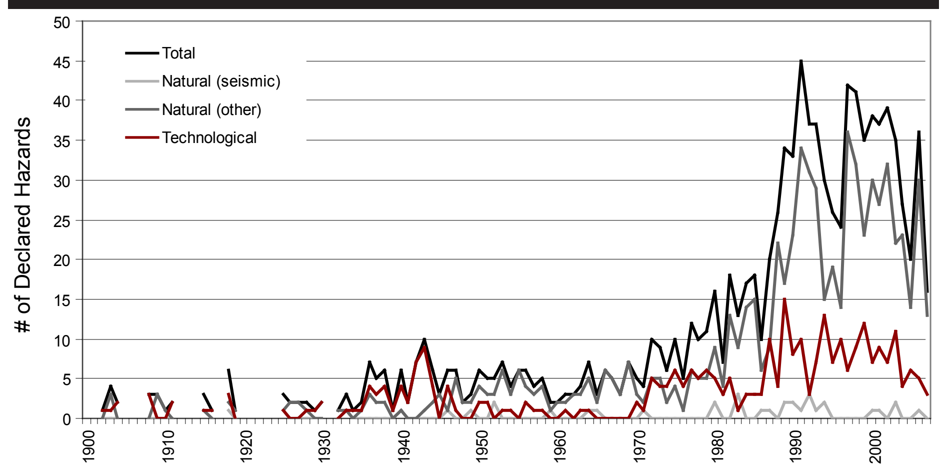


There is still little evidence that the magnitude of natural events will increase in the future. There are strong correlations between the magnitude of hydrological events and climate change and human development. An increase in the magnitude of climate impacts including both temperature and precipitation changes are anticipated to increase the magnitude of flooding, droughts and landslides. Further changes in human development, in terms of density of urban development, impervious land cover and aging infrastructure is anticipated to increase vulnerability levels. There is emerging research leading to the hypothesis that changes in the hydrological regime may also influence seismic activity (Hurwitz et al. 2003).

Frequency of Hydrologic Disasters (*Number of hydrologic disasters per year within the Puget Sound basin*): Hydrological disasters include floods, landslides, major storms and droughts. The frequency of events are correlated to changes in the hydrological cycle, development patterns (especially impervious surfaces), and infrastructure (including stormwater management and armoring). According to the Center for Research on the Epidemiology of Disasters an event is considered a disaster if more than 10 people are killed, more than 100 are affected, a call is made for international assistance and/or a state of emergency is declared (2007). Implications of the disasters include increased risk to the health and safety of the Puget Sound's residents, increased costs of infrastructure improvements and repairs, and increased risk of damage to the current state of sensitive natural areas.

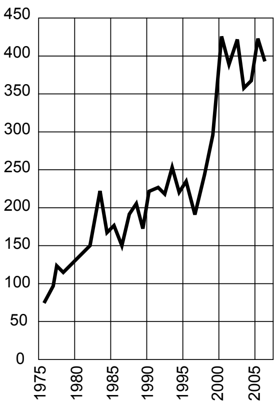
Damage from floods currently exceeds damage by all other natural hazards in Washington State (WA EMD 2005). Counties within the Puget Sound Basin are the most vulnerable to floods, with Presidential Disaster Declarations occurring about every 3-5 years (per county) (Ibid). Since 1956 there have been 28 presidential Major Disasters for floods in this State. Landslides are most frequent along the I-5 corridor, along the Pacific coast and bluffs, and the Cascade and Olympic mountain ranges (Ibid). Major storms, including extreme precipitation events, having been occurring with greater frequency in Pacific Northwest Region over the last 50 years (CIG 2007). In the past century this State has experienced several severe droughts, many lasting more than a single season. Eastern Washington is more vulnerable to droughts than the Puget Sound basin (Figure 5.23).

Figure 5.23 Frequency of hazards (CRED, 2008)



Current trends show that hydrological changes including those impacts of El Nino, the Pacific Oscillation and climate impacts can influence the frequency of major disasters. These changes can be exacerbated by changes in land cover including loss of vegetative cover and soil stability. Globally the number of hydrological disasters have tripled in the last 25 years (Guha-Sapir et al. 2004)(Figure 5.24).

Figure 5.24 Global hazards (Guha-Sapir, 2007)



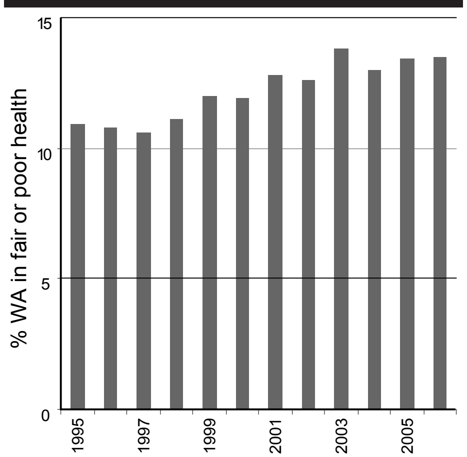
Public Health

The science and practice of protecting and improving the health of a community, as by preventive medicine, health education, control of communicable diseases, application of sanitary measures, and monitoring of environmental hazards (American Heritage Dictionary, 2007).

Health Status (%*Self assessed with fair or poor health (CDC – BRFS)*): The health status of Puget Sound residents is influenced by many factors including healthy behavior, the environment, genes and medical care (Jackson and Kochititzky 2005). This indicator focuses on how residents perceive their own health status as indicated by the CDC's Behavioral Risk Factor Surveillance system. Data is collected for 1995-2006 for Washington State. Specifically, respondents were asked to evaluate their own health status, on a ranking of excellent, good, fair or poor.

In 2006, 13.5% of respondents in Washington State said their health status was 'fair to poor'. For comparison, across the nation 14.7% responded with a 'fair or poor health', Kentucky had the worst health status with 23% and Minnesota the best with 10.8% (CDC, 2007) (Figure 5.25).

Figure 5.25 Health status (CDC, 2007)

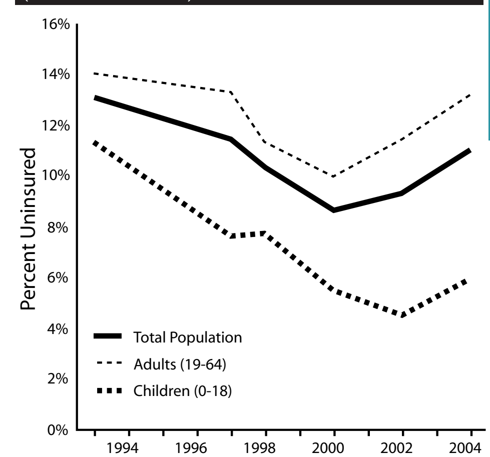


According to panel interviews the future health of Puget Sound residents will be compounded by increasing populations which will generally increase environmental contaminants such as emissions, water-borne pollution, congestion, time in traffic, less open space per capita, and increase resource pressures. On the other hand, there will likely be advances in medicine including early screening for diseases and more effective treatments. Technological advancements may also allow us to reduce negative impacts to the environment for example reduced emission vehicles and reduced affluent from wastewater treatment plants.

Resource Distribution (% ***without health insurance*****):** How resources are distributed across the region has significant implications on the region's quality of life, equity and resiliency towards health epidemics. As economic inequality grows a smaller percentage of the population consumes greater percentages of the region's goods and services. As resources become scarcer and services strained due to growing population numbers and exploitation of current stocks, the concern over resource distribution will rise. Maintaining an unhealthy segment of the population not only creates social equity issues, it is also not cost-effective. More and more the public health profession is returning to the belief of treating the community and not individuals. Especially during times of crises, whether from an infectious disease or a natural hazard a disproportionate distribution of resources can lead to great economic strain. Hurricane Katrina may be a prime example of the implications. Resource distribution can be measured through various indicators. For this report the number of individuals without insurance is utilized due to its high attainability and widespread usage.

According to findings from the Washington State Population Survey (SPS), the percent of Washington residents without health insurance increased from 8.4 percent in 2002 to 9.8 percent in 2004 (Ammons 2007)(Figure 5.26). This increase in the percent uninsured is statistically significant at the 20 percent level. The change in the percent uninsured represents an additional 100,000 uninsured people in the state for a total uninsured population of approximately 606,000, or almost 1 in 10, Washingtonians. The increase in

Figure 5.26 Percent uninsured (Ammons, 2007)



uninsured numbers is also being seen nationally and has been reported by the Census Bureau (2007).

Washington's health care system will experience growing demands due to a rapidly aging population and a growing poor ethnic population; these two groups have different health care needs. Further we do not have a good higher education system to prepare a new workforce. (Kirshner and Thadden, 2004). On the other hand there is a strong push towards public health care for all at both the State and national level. Governor Gregoire is currently working on the 'Healthy Washington Initiative' to ensure adequate health care for all Washington residents by 2012 (Gregoire 2007).

Resource Abundance (Acres of shellfish growing areas / Acres of farmland): Aquaculture and agriculture are the main food producing practices in the Puget Sound (PSAT, 2007). The health of Puget Sound residents is intricately tied not only to the availability of these resources, but also their condition. As resources diminish costs rise and nutritional food becomes less available especially to minority populations. Further, contamination of the food sources due to environmental pollutants can severely impact public health forcing residents to rely on more distant food resources.

The Puget Sound is one of the largest shellfish producing regions in the United States. Furthermore, shellfish are a staple dietary component for tribes and immigrant populations. Shellfish, including clams, oysters and other bivalves filter marine waters accumulating bacteria, viruses and other harmful pathogen. While the shellfish are not impacted by these pathogens, humans consuming contaminated shellfish can suffer from severe illnesses. Shellfish growing areas are thereby monitored on an ongoing basis to ensure public safety (State of the Sound).

West of the Cascades our agricultural industry tends to be represented by small farms focusing on dairy products, poultry and berries (MSRC, 2003). As land values for new development rise, agricultural fields begin to disappear. Once productive soil is covered by development it is difficult to recover this productivity. Industrial agriculture has also been associated with an increase risk of contaminated products including e coli and pesticides (WA Department of Health, 2005).

Concentrations of toxins in Puget Sound shellfish and the geographical scope of shellfish closures have increased over the past four-to five decades. Since the 1980s, the frequency of detection of PSP toxins has increased in the southern basins of Puget Sound, an area containing the region's most productive shellfish beaches (Snover et al, 2005). In 2005, nearly one-third of the Sound's shellfish growing areas had high enough levels of fecal coliform bacterial pollution to restrict harvest (PSAT, 2007) (Figure 5.27). According to the agriculture census, between 1987 and 1997 Washington lost nearly 1 million acres of farmland and more than 4,500 farms. Washington is currently losing 23,720 acres of farmland each year (Figure 5.28).

Figure 5.27 Closed shellfish havesting beaches (PSAT, 2007)

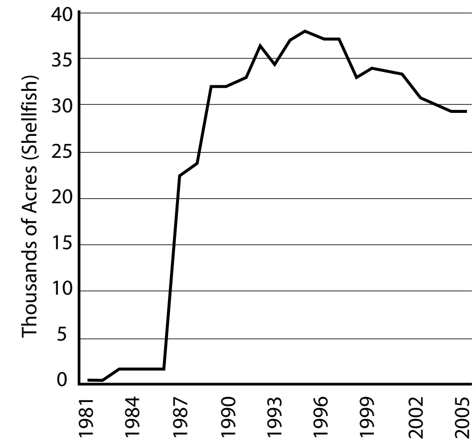
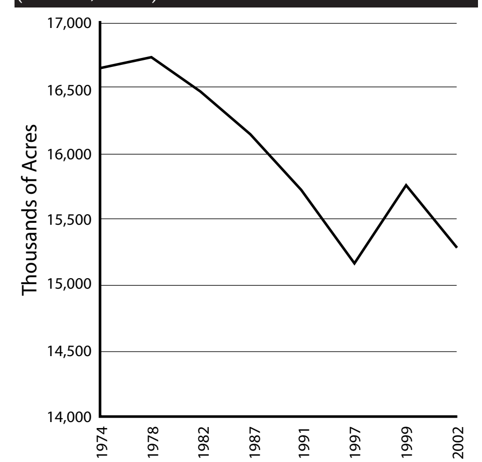


Figure 5.28 Acres of farmland (MSRC, 2003)



Growing human development in the Puget Sound region is likely a major contributor of the recent increases in PSP toxins. Increased nutrients (via activities such as aerial forest fertilizing, sewage outfalls and agricultural runoff) can provide more favorable growth conditions for the algae producing PSP toxins. The dominance of aquaculture will likely increase in the next 50 years, as we try to feed a larger population. The impact of aquaculture on natural areas will depend largely on regulation enforcements. Threats to our agricultural productions come from loss of soil productivity, rising water and energy costs, consolidation of agricultural production into larger farms and competition from Asian producers (MSRC, 2003). The cost of transporting global agricultural product may increase with increasing fuel costs influencing a growth in the local market. The role of China's agricultural production in the future is uncertain and will depend on cost of transportation and political shifts.

The cost and health of regional fish and produce will likely affect regional consumption patterns.

Technology and Infrastructure

Technology can be considered the means by which humans use nature for their own benefit (Headrick, 1990). Infrastructure can be thought of as those services and facilities that support day-to-day economic activity. Infrastructure includes roads, energy and water provision, waste disposal, and transportation. For this project, infrastructure and technology are clustered together as a single driving force. While these are really quite different forces, their interdependencies are so high it is hard to talk about one without the other. The implication of major technological change in the Puget Sound region is dependent on a restructuring of the region's infrastructure.

Technological change can be seen as both society's salvation and demise. The motivations behind technological innovation are considered to be "power over nature (to go faster, to light the darkness, to do more work with less effort, to extract wealth form the earth) and power over people (to defeat enemies, to outwit competitors and to control others)" (Headrick, 1990, p. 55). In the past 200 years, technology has changed in kind, complexity and rate leading to the attainment of major societal achievements. However, as shown through history, the impact of technological change rarely stops at the original and intended goal. In fact the unintended consequences of past technological change can be linked to most of our current environmental problems. Nevertheless, it is still a commonly shared hope that new innovative technology will bail society out of their environmental problems (Meadows, 1972).

Within this report we focus on four major forms of technology and infrastructure; transportation, energy, waste (solid and water) and water management (drinking and storm water):

- **Transportation:** Generally transportation can be divided by public and private transportation means; primarily cars and mass transportation (light rail and buses).
- **Energy:** Energy provision reflects the form and amount of energy supplied to Puget Sound residents and industries, to heat their homes, power appliances and operate machinery focusing on both electrical and gas energy provision.
- **Wastewater + Solid Waste:** Sewer and septic systems control the wastewater coming from residential, industrial and commercial lands. The Growth Management Act (GMA) distinguishes among rural and urban service areas (WA DOH, 2007). Within urban areas sewer service must be provided for households, while septic tanks (with few exceptions) are not permitted. Solid waste refers to trash, recyclables and compost.
- **Drinking Water + Stormwater:** Drinking water refers to the collection, treatment and distribution of freshwater to regional residents. Stormwater refers to the collection and removal of excess runoff that does not infiltrate into the ground. Generally, in urbanized residential, industrial and commercial lands runoff is collected via drains and gutters, conveyed through underground pipes and released into nearby waterbodies (or combined with waste-water, see above).

While each form has its different relationships to other driving forces and divergent implications for regional change the three dimensions selected are relevant for all four forms. Connectivity focuses on the regional connections of the overall system; specifically whether infrastructure stops at municipality or household boundaries or if it is seamless throughout the region. Investment looks at the amount of funds allocated towards the particular form of infrastructure, reflecting both the pressure to redevelop or extend a specific form of infrastructure and society's valuation of the service gained. Lastly, the type of technology or infrastructure looks broadly at how adaptive versus rigid a given technology is. Adaptive infrastructure is generally proactive, flexible and context sensitive; mirroring natural cycles and using resources efficiently. On the other hand reactive infrastructure is reactive, rigid and de-contextualized; aiming to control and minimize natural variations and is resource intensive.

Connectivity

Transportation: The automobile has generally benefited from high connectivity at the local, regional and even national level. Creating efficient road and highway systems has seen concerted efforts of every municipality. One major criticism of increased road connectivity is the high correlation to negative environmental impacts, primarily forest fragmentation. Planners generally acknowledge that road expansions, while a necessary service provision, have served as a catalyst for development intrusion into natural lands. In terms of mass transit, this region is currently vested in increasing light-rail connectivity. Current plans project service extension to Tacoma and Redmond. By 2050, we can likely see extension out to Everett and Issaquah.

Energy: Currently energy provision is highly connected, with Puget Sound energy providing the majority of the Puget Sound basin. In the next fifty years we may see a decrease in connectivity as renewable energy sources are utilized on site level basis. For example we may see buildings or neighborhoods powered by on-site power generators (whether solar, wind, fuel cells or hydropower).

Wastewater + Solid Waste: Currently the major distinction in wastewater treatment is between septic tanks and sewer plants. Septic tanks generally function on a per-household level and are not connected to a central facility. There are 5 sewer treatment plants in the region, with King County's Brightwater facility expected to be the largest. The region currently holds 1.2 million septic tanks and is expected to double in the next fifty years. There is currently a big effort to connect single family drain fields into larger systems. Advancements in membrane technology might make it more feasible to treat wastewater on smaller scales and release highly treated graywater back into neighboring waterways. In terms of solid waste currently each municipality maintains its own waste collection and recycling facility. This report has not collected any information pertaining to future connectivity of solid waste.

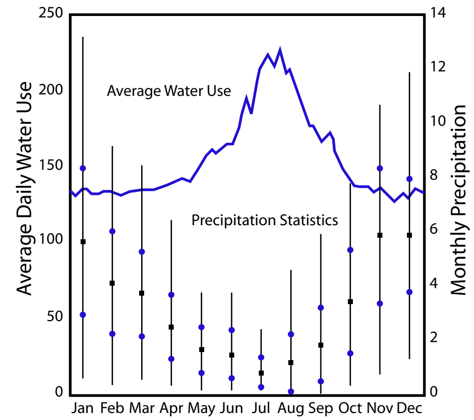
Drinking Water + Stormwater: Stormwater can be connected by underground pipes and large treatment facilities or natural water ways (creeks and streams). Natural land cover reduces reliance on artificial stormwater management as precipitation gets infiltrated into the ground. By definition, the entire Puget Sound basin is hydrologically connected. However, within this report, natural systems are generally considered less connected, as precipitation mostly remains close to where it falls (or moves slowly), whereas artificial stormwater drainage systems are considered more connected. Recent trends are pushing towards the application of 'natural drainage systems' to reduce the reliance on underground pumps to convey stormwater. In terms of drinking water, urban municipalities provide drinking water from large reservoirs and supply water to individual homes; rural municipalities often rely on private well systems. As this region urbanizes the reliance on wells will likely decrease.

As the regional population grows and developments spread total demand for drinking water and stormwater management services will increase. Increasing temperatures and decreased summer flows could make it more difficult for water suppliers to meet the needs of consumers and in-stream flow requirements, especially in snowmelt-fed watersheds (Figure 5.29). Increase in impervious surface due to new developments and natural land cover alterations will increase the volume of runoff requiring collection, conveyance and release.

Investment

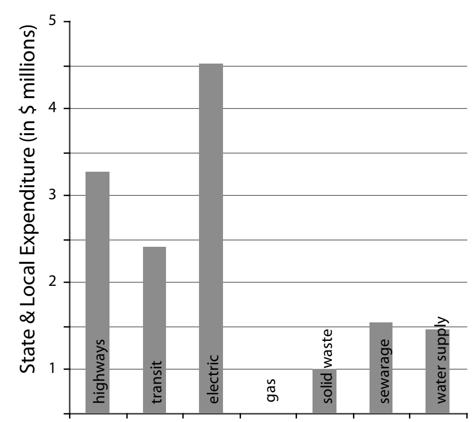
Transportation: Over the last 30 years we have doubled the amount of roads putting significant strain on our transportation infrastructure. Major public investments will be required over the next 50 years to upgrade and extend upon current transportation services. A critical uncertainty lies with the level of present financial sacrifices the public is willing to make for future services. Adding further complexity to the magnitude of investments are questions of spatial distribution (i.e. will we invest in rural or urban infrastructure) and upgrade versus extension of services. In the future, congestion pricing will likely be utilized to produce revenue for transportation projects. A much more significant uncertainty may lie in the form of new transportation options in 50 years. This region may find itself investing in technology that is not currently available.

Figure 5.29 Water demand and supply (Snover et al, 2005)



Energy: Currently the Puget Sound enjoys lower monthly energy bills than the national average, $66.19 and $81.42 respectively (Energy Information Administration (EIA), 2006). If the cost of gas rises as expected, coupled within greater stream flow fluctuations affecting hydropower, and population growth the cost of energy will rise. Depending on the level of energy scarcity this region might find itself needing to significantly reinvest in new renewable energy technology. A redevelopment of our current energy infrastructure will require significant investments and public buy-in.

Figure 5.30 State expenditudes (OFM, 2005)



Wastewater + Solid Waste Definition: Currently 60% of infrastructure spending goes towards sewer and 5% goes towards solid waste (OFM, 2007)(Figure 5.30). While Seattle has an aggressive recycling program, future investments of small and rural municipalities in recycling facilities may decrease the region's solid waste volume. In terms of wastewater, the region maintains miles of wastewater infrastructure that has been built based on past hydrologic events and their fluctuations. Much of this infrastructure combines both stormwater and wastewater in the same pipes. In major storms the volume of water may exceed the wastewater treatment plant's capacity and untreated sewage is allowed to flow into the Sound (called a combined sewer overflow (CSO) event). Climate impacts may significantly influence our ability to control and reduce CSO by adding in larger peaks and less land storage. If this region attempts to unlink waste and storm water it will require a significant investment.

Drinking Water + Stormwater Definition: Depending on the magnitude and fluctuations of climate impacts the cost of providing drinking water and managing stormwater might escalate significantly. As noted in the wastewater section above, an increase in impervious surfaces coupled with higher winter precipitation may exhaust current infrastructure capacity. In terms of drinking water, increase demand due to a growing population coupled with decrease summertime supply due to early snowmelt and lower summertime precipitation volumes will likely increase the cost of water. Depending on our level of urbanization and impacts of climate change it is likely that over the next 50 years this region will need to restructure its water infrastructure requiring significant investments

Type

Transportation: One solution is to build more highways, another is to increase the proportion of commuters using mass-transit systems. In the next fifty years cars will likely benefit from either increased fuel economy (50-95%) and reduced emissions, or a new propulsion system (i.e. fuel cells) which will eliminate reliance on fossil fuels and any emissions. While fuel cell cars might considerably reduce environmental impact they might increase congestion.

Energy: The future of our energy supply will certainly demand a decrease in the use of non-renewable resources such as crude oil and natural gas and an increase in renewable resources such as solar and nuclear power. What is rather uncertain is what technology will be used, and how quickly we will transition. The amount of water available for power generation in the Northwest varies substantially from wet to dry years. Because Puget Sound Energy depends heavily on hydroelectric generation this variability creates considerable uncertainty for power supply planners. By 2025 demand will significantly surpass supplies in the region (PSRC, 2005). While renewable energy is established in the region, Washington exceeds the national average for electricity usage (Sightline, 2006. Puget Sound Energy's projections show that by 2040, we will likely see additional advancements in energy conservation and the further development of alternative energy sources - particularly in the areas of solar, wind power, tidal and perhaps even geothermal energy-all of which are currently being implemented on some scale.

Wastewater + Solid Waste: In recent years Seattle has significantly increased the proportion of waste that is recycled or composted as opposed to discarded. Future treatment plants may rely more heavily on natural biofilters to treat wastewater. Further, some European countries are investing in water-free plumbing (i.e. composting toilets) to reduce wastewater volumes.

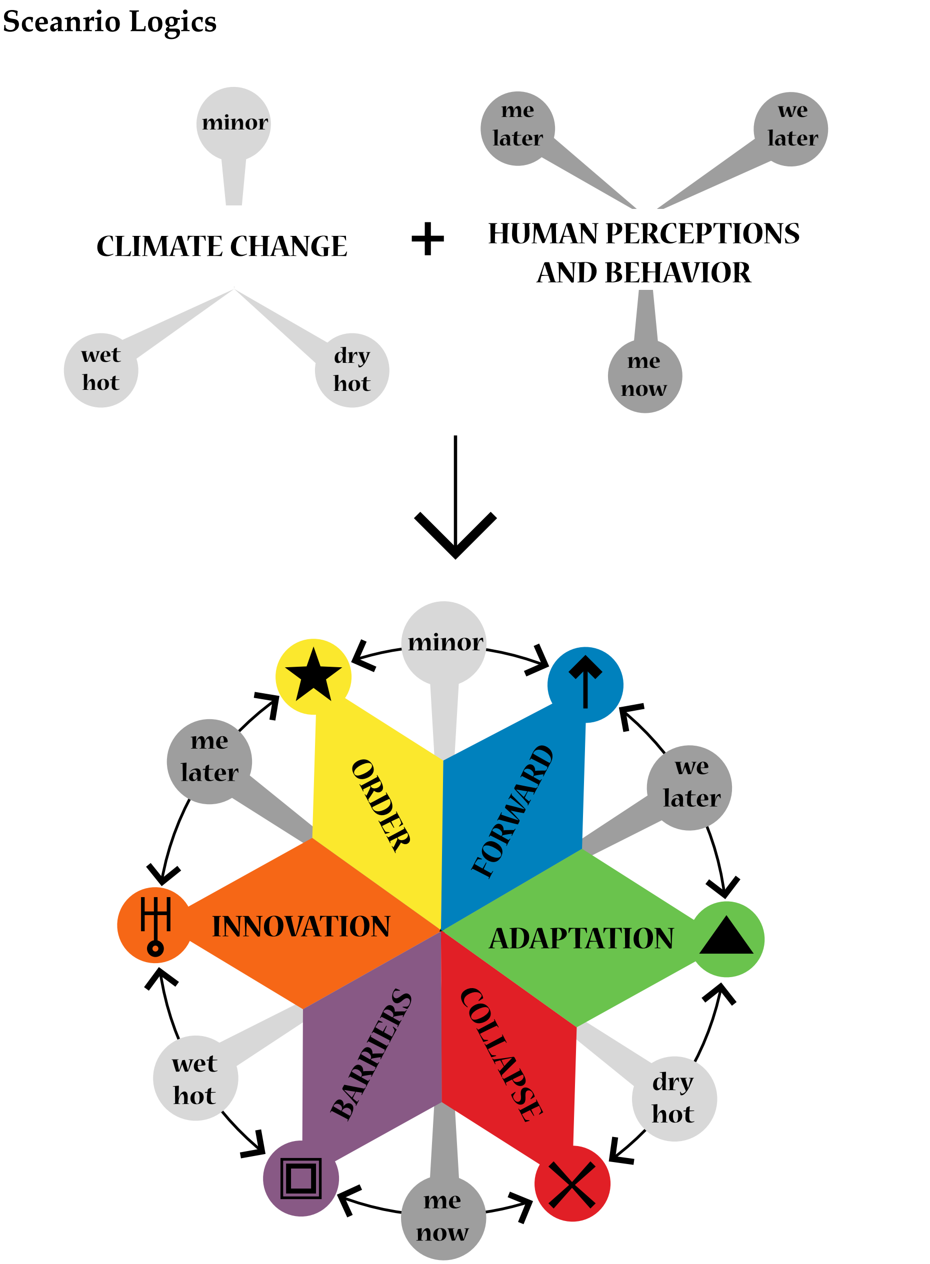
Drinking Water + Stormwater: The most significant transition for stormwater delivery may come from shifting from a system of pipes and pumps to a natural drainage strategy (including bioswales, greenroofs, cisterns, raingardens). These systems generally detain stormwater on the site for to prevent the surge of the first flush and resultant CSO events. Further, some systems utilize the stormwater onsite or allow the water to infiltrate, recharging underground aquifers. Over the next fifty years, depending on the level of urbanization and changes to the hydrological regime this region may invest in larger pipes or more natural drainage.

6. Sound Scenarios

Overview

The Puget Sound Future Scenarios depict 6 alternative futures for the Puget Sound region by the year 2050. They are intended to be highly divergent, plausible stories, both compelling and informative. The scenarios focus on uncertain future trajectories for two driving forces: climate change and human perceptions and behavior and explore their implications on future conditions in this region (Figure 6.1). The scenario narratives combine the most divergent and relevant future trajectories of each of the key drivers with supporting drivers, storylines and system states. Together they represent significant implications for the opportunities and challenges of nearshore ecosystem restoration in this region. Table 6.1 provides a brief synopsis of each of the 6 scenarios.

Figure 6.1 Scenario logics



Forward: Low climate change coupled with a greater social ethic of cooperation provided the Puget Sound the opportunity and resources to proactively address environmental problems and improve the quality of life for all of its residents. While the region's economy continued to grow and immigration doubled the Sound's population, the region managed to maintain and restore ecological function. Residents, governments and industry shared a new understanding of the Puget Sound ecosystem as an integrated human-ecological system creating a renewed relationship with their environment.

Order: While climate change was a best-case scenario, population growth coupled with increasing consumption placed pressure on the Puget Sound's resources. An increasingly fragmented governmental structure spurred conflict between municipalities and interest groups. In spite of existing environmental regulations, a lack of coordination among governmental agencies was a major obstacle in improving ecosystem function. Sprawling developments coupled with a low investment in the region's infrastructure, education and health significantly reduced the quality of life in the region.

Innovation: More and greater climate fluctuations increased the Puget Sound's vulnerability to floods, windstorms and fires. Technological innovation mitigated negative impacts on residents and infrastructure. The high tech industry led the regional economy, drawing in skilled labor and high wages and largely controlling the political arena. Growth rates of new ideas, production, immigration and housing development all increased, generating wealth and jobs. Innovation allowed per capita consumption levels to remain high through increased efficiency and closed-loop industrial processes.

Barriers: Society in the Puget Sound region divided as the disparity between the rich and poor was magnified. Escalating climate impacts posed significant threats to private property, regional infrastructure and natural resources. Residents responded by building stronger walls, moving uphill and securing their investments. As cost of fuel and mitigation rose, the rich buffered their families from impeding harm, while the poor were left behind with a continuously degrading economy. Government regulations were relaxed in an effort to overcome financial hardships, but instead facilitated a growing economic divide and poor management decisions.

Collapse: Decreased precipitation rates, warmer temperatures and a self-interested short term society spelled disaster for the Puget Sound region. Resource extraction and pollution load exceeded critical thresholds causing harm to ecosystem functions. Increased fragmentation and decreased precipitation led to droughts, forest fires and massive pest outbreaks. Increasing government costs and dwindling resources led to poor investments in infrastructure improvements and public services. As the beauty and health of the Puget Sound landscape slipped so did major industries, causing a severe economic depression followed by out-migration.

Adaptation: Despite major challenges caused by climate change, adaptive management and a positive consciousness regarding environmental change allowed the region to cope with the emerging problems and maintain high standards of life. Cooperation among residents, businesses and governmental units allowed this region to prosper despite increased vulnerability brought on by climatic impacts. Production rates decrease, but collective wealth rose due to investment is education, health and shared community resources such as public transit and renewable resource infrastructure. A growing awareness of future uncertainty embedded the precautionary principle into resource management and environmental policies, erring on the side of caution and increasing the region's resiliency.

Table 6.1 Short summaries of the six scenarios

Key drivers

Climate Change

While there is vast scientific agreement regarding the evidence of climate change, there is high uncertainty about potential trajectories and their regional impacts. The scenarios focus on two key dimensions of climate change in the Puget Sound Basin by the year 2050 the: 1) magnitude of change in annual temperature and precipitation, and 2) fluctuations described by the change in variance from historical trends of both temperature and precipitation patterns (Table 6.2).

The scenarios focus on the most divergent trajectories for 2050 for both temperature and precipitation change. The graph on the left isolates the three model simulations selected from the complete set. The table below defines the specific temperature, precipitation and variance attributed to each of the three directions explored by the Puget Sound Future Scenarios.

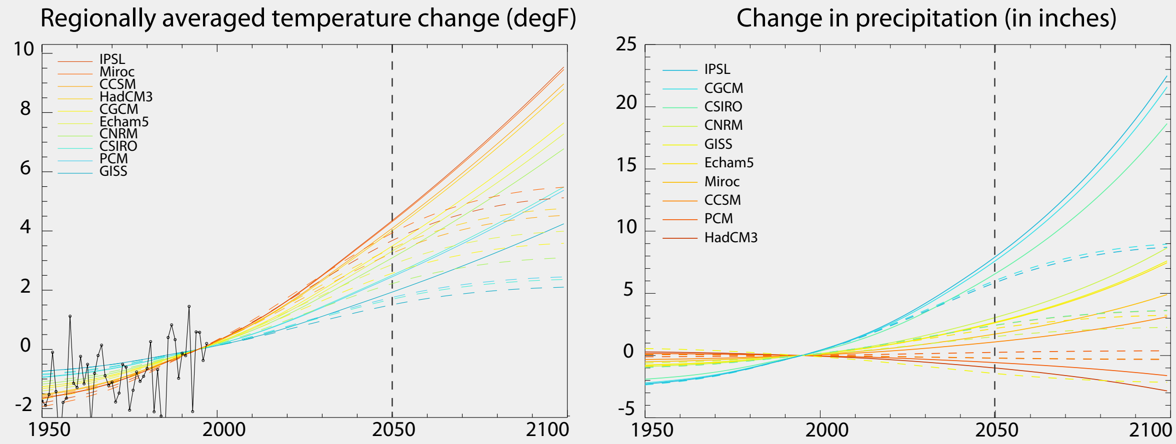
While the key drivers focus on only these two dimensions the final scenarios respond to interdependent implications of climate change including sea level rise, snow pack reductions, streamflow volumes, water quality, forest area, hydropower cost, agricultural and fishery yields, water supply competition, and pressure on flood and storm management. In general, greater changes in magnitude are correlated to changes in levels such as seal level rise and streamflow volumes and changes in the frequency are correlated with severe events, i.e. windstorms and flooding (see Appendix D1).

CLIMATE CHANGE

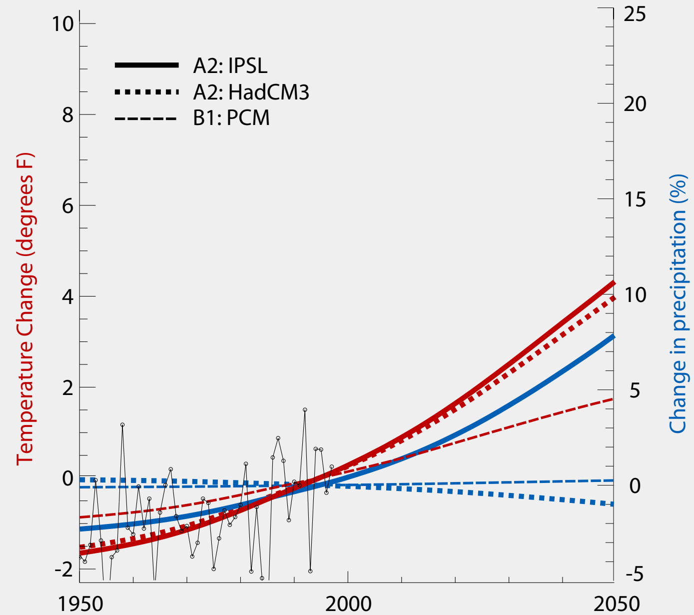
	Magnitude		Fluctuations
	Temperature	Precipitation	Variance
minor	1.75degF	0″	Historical
dry hot	4degF	1″	Historical
wet hot	4.4degF	8″	Greater

Table 6.2 Climate change scenarios. *Right top* Mote et al 2005, p6-7

Refinement of Key Drivng Force Trajecories



Each color represents a model simulation; A2 scenarios are solid and B1 scenarios are dashed (Mote et al. 2005, p6-7).



	minor	dry hot	wet hot
IPCC Scenario	B1	A2	A2
Model Simulation	PCM	HadCM3	IPSL
Temperature	1.75degF	4degF	4.4degF
Precipitation	0.2%	-1%	+8%
Variance	historical	historical	highly variable

Human Perceptions and Behavior

How society behaves has cascading effects on many drivers influencing the region's future. For example the regulations people are willing to endorse, the way they develop land, the businesses people invest in, the products they purchase, the waste they generate are all influenced by human perceptions.

The scenarios focuses on two key dimensions of human perceptions and behavior: 1) people's values concerning the distribution and allocation of regional services and goods and 2) how much value people place on having resources now as opposed to in the future. Social values concerning distribution and allocation portray two polar societies: individualistic refers to a society which maximizes individual or household utility; collectivistic refers to a society that reduces household utility in order to maximize regional utility. Future valuation describes a preference for short-term decisions that maximize utilizing resources now, versus long-term decisions which invest current resources in order to have more opportunities in the future (Table 6.3).

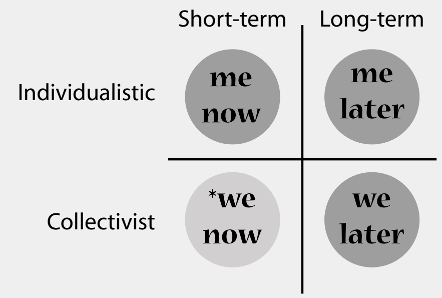
HUMAN PERCEPTIONS AND BEHAVIOR

	Social Values	Future Valuation
me now	Individualistic	Short-term
me later	Individualistic	Long-term
we later	Collectivistic	Long-term

Table 6.3 Human perceptiosn and behavior scenarios

Refinement of Key Drivng Force Trajecories

Future valuation is not necessarily correlated with the social constructs of individualism and collectivism. Here, investments are utilized to describe the relationship between the social construct of individualism and collectivism and future valuation. Collectivism occurs when societal goals are compatible with individual goals, and obligation push people towards achieving those shared goals. In general these shared societal goals strive for long term or generational change. This society would favor a long term public investment (i.e. transit lines, public schools and universal health care). In times of a crisis a short-term collectivist society may arise, but this societal urgency is generally highly ephemeral. This society can be characterized by short-term public expenditure (i.e. disaster relief). An individualistic short-term society is composed of individuals whose personal goals are developed independently of societal goals and who value immediate returns. This society invests in immediate personal (or household) consumption of goods and services. Lastly, an individualistic society with a high future valuation can be characterized by individuals have long term goals that may not be consistent with the goals of the society as a while. These individuals (or households) may invest in long term savings and or private education.



*the 'we now' society is inherintly unstable and only thrives for short time periods therefore we felt it was inappropriate for developing 50 year scenarios.

	me now	me later	we later
Social Construct	Individualism	Individualism	Collectivism
Level of Sharing	Low	Low	High
Goals	Inconsistent	Inconsistent	Compatible
Future Valuation	Short-term	Long-term	Long-term
Discount Rate	High	Low	Low
Public Investments	Low	High	High

Supporting trajectories

Panel discussion identified 32 indicators to help describe major differences between the final scenarios. The Driving Forces section of this report describes each indicator in terms of its relevancy, current status and expected future trend. The full set of assumptions about each indicator under each scenario is included in Appendix D: Scenario Assumptions. A limited selection of the most relevant trajectories helps narrate each scenario. Indicator trajectories are not based on model runs and cannot be validated as typical model simulations but instead are based on assumptions and expert knowledge about the relationship between the drivers, and consequent implications on the future conditions within that scenario.

General trends exhibit strong correlations among specific dimensions of the supporting driving forces. For example, economic growth is often coupled with population growth. These four sets of relationships are divided into: growth rate, socio-economic characteristics, governance and regional investments. Growth rate reflect the change in the rate of growth as compared to the recent past, focusing on overall economic, demographic, and development growth trends. Socio-economic characteristics supplement the growth rate, characterizing the type of growth associated with specific trajectories. For example, are development patterns sprawling or high density, are populations aging or young, is the economy depended on imports, exports or a balance of both. Governance describes the strength of governance dominating regional changes and the types of partnerships that are formed. For example, a strong government exhibiting leadership and collaborations among many local units of governments, as opposed to a weak and ineffective government that supports a fragmentation among multiple constituencies. Regional Investments is an overarching description of the amount invested in the region including education, public health, ecosystem health, public infrastructure and social equity. The magnitude of investment is supplemented by a general characteristic of what is invested in.

Storylines

The storylines of each scenario are unique, trying to clearly capture the essential elements of each plot. They reflect many of the ideas we heard from participating experts, about the overarching changes society is experiencing and potential viewpoints about how the future may turn out. In general, we heard that a shift in societal behavior towards collectivist goals and long term investments is essential for positive change. Therefore only one 'optimistic' future outlook is paired with an individualistic human value (innovation), and none are paired with a short-term future valuation. Table 6.4 briefly describes the six worldviews and future outlooks associated with each scenario.

Table 6.4 Worldviews
The **Forward** scenario portrays a paradigm shift in human-ecological interactions, where human and ecological systems are seen as interdependent and coevolving. Management policies are based on adaptive strategies that simultaneously expand the Region's economic, social and natural capitol.
Order exposes a society that relies on regulation to govern human behavior. Heavy top-down restrictions on consumption are presumed to be most effective in maintaining a stable-state ecosystem.
Innovation reflects a technological optimist society, one based on the premise that technological innovation will be able to solve all current and future ecological problems. It reflects a perspective of human domination over nature.
Barriers portrays a society who perceives protective government as interfering with a free market and should be relegated to dealing only extreme requirements such as law enforcement and international security.
Collapse exhibits a society that assumes further exploration and exploitation will allow us to overcome declining yields and increasing costs.
Adaptation signifies a dramatic societal shift, where new challenges are met with an adaptive response. Society abides by the precautionary principle and believes that increasing uncertainty can be best handled creating buffers for error.

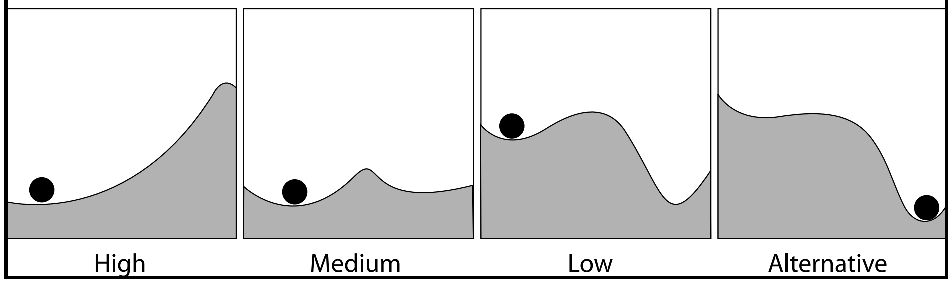
System state

The final piece of each narrative focuses on the system state within each scenario, mainly the level and types of pressures, and the resulting ecosystem resilience. This part of the narrative explicitly looks at the Puget Sound ecosystem and synthesizes the potential relationship between the future conditions of the region as a whole, and implications for restoration strategies. The relationship between external pressure and ecosystem resilience is characterized by a two-part hypothesis: the importance of the level of pressure in catalyzing change, and the success of change in enhancing or protecting ecosystem resilience. For example, a high external pressure can force change reducing ecosystem resilience further (i.e. Barriers) or function as a catalyst for sustainable approaches (i.e. Adaptation). On the other hand, low pressure can provide stability needed to test appropriate strategies for achieved resilience (i.e. Forward) or cause inaction, as society delays responsibilities (i.e. Order). Figure 6.2 defines the three sources of pressure and four levels of resilience described utilized within the six scenarios.

Figure 6.2 Sources of pressure and levels of resileince

Pressures	**Economic**	Economic pressure can stem from different levels of economic growth, stability, rising costs of living and escalating infrastructure costs.
	Social	Social pressures can stem from income inequity, poor health status, low educational attainment levels and crime.
	Ecological	Ecological pressures generally affect humans through resource scarcity, pollution and changes in magnitude and frequency of natural hazards. Ecological pressures arise when ecosystem functions are impaired.

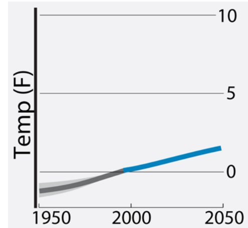
Ecological resilience is a measure of the amount of perturbation a system can withstand before transforming into an alternative stable state. The foreground curves represent the stability landscape of the system state. The deeper the stability pit, the more stable a system is while the wider the pit, the more resilient the system is to perturbations. The four diagrams below represent the four system states represented within the 6 scenarios.



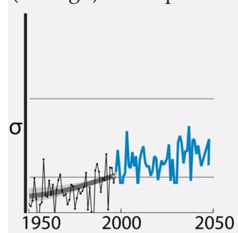
Scenario narratives

FORWARD

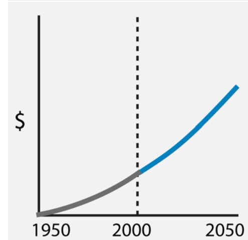
Figure 6.3 Forward indicators



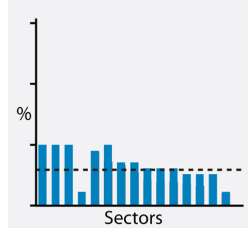
a) slight increase (1.7degF) in temperature



b) Variance consistent w/historical pattern



c) GDP increasing at current rate



d) industry is highly diverse

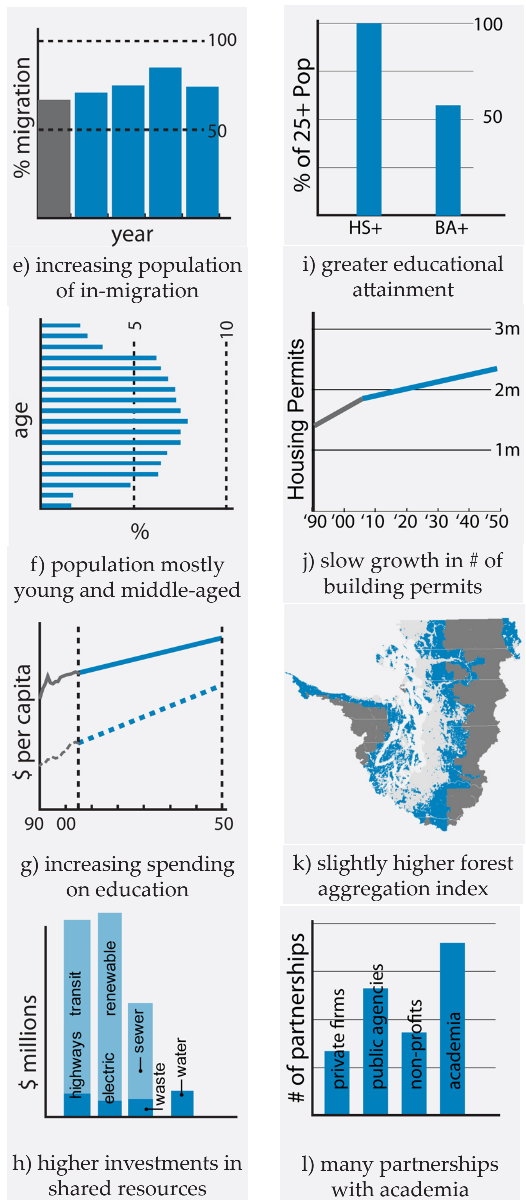
Society surprised by delayed climate impacts Regional impacts of climate change remained relatively minimal as climate change showed a delayed response to carbon emissions, and regional variations of climate change started to emerge. Annual precipitation patterns reflected no significant change, while the temperature increased modestly by less than 2degF (Figure 6.3a,b). But regional and federal political leadership succeeded in capturing public attention towards the time pressure required for action and the significant potential for future hardship. Puget Sound residents became knowledgeable about the regional interdependence of their actions, and believed the long-term goals of society were compatible and better achieved through cooperation. Society has the chance to proactively prepare and respond to delayed climate impacts through investments and a more equitable distribution of resources. Households served regional obligations despite some personal sacrifice, investing a larger share of the household income towards public long term investments and voluntaringly reducing resource consumption.

Fast growth strengthens local investments
While climate impacts were lower than anticipated, economic growth proved surprisingly higher than anticipated. The Gross Domestic Product of the Puget Sound region continued to increase at a fast rate, almost doubling its value in 2000 (Figure 6.3c). The diversity of industry types in the region increased, further supporting economic growth and providing a stable business environment (Figure 6.3d). Greater opportunities for high wage jobs in the region created a continuous inflow of skilled migrants (Figure 6.3e). The greater proportion of young adults moving into the region effectively

shifted the age distribution, making the Sound more attractive to new businesses (Figure 6.3f).

Economic growth in the region increased the available resources for regional investments. Economic opportunities were coupled with a support for long-term investments due to a highly educated population who places a greater value on the future (Figure 6.3g). New investments supported efficient, sustainable and flexible designs that accommodated the changing needs of the region, reducing reliance on dwindling oil supplies and providing benefits for generations to come. Further, a time of affluence strengthened opportunities for cooperation, leading to cross-jurisdictional investments and more efficient use of government resources (Figure 6.3h).

Figure 6.3 Forward indicators *(cont.)*



e) increasing population of in-migration

i) greater educational attainment

f) population mostly young and middle-aged

j) slow growth in # of building permits

g) increasing spending on education

k) slightly higher forest aggregation index

h) higher investments in shared resources

l) many partnerships with academia

Thriving healthy communities provide a high quality of life for all

A young and mobile population dominated the Sound, reflecting preferences for dense, mixed use and vibrant communities (Figure 6.3i). While the construction of new houses continued, the rate of building permits slowed as multi-unit buildings dominated the urban landscape (Figure 6.3j). Market preference for urban living decreased development pressures into natural lands along the fringe, and thereby protected the ecosystem function of forests (Figure 6.3k). Dense neighborhoods were interconnected by rapid transit lines significantly reducing reliance on costly transportation alternatives such as single occupancy vehicles. Economic growth expanded immigration of a diverse population and Puget Sound neighborhoods are enriched by ethnically diverse communities, supporting a movement towards higher tolerance and awareness.

Thriving communities boasted equitable access to resources from open space to public health. Substantial regional investments in academic institutions were to provide free access to classes for all citizens. Connected open space networks were shared among communities and did not lie behind fences and signs. Access to nutritious and local foods was mediated by subsidized local agriculture and heightened awareness of personal benefits. A healthier population was less expensive to protect, allowing universal health care to become a reality as early as 2020. Access to greater resources and better services supported a higher equity among the Sound's residents, further fueling cooperation and commitments to long-term investments. By 2050, the Puget Sound was nationally top ranked for educational attainment levels, universal health care, and energy efficient transit system.

Art connects policy to science

Environmental education was infused at an early age, hoping to reach changes in adult behavior through younger generations. Classrooms were often found out in nature, allowing students to be actively engaged in restoring natural areas. Ecological principles were focused around the interdependence between human and nature, with a functional partnership towards a hybrid framework. Understanding the connection between the Sound's human and natural functions led to a support of higher ecosystem standards and sustainable practices. For example, residents understood the relationship between runoff and poor water quality, and supported measures to reduce impervious areas and restore natural waterways. Human preferences changed as well, towards voluntarily reducing consumption of non-renewable resources and supporting research into lower impact technologies.

Meanwhile, decision makers partnered with regional scientists and academics to develop more informed policies (Figure 6.3l). Monitoring stations spread throughout the Sound to collect critical information about the health status of the Puget Sound. Active participation from the public further supported active monitoring as ordinary citizens learned to read changes in their landscape. The increasing knowledge base and lower than expected climate impacts gave the region a chance to take an experimental approach, test policies and adapt management strategies to gain a new understanding of the Puget Sound ecosystem. As the Sound's population gained interest in ecosystem affairs biological indicators reported on the Sound's status on the front page of regional newspapers.

Strong leadership and access to nformation stimulates an impressive array of innovations

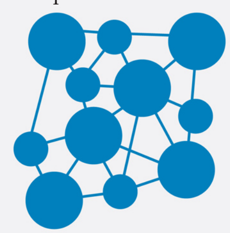
Governmental leadership in the Sound developed an adaptive roadmap with attainable goals for enhancing ecosystem resilience. Economic incentives and heightened community involvement pushed industries to help attain goals through developing and utilizing more efficient technology. The Puget Sound's tradition of innovation was further catalyzed by flexible adaptive management regulations and an ever increasing knowledge base (Figure 6.3m). New technological innovations reduced the regional waste stream, from effluents flowing into the Sound to filters enhancing air quality. Meanwhile, while renewed interest in politics and activism increased the number of decision makers, there was a serious commitment to working across political boundaries and leveraging the power of collaboration (Figure 6.3p). An involved and active community supported by strong leadership fought to maintain high standards of ecosystem functions for future generations.

Hybrid, equity and flexibility

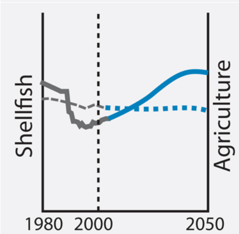
The Puget Sound in 2050 could be described by an overarching ecological paradigm that integrated humans and nature as partners in a hybrid framework and influenced regional resource management, from investments in renewable energy to awareness of the relationship between public health and ecosystem health. There was an increased emphasis on sharing resources and services among the Sound's residents, from affordable housing and universal public health care to open space and educational attainment (Figure 6.3o,p). A stable economic and climatic environment provided political leaders,

Figure 6.3 Forward indicators *(cont.)*

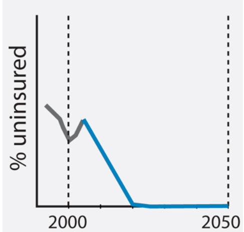
m) renewable resources, adaptive and shared



n) many decision makers, networked governance



o) more shellfish beaches, same farmland



p) all insured by 2020's

scientists and households the opportunity to learn through experimentation how to adapt to environmental change. Society's dominant worldview was that the region could simultaneously expand its economic, social, and natural capital through collaboration and knowledge. This strategy served the Puget Sound well, leading to very few external pressures and a higher resilience, reducing the basin's vulnerability to future pressures.

Nearshore ecosystem restoration is facilitated by low pressure and high resilience

A positive feedback loop strengthened investments into restoration and enhanced ecosystem resilience. An increased social awareness of both human health connections to the nearshore ecosystem function and future vulnerability fueled public investments to purchase thousands of acres of shoreline for protection. Monitoring and active public involvement in nearshore ecosystem restoration and protection rapidly disseminated the success of these projects through social networks. Consequently, private industry, catalyzed by public interest and immediate benefits, contributed to furthering ecosystem restoration by purchasing upland forestland, volunteering to reduce waste streams and investing in new efficient technologies.

This positive feedback was facilitated by low levels of environmental and economic pressure due to the stable economy, minor climatic impacts, and growing government revenues. Greater ecological resilience lowered regional pressures; rising resource abundance enhanced the economic feasibility of sustainable harvests; healthy and abundant local resources enhanced public health; and natural waterways dampened the impacts of floods and droughts. Strengthening this positive loop was a high quality of life for Puget Sound, due to great and equitable public resources and services, including an aesthetic and functional shoreline that brought in more people and further supported economic growth and investments in the region. In fact the only pressure this region faced was growth management, which, thankfully, was mediated by congruent social goals and an active public involvement in local politics.

★ ORDER

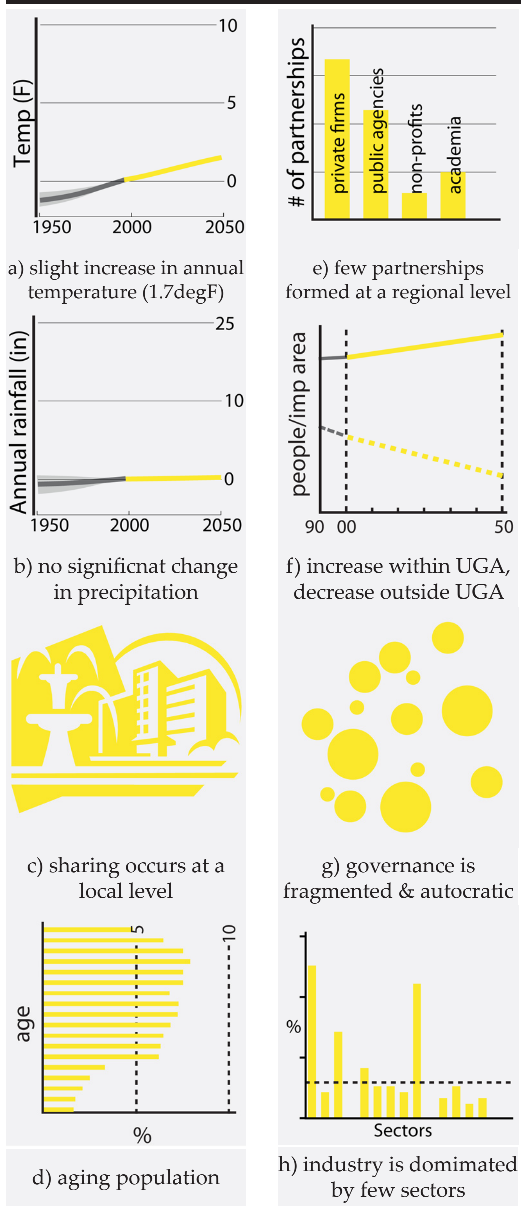
Resource consumption threatens ecological resilience in spite of a modest climate change

While climate change impacted this region less than originally anticipated (Figure 6.4a,b), a high consumption of resources led to escalating environmental degradation. When the significant implications of climate change were delayed, political leadership failed to motivate substantial and cooperative action from its citizens. Regional attitudes focused more on property rights and displayed a high divergence of goals and approaches. In general, while most households valued long-term investments, from buying houses and investing in education to staying healthy, they viewed these as a personal matters, best kept to household decisions (Figure 6.4c). By 2050 the temperature had increased slightly, and the number of extreme weather events had risen steadily in accordance with a historical pattern. Government regulation attempted to govern the distribution and protection of resources, encroaching on individual behavior while still unable to enhance the region's ecological resilience.

A fragmented population leads to a fragmented landscape

The region's population was aging, with the highest percentage over 50 and the smallest under the age of 20 (Figure 6.4d). While the regional diversity increased, ethnic, income and age distinctions were sharpened by exclusive neighborhoods. By mid-century the Puget Sound was characterized by divergent enclaves of diverse demographic groups, each represented by a different political unit. Regulations focused on protecting the environment but couldn't bridge the gap between myriad constituencies and local jurisdictions. Failed attempts at reaching consensus on approaches to govern common pool resources[13] further divided the population, and left governments with a piecemeal regulatory framework (Figure 6.4e).

Figure 6.4 Order indicators



a) slight increase in annual temperature (1.7degF)

e) few partnerships formed at a regional level

b) no significnat change in precipitation

f) increase within UGA, decrease outside UGA

c) sharing occurs at a local level

g) governance is fragmented & autocratic

d) aging population

h) industry is domimated by few sectors

New housing developments targeted beautiful scenery, along the shore and upland in forested areas (Figure 6.4f). New small town communities sprang up, equipped with mixed use centers that included grocery stores, trails and satellite medical centers. New developments fragmented habitat, increased impervious surface and vehicle trip length. Most of the Sound's farms were eliminated due to development pressures and low global food costs, leaving a limited number small specialty farms behind. Regional government became more fragmented, with more than a doubling of local units of government by 2050. Each unit fought for local dollars, and refused to invest in regional projects (Figure 6.4g). Instead, public investment dollars unintentionally subsidized sprawl, extending government services into new communities rather than improving on existing failing infrastructure.

Regulations wrestle with economic growth

The economy continued to grow as projected around the turn of the century; however a few sectors dominated the industry threatening the stability of local jobs and high wages (Figure 6.4h). New workers came into the region in cycles, including both unskilled labor to support new construction activity and a skilled young workforce for the technology and information industry (Figure 6.4i). Meanwhile, aiming to control the distribution of natural resources among the Sound's growing population, regulations sprouted from multiple overlapping jurisdictional boundaries. Policy makers reverted to a command and control (CAC) regulatory system that placed limits on private industry, land developers and household activities. Increasing costs filtered down to consumers and regional products. Large segments of the population

13 Common Pool Resources (CPR) are goods shared by a collection of people where excluding actors from using them is difficult and the use by one individual or group means that less is available for use by others.

including seniors with inelastic incomes, and new low-income migrants were forced to purchase lower value commodities, most heavily reflected by low-quality, high energy foods ((Figure 6.4i).

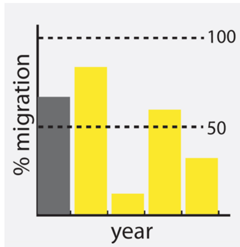
As public hardships grew, people looked to the regional government to pull the Puget Sound out of difficult times. A zero-sum approach prevented regional leadership from pursuing strategies that benefit both the environment and the economy. Strengthening regulations were intended to halt additional impacts on natural systems; to limit the extent of development and protect natural land cover, to reduce industrial emissions, to protect air and water quality, and to require higher standards for wastewater and drinking water. These regulations were severely opposed for stagnating economic development. On the other hand, many leaders argued for loosening regulations in order to make it more attractive for businesses to operate in and relocate to this regional to provide incentives for new development, to decrease the timeline of the permitting process, and to reduce and subsidize costs of operations. Strategies reflected an opposition between ecological and economic goals. Lacking a coordinated regional effort, no single municipality was willing to sacrifice economic growth opportunities and regional policy remained ineffective (Figure 6.4j).

Uncoordinated investments yield fewer returns

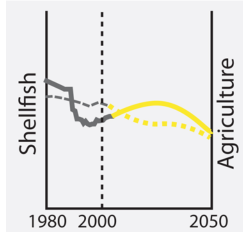
Due to the number and fragmentation of governmental units, policies were confusing, redundant and inefficient. Too often regulations governing effluents failed to control hidden and emerging pollutants; industries found loopholes; developers were discouraged from seeking creative and cost-effective solutions; households were frustrated and misguided about their impacts and the connections to the regional system. Increasing taxes were being absorbed into increasing personnel costs, additional regulatory forces and the extension of new infrastructure. Each municipality spent more money on new roads, power generation, sewer and water services. As municipalities failed to cooperate for shared utility and resources, high levels of redundancy increased regional service costs per capita (Figure 6.4k).

As investments continually funded failing policies and new infrastructure, decision makers overlooked investments in existing failing infrastructure and public institutions. The overall regional level of services for schools, health care, water infrastructure and transit lines slowly declined. Senior and minority populations supported reforms to invest in local K-12 education, but did not back regional attempts to invest in higher education ((Figure 6.4l). Disinvestment led to declines in public resources including contaminated beaches, over-harvesting of lower quality catch and a loss of open space ((Figure 6.4m). As the region's funds were spent locally, political hopes to provide universal health care provision repeatedly failed. Meanwhile, the cost of providing health care escalated due to a poor quality and reduced abundance of local resources, rising obesity, and an aging population (Figure 6.4n).

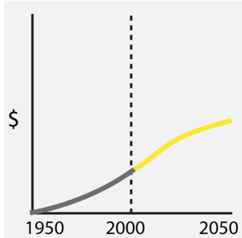
Figure 6.4 Order indicators *(cont.)*



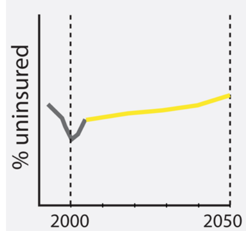
i) migration fluctuates in cycles



m) slow decline in shellfish and agriculture

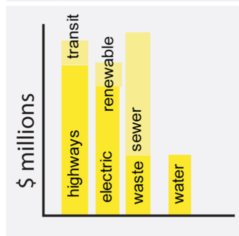


j) reduced increase in GDP over time

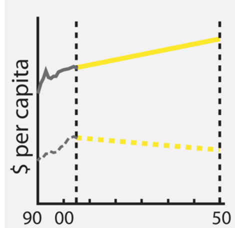


n) percent uninsured same as today

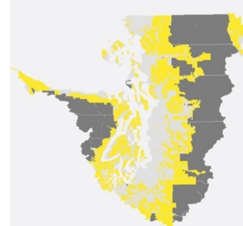
k) fragmented connectivity of infrastrucure



o) increased $s for service extensions



l) investments increase for new schools


p) reduced forest aggregation index

A rigid infrastructure fails to adapt to increasing vulnerabilities

A growing population's need for resources and services put increasing demands on regional infrastructure; however, due to a lack of investment in new concepts and technologies, the aging and rigid existing infrastructure proved ineffective and resource intensive (Figure 6.4o). While climate impacts remain minimal, the hydrological regime was significantly altered by human activities, mainly through a combination of land cover change and effluent discharges. Reduced forestland and an increase in acres of impervious surfaces reduced the infiltration capacity of the basin and doubled peak wintertime stream flows (Figure 6.4p). New pipes and drains in upland municipalities failed to handle increasing frequencies of major floods, and resulted in numerous sewer overflows into adjacent water bodies. Water quality in the region was severely degraded, leading to health advisory limiting consumption of local fish to one per week and permanently closing the majority of shellfish harvesting beaches. Energy costs soared as the cost of oil rose. while demand continued to increase. The region, still relying heavily on power plants and hydropower, was unable to rapidly switch to alternative energy sources. Finally new roads supporting new sprawling developments were rarely occupied as fuel costs prohibit long commutes.

Consumption, control and conflict

The Puget Sound stagnates under command and control policies implemented to support the worldview that there was an implicit trade-off between common pool resources and economic growth. As the region began to experience dwindling resources due to population growth, increasing per capita consumption and lower resource yields, individual households gained more from increasing their own consumption in relation to other households. The view that individual goals were better met through competition than cooperation naturally led to a suboptimal protection of shared resources. A reactive regulatory approach reemerged to respond to increasing environmental problems, leading to increasing environmental disputes and non-compliance with set standards and limits. Nature was perceived as malleable (i.e., controllable) as rivers were pushed into channels, fish were raised in pool, and forests grew in even age stands. When returned yields declined, nature was pushed further with more fertilizers, more fish per pool and faster logging cycles. Economic functions were pitted against ecological functions, leading to reduced overall benefits. As each municipality failed to see the connections between regional issues and their own, they continued to support baseless governmental conflict, wasting limited regional resources.

Restoration suffers from conflicting upland goals

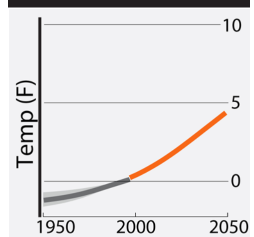
By 2050 the Puget Sound region was faced with a growing portfolio of economic, social and natural pressures. Economically, a reduced diversity of industry sectors had threatened the Sound's economic stability, leading to cycles of economic inactivity, affecting fluxes of migrant works and surges of layoffs. Further, as government interference in industry activity grew, the region lost its national draw. Socially, the Sound was characterized by divergent enclaves of demographic groups, increasing in-group cohesion but decreasing overall regional congruency. This pressure directly influenced governmental action, fragmenting regional regulations by municipalities and interest groups, reducing the efficacy of government spending and averting attention from real issue. While costs increased, the overall quality of life declined, creating growing social hardship and strife. Ecologically, pressures stemmed from increased fragmentation of natural land cover, a growing waste stream and increased resource extraction, all increasing the vulnerability of the Sound's ecosystems. As ecosystem pressure increased in frequency and magnitude, ecosystem resilience was reduced, and the consequent impact of additional pressure grew. Restoration actions suffered as lowland actions were overshadowed by upland changes. Upland municipalities were unwilling to use local economic resources to support lowland efforts, especially as the number of local issues grew. Meanwhile fragmented sites of restoration were repeatedly damaged by increasing inflow of polluted runoff, leading to frustration and disinvestment by local municipalities.

INNOVATION

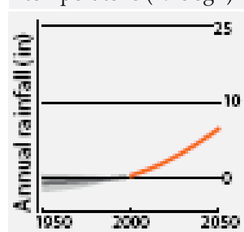
A hot and rainy climate is controlled through long term investments in new technologies

The Puget Sound region was the target for higher than global average climate impacts. Over the last fifty years the temperature had risen by 4.4degF while the annual precipitation had increased by 8% (Figure 6.5a,b). Significant increases in the variance of extreme events exacerbated the situation, as the region experienced more 100-year storms, more multi-year droughts, more record breaking heat waves and stronger windstorms (Figure 6.5c). These changes dramatically altered the hydrological regime and significantly affected its ecosystem functions. Puget Sound winters were wetter, with precipitation falling more as rain and less as snow. Summers were drier, characterized by limited streamflow volumes and exacerbated by reduced snowpack and earlier spring runoffs. The combination of higher summer temperatures and lower stream volumes significantly exceeded stream water temperatures causing major fish-kills and blankets of plankton blooms. Fearful of future implications for this region and frustrated with its bureaucracy, powerful interest groups sought private measures to invest in this region, which then became enraptured with the potential for new technological innovations to buffer human lifestyle from ecological vulnerabilities (Figure 6.5d). Instead of

Figure 6.5 Innovation indicators



a) major increase in temperature (4.4degF)



b) major increase in precipitation (8%)

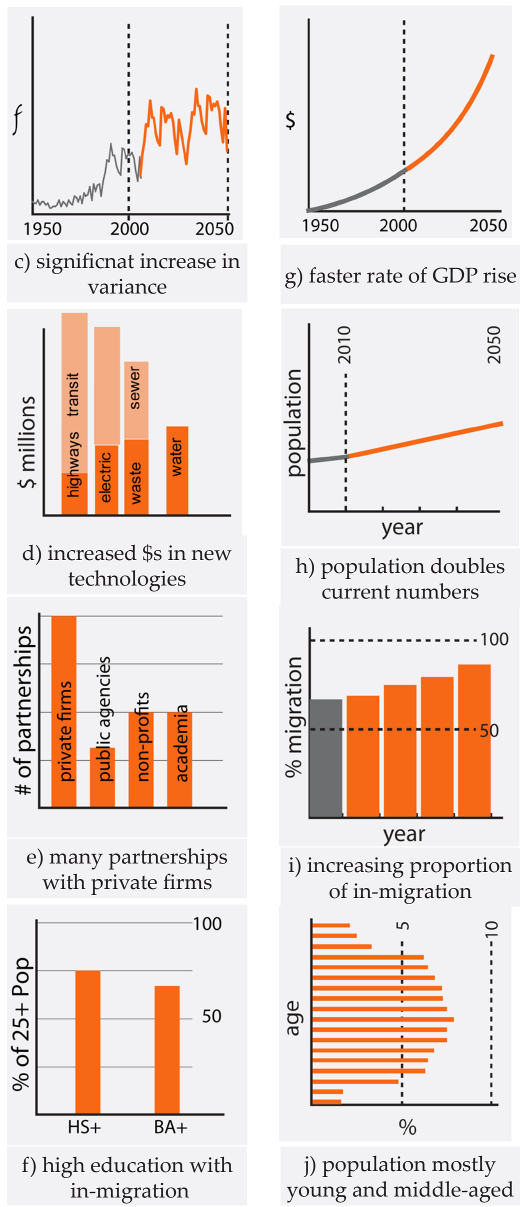
investing in public services, households funneled their money into high-tech corporations, who in turn promised to create positive change in the region.

Public-private partnerships bring skilled labor to the Sound

As the power of private industry in the region grew, the power of government shrank. Nervous about losing their power and eager to maintain the region's economic stronghold, politicians pushed partnerships with private firms (Figure 6.5d). These partnerships provided incentives for local firms to stay in the region and for innovative high-tech firms to move in. Decision makers eased downtown development regulations and opened trading opportunities, inviting economic growth. The Puget Sound attracted global innovators who brought in investment dollars and the continuous inflow of a skilled young workforce (Figure 6.5e). The Sound became a sandbox for technological innovation.

Over the last 50 years economic growth in the region had skyrocketed. The Sound's GDP, heavily dominated by high tech industry, had increased at unprecedented rates (Figure 6.5f). Feeding off this economic growth was a rapidly growing population, more than doubling 2000 numbers (Figure 6.5g). While fertility rates decreased, population growth relied heavily on in-migration, further increasing each decade (Figure 6.5h). By 2050 more than 80% of annual population growth stemmed from in-migration of young and skilled workers. The regional pulse created by the inflow of young adults altered the age-distribution, with the greatest percentage of the population between the ages of 25 and 45 (Figure 6.5i). The fast and significant population growth fueled a wave of building construction, especially within urban areas (Figure 6.5j). Downtown developments became taller and more energy efficient, while new satellite towns sprang up around the urban fringe. New towns appear over night, boasting beautiful and protected natural surrounding with rapid rail commutes into downtown cores.

Figure 6.5 Innovation indicators *(cont.)*



c) significnat increase in variance

g) faster rate of GDP rise

d) increased $s in new technologies

h) population doubles current numbers

e) many partnerships with private firms

i) increasing proportion of in-migration

f) high education with in-migration

j) population mostly young and middle-aged

Increased efficiency leads to increasing consumption

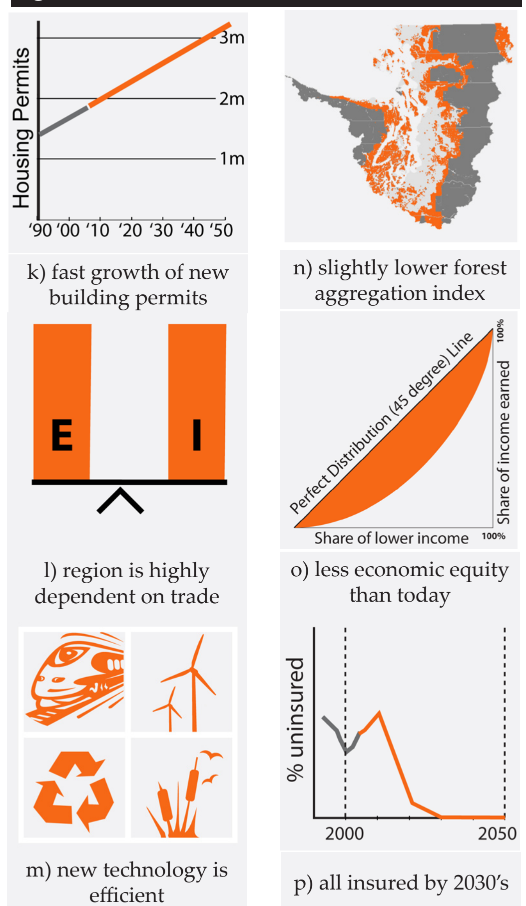
An increasingly young and globally mobile population continuously exceeded past consumption rates. Global imports dominated online markets with everything from food to information gadgets (Figure 6.5k). Goods were generally smaller, faster and more ubiquitous, seamlessly serving both leisure and business needs. As population numbers doubled, affluence grew and the cost of goods declined, consumption rates grew exponentially. However, while scientists warned of surpassing the region's carrying capacity, innovators focused on reducing the impacts of products in an effort to keep the population's high demand. Private industry went so far as matching government dollars towards restructuring the entire basin with adaptive and efficient cutting edge technology. By 2050 the Puget Sound region not only enjoyed these new benefits, but also becomes a global leader in innovation and production of new technology.

Efficient technology emerged from three elements: reduced energy dependence, shortened life cycles of products and higher yields per acre (Figure 6.5l). Energy providers allowed customers to choose from a variety of renewable energy resources that were adaptive to changing environmental conditions. Transportation systems relied on more efficient fuel consumption, from light rail systems connecting disparate towns in the Basin to hybrid single occupancy vehicles. In terms of shortening life cycles, the key had been developing a closed loop system to reuse materials before they become waste by creating used material banks and recycling wastes closer to the original source. Regional treatment plants rapidly filtered wastewater to very high levels, allowing direct discharge into local water bodies. Recycling plants accepted and sorted household wastes and were able to utilize more than 90% of the waste stream. Lastly, the agriculture and aquaculture sectors, initially hard hit by frequent floods developed new mechanisms to substantially increase harvesting yields through crop modifications and new farming techniques.

Private investors support charitable organizations
Private industry, eager to develop a positive global image, was the leading supporter of regional charitable contributions. Investments included both social and ecological programs, and functioned to meet externalities not readily addressed by market forces. While the early part of the century exhibited rapid forest fragmentation as new housing developments placed pressure along the urban fringe, the remaining forestland was permanently protected by donations to regional land trusts (Figure 6.5m). As a young and affluent class moved in, a growing economic inequity threatened the quality of life in the region (Figure 6.5n). Substantial investments by the private sector in the region's public academic institutions provided small classes and world-class instructors to all residents. Further, large firms collaborated to sponsor affordable health care for lower income groups (Figure 6.5o). Contributions even supported new mixed-income neighborhoods, trying to meet the needs of all of their employees. By 2050, income taxes had been eliminated, the role of government had shrunk, and large corporations had become the most significant contributors to maintaining a high quality of life for the residents of the Puget Sound.

Technology buffers residents from natural fluctuations
Innovative technology served multiple roles within society, from maintaining a high consumption rate to catalyzing growth in the region. However the most significant role technology played was in buffering residents from the storm brewing outside their windows. Four main approaches successfully buffered residents from climatic impacts: water storage, alternative energy, flexible erosion control and pest management. Each approach relied on adaptive and efficient technology to reduce the impacts of fluctuations on raising the cost of living in the region and threatening household security. However, while new technology affectively protected a high quality lifestyle for Puget Sound residents, unexpected technical errors and natural fluctuations caused numerous disasters along the way.

Figure 6.5 Innovation indicators *(cont.)*



k) fast growth of new building permits

n) slightly lower forest aggregation index

l) region is highly dependent on trade

o) less economic equity than today

m) new technology is efficient

p) all insured by 2030's

The greatest issue concerning the Puget Sound was containing high volumes of water during winter months. High precipitation levels flooded homes and scoured waterways rapidly carrying toxins into lowland water bodies. The Sound developed a network of reservoirs from green roofs to underground storage tanks able to substantially increase the retention capacity of the Basin. Second, rising fuel costs and tight emissions regulations eliminated the utility of fossil fuels, especially in a region that produced no fossil fuels of its own. A portfolio of strategies from fuel cells to wind farms powered up the Region with renewable energy sources. The region became a test bed for in-coming renewable energy technology as industries were subsidized to experiment within the Sound. Thirdly, strong winds, large runoff volumes and fluctuating sea levels were eroding steep slopes throughout the Basin. Innovations focused on flexible armaments that supported upland developments while allowing some nutrients and sediment through-flow. By 2050 over 60% of the Puget Sound shoreline was covered by a plant based fabric that buffered hillside homes from an escalating magnitude of coastline disasters. Lastly, pest management was the leading problem for agricultural fields and the aquaculture industry. Engineers developed new pest-resistant crop communities that, when grown together, out-competed both native and invasive plants by utilizing longer growing seasons and high volumes of water.

Inspiration, freedom and progress
As many optimists in the 19th century had hoped, innovative strategies were presented to save humanity from the implications of global ecological degradation. Technology was utilized to create more efficient solutions, reproducing nature in order to effectively increase the earth's carrying capacity. The Puget Sound became a model and think tank for these ideas and inspired other regions of the world. The Puget Sound achieved a higher quality of life for its citizens by partnering public firms with political leadership to solve regional problems.

Deregulation and market incentives provided the economic freedom businesses needed, and spurred creative solutions. While technological mistakes were frequent and significant, solutions were always on the horizon and lifestyles never suffered for long. Technological progress was touted as the greatest tool against climate change and ecological degradation, pushing new ideas to take center stage, and dismissing old methods as ineffective. Globalization led to progress in human relationships, with a greater openness to a diversity of cultures, and emphasis on higher education attainment and universal health care as means of reducing social differences.

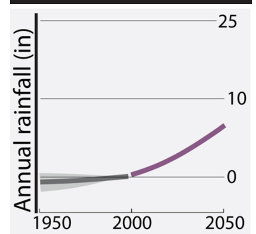
Technological disasters test the Sound's resiliency

Despite major investments in new infrastructure, as regulations loosened, ecosystems often suffered the consequences of short-sighted engineering solutions. For example, early wastewater treatment did not treat many chemicals contaminating waterways; early wind farms harmed migrating birds; tidal energy infrastructure disturbed orca pods; increasing trade led to oil spills and more water borne effluents. Higher temperatures coupled with global imports led to major pest outbreaks and plummeting public health levels. New treatments rapidly stopped the spread of epidemics, but not before creating widespread panic. The magnitude of impacts increased significantly with major events as novel technology and unanticipated changes caused major catastrophes. These disasters were always met with a strong public outcry and immediate cleanup, but left the ecosystem resilience lower. By 2050, due to increasing vulnerability of the Sound's ecosystem the relationship between humans and nature was one of dominance and manipulation. Restoration strategies were simultaneously improved by innovative solutions, and spoiled by unprecedented levels of disturbance to the system. As pressures from increasing consumption, escalating climatic impacts and unintended technological mishaps grew, the Sound's ecosystem resilience became more vulnerable to collapse.

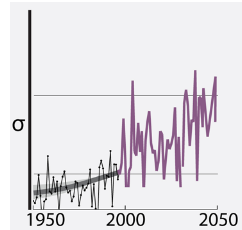
BARRIERS

Reactive and uncoordinated action leaves millions behind when hydrological disasters plague the Sound

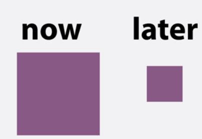
Figure 6.6 Barruers indicators



a) increase in annual precipitation (8%)



b) significant increase in variance



c) high discount rante

d) new infrastrucure is reactive and rigid

Escalating climate change provided little warning before impacts were experienced by many of the Sound's residents and businesses. Within decades Puget Sound winters were characterized by floods and windstorms and summers by pest outbreaks and heat waves. Annual temperature rose by 4.4degF while annual precipitation levels rose by 8% (Figure 6.6a). Extreme temperature and precipitation ranges magnified as the Sound experienced more record breaking summer highs, winter lows (Figure 6.6b). The impact on private property and public infrastructure was immediate and costly. Agricultural valleys flooded, landslides pulled coastal developments into the sea, whole neighborhoods lost power for months, highways were torn off the road, bridges lay underwater, and fishing grounds collapsed overnight as salt-water intrusion filled coastal inlets. While activists and politicians complained against the region's lack of foresight, households reacted by building stronger armaments (Figure 6.6c,d). As each household focused on immediate and self-gratifying solutions to protect their family and income investments, the poor were left behind with a continuously degrading environment. By 2050, the Puget Sound had become a divided region, with extreme gaps between the rich and poor and between humans and nature.

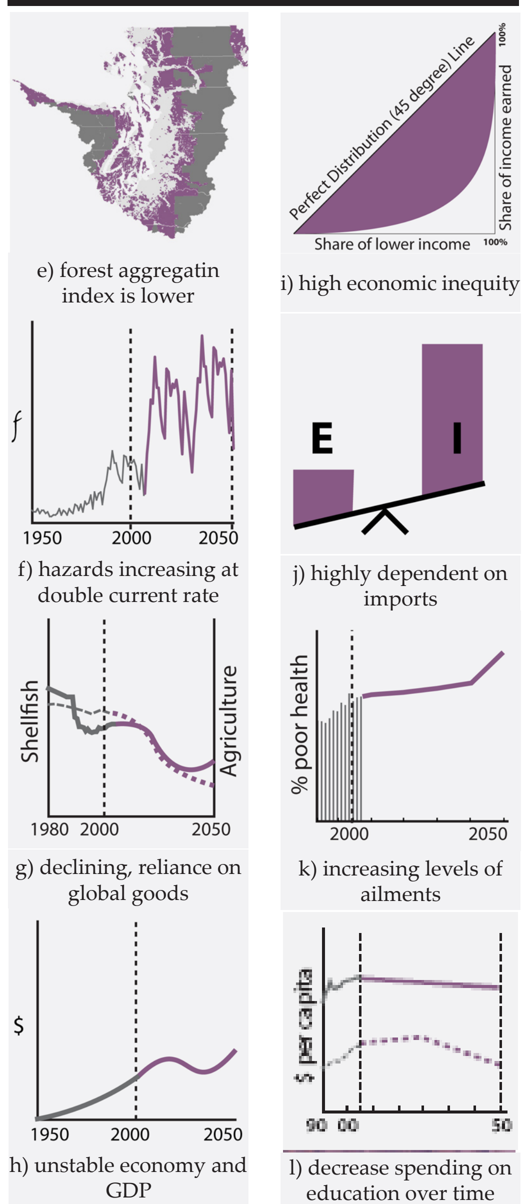
Strong walls keep out change

As the first series of hydrological disasters hit lowland areas, households reacted by building stronger and more rigid infrastructure to protect their homes and safety. This consisted primarily of higher walls to keep out rising sea levels, floods, and erosion. Those who could afford it moved further upland into bigger homes within gated communities. These sheltered neighborhoods generally provided residents with a full spectrum of essential services, from open space, supermarkets, day care and neighborhood maintenance. Neighborhoods were secluded from the immediate environment but highly depend on external resource input. In wealthy lowland communities each home became an independent emergency center, equipped with backup generators, surplus dry goods and emergency utilities. Many residents purchased utility vehicles to ensure their safe passage through surprise hail and wind storms, floods and damaged transportation infrastructure, all of which were becoming more common occurrences in the Basin.

As new homes and infrastructure converted and fragmented natural land cover in the Basin into impervious surfaces, the magnitude and frequency of hydrological disasters grew (Figure 6.6e,f). The rate and volume of runoff increased, destroying aging and inadequate infrastructure and escalating the levels of pollutants in waterways. Large volumes of water were funneled into underwater tanks to protect houses from erosion and flooding. As windstorms grew in intensity the majority of mature trees within lowland neighborhoods were removed to protect houses. Waterways had high nutrient levels due to increasingly rapid runoff. When coupled with rising temperatures and moisture levels, pest outbreaks plagued lowland neighborhoods. Within decades lowland vegetation, especially along stream corridors, was destroyed to eliminate potential breeding grounds. The highly reactive strategies rapidly fueled an ecological response of higher magnitude and greater frequency of disasters.

Economic inequity grows as the cost of living increases
As the number of disasters grew, costs rose exponentially. Costly damages to houses devastated families, and left thousands homeless. The rising cost of energy coupled with greater variation in temperature created hardship for many households. The cost of food rose as well, as local food abundance dwindled. Agricultural yields plummeted as lowland farms endured entire seasons of underwater and massive pest outbreaks. More than 50% of the shellfish harvesting beaches closed due to high bacteria levels (Figure 6.6g). Meanwhile tax burdens grew as government aid was funneled into rebuilding essential infrastructure such as utility lines and broken water mains. An unstable economy exacerbated an already difficult economic situation as many firms were forced to leave, reducing the overall diversity of the region (Figure 6.6h). Rising unemployment was most heavily concentrated among traditional jobs reliant on natural resources (i.e. logging, fishing, agriculture). Higher costs of living coupled with lower available public funds made for a difficult regional situation.

Figure 6.6 Barruers indicators *(cont.)*



e) forest aggregatin index is lower

f) hazards increasing at double current rate

g) declining, reliance on global goods

h) unstable economy and GDP

i) high economic inequity

j) highly dependent on imports

k) increasing levels of ailments

l) decrease spending on education over time

While the rich leveraged savings, the poor were left in devastating conditions (Figure 6.6i). Many lower income families lived in dangerous conditions, often in flood damaged homes and without electricity. While the rich lived in bigger homes buffered from environmental pressure, the poor remained in hazard prone lowland areas, bearing the brunt of failing infrastructure and a contaminated environment. This division not only split demographic groups geographically, but in time heightened the difference in economic, social and ecological conditions between the two groups. Lower income families often subsided on contaminated food and water, or low quality heavily processed foods. Meanwhile higher income households relied on global imports, from medicine and food to building materials (Figure 6.6j). Further, lower income families came into closer contact with pest outbreaks and epidemics, but had limited access to health care (Figure 6.6k). The higher the cost of living, the greater the division grew between higher and lower income residents. Unable to buffer their families from their immediate environment, poor families struggled through continuously degrading conditions.

Public investments are divided and reactive
As regional resources declined, and municipalities competed over funds, no long term public investments were pursued. The projects that took place relied on local

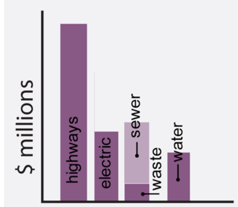
funds; therefore rich neighborhoods who could invest in local services were able to enhance their immediate environments, while the poor could not afford to elicit change. Money poured into private schools while public K-12 education suffered from highly reduced per capita spending (Figure 6.6l). Health care supported by private industry left millions of lower income residents without access to medical services. New roads, sewers and alternative energy sources were brought in to repair wealthy neighborhoods, while the poor struggled with inefficient, aging and failing infrastructure (Figure 6.6m).

Most investments were highly reactive, utilizing short-term strategies to fix current problems. Pest management generally consisted of vegetation removal or stronger concentrations of pesticides. Flood management occurred through more and stronger bulkheads and levees. Sewer plants increased their capacity for water intake and reduced treatment time. Stronger electrical poles were built to withstand stronger storms. Erosion protection relied on thick retaining walls and slope modifications. Transportation networks supported higher capacities and faster travel. The limited restoration actions that took place focused on site level re-vegetation and clean-up efforts within urban waterways. While the strategies were initially heralded as producing desirable results, within decades unintended consequences created even bigger problems; shoreline armoring became obsolete as a confluence of increasing tidal fluctuations and upland erosions diminished the coastline (Figure 6.6n); new roads lay vacant as rising fuel prices forced residents out of their cars; re-vegetated streambanks were scoured by accelerating runoff peak flows; cleanup efforts were exhausted by a quadrupling of combined sewer overflows.

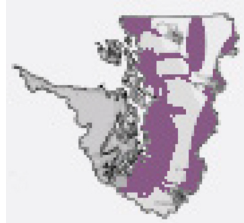
Puppet government panders to the rich

As society divided, so did governmental entities. Instead of a much needed collaborative government, fragmentation worsened the situation (Figure 6.6o). New neighborhood groups fought to keep funds locally. Politicians relied on short-term solutions to get elected and serve their constituency. Rich neighborhoods maintained high levels of services while the poor relied on federal assistance, non-profits and charities. Governance in the 2050's was represented by a weak consortium of local units, pandering to private firms and unable to think beyond their constituencies' immediate boundaries. While many bills were passed, their effectiveness was minimal. Upheaval grew as lower income groups saw they were not represented by the region's government. Many groups protested and revolted, leading to the rich retracting further into walled communities. More government spending was devoted to security and regulations and less on long-term investments in the region. While non-profits agencies tried to represent the environmental injustice and undue burden of the poor, they could not leverage the political attention or enough funds to affect change.

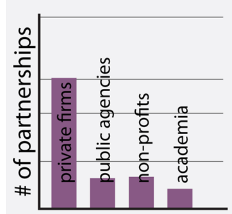
Figure 6.6 Barruers indicators *(cont.)*



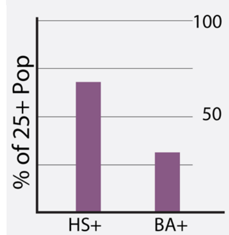
m) increased investment in energy and protection



n) highly vulnerable at the coast



o) few partnerships formed



p) increased division, more BAs, less HS

Division, safety and reaction

When disasters hit the Sound residents relied on free market enterprise to regulate consumer behavior and produce optimal conditions. For the Sound's wealthy population this strategy produced relatively positive results, and a high quality of life was artificially preserved as ecological devastation fell on the other side. The reliance on economic goods to alleviate environmental problems led to a widening divide between the Sound's population, both physically and socially. For the Sound's lower income residents and minority populations, escalating disasters led to hardships. By 2050 while one segment of the Sound's population experienced a high quality of life, with higher educational attainment, better health care, open space and access to high quality resources and good jobs, another segment was living in devastating conditions, with high unemployment and low-paying jobs, low educational attainment levels, reliance on contaminated local resources and poor health without insurance (Figure 6.6p). The gap between the rich and the poor fueled contempt and distrust, higher crime rates and a competition over already limited regional resources.

As nature was perceived as a barrier, needing to be controlled and manipulated in order to serve human functions (food, shelter, water), few linkages were made between the degradation of the natural system and the human condition. As natural functions declined fluctuations grew, and society found itself needing to erect stronger controls over nature to protect its safety. Reactive and short termed policies dealt with immediate problems and ignored long term consequences. Short term policies eventually become ineffective, leading ecosystem services and human functions into far worse conditions.

The nearshore gets buried in the wake of pressing social issues

Rising fluctuations of climatic conditions caused a series of disasters, especially along the Sound's coastline. Short term solutions attempted to cover up massive problems, but actually exacerbated vulnerabilities and led to increasingly costly clean up efforts. Most at risk were lower income populations that were not protected by robust physical and economic buffers and safety nets. As the inequity grew, ecosystem problems were masked by social and economic issues, mostly heavily due to crime and poverty. Political attention was heavily focused on economic and social issues, and could not afford (both politically and financially) to handle underlying ecological issues. As external pressure continued to rise, ecosystem resilience plummeted to exceedingly low levels.

COLLAPSE

Ecosystem failure catalyzed by a hot and dry climate and a short-termed individualistic society

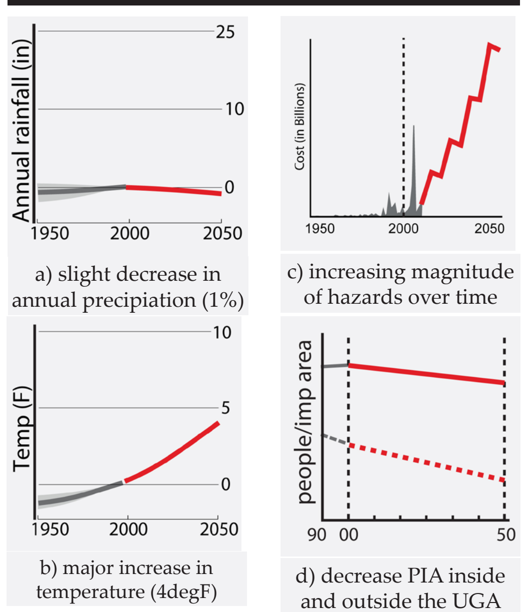
Warning signals of environmental collapse were largely ignored, thresholds miscalculated, and fluctuations misinterpreted as natural variability. By the time leaders and citizens decided to act it was too late and the Sound ecosystem collapsed. After the collapse, the new system exhibited heavily reduced ecosystem functions and services. While a myriad list of stakeholders and their actions were responsible, the initial catalyst could be traced back to a hot and dry climate and an individualistic, short termed society.

While most climatic models predicted an increase in precipitation in this region, the opposite became reality. By 2050 the annual precipitation fell by 1% and annual temperatures rose by 4 degF (Figure 6.7a,b). The overall annual change in precipitation was minimal, but the hydrological regime was pushed to extremes as the Sound experienced wetter winters and far drier summers (Figure 6.7c). Responding to growing economic concerns society exhibited increasingly selfish and short-term behavior. Natural resource reserves were exploited at unprecedented rates and the willingness to share resources within the region fell to low levels. As ecosystems were pushed beyond critical levels, the warning signals of collapse came with increasing urgency: first a series of fish kills, a long list of beach closures, failing septic systems, energy shortages, and ultimately the death of the last salmon.

Summertime water competition leaves ecosystems thirsty

A combination of factors increased summertime water consumption while water quantity drastically fell. Firsthand, the region's consumption rates grew due to increasing population numbers. By 2020 an additional one million residents put increasing pressure on the Sound's water resources. Further, per capita water consumption rose as a greater percentage of the population lived in homes surrounded by large carpets of lawns and higher temperatures required more frequent irrigation. However, it was the agricultural industry that placed the greatest strain on water resources by exceeding past consumption rates. Meanwhile the available water within aquifers and streams fell to near drought conditions. Springtime precipitation volumes were reduced, while the timing of the last rainfall occurred earlier in the season. Further, snow pack, generally providing the majority of spring time stream flows, was considerably reduced to higher elevations and melted at increasingly earlier dates. By the heat of summer, no snowpack was left to feed the region's waterways. The combination of higher water usage with lower levels of water quantity left the Sound drier than ever before.

Figure 6.7 Collapse indicators



a) slight decrease in annual precipitation (1%)

b) major increase in temperature (4degF)

c) increasing magnitude of hazards over time

d) decrease PIA inside and outside the UGA

Increasing summertime competition over water created higher costs for people, but left ecosystems at dangerously low levels. As water demand increased, the amount of out-of-stream usage increased, leaving streams essentially dry for entire seasons. Further, as the amount of impervious area within the basin rose, wintertime floods did not replenish soil water levels and left surrounding land cover in kindle dry conditions when temperatures were at their highest (Figure 6.6d). Drought, especially east of the Mountains, became a frequent occurrence as Palmer Index values rose. The frequency of forest fires rose accordingly, destroying homes along the foothills (Figure 6.6e). Exacerbating the situation, as water volumes in water bodies fell to low levels, the pollutant levels concentrated, producing high nutrient and toxic conditions within the Sound's riparian habitats. Water quality levels were abated by faster runoff rates picking up greater volumes of pollutants along the way.

Businesses leave as the Sound loses its niche

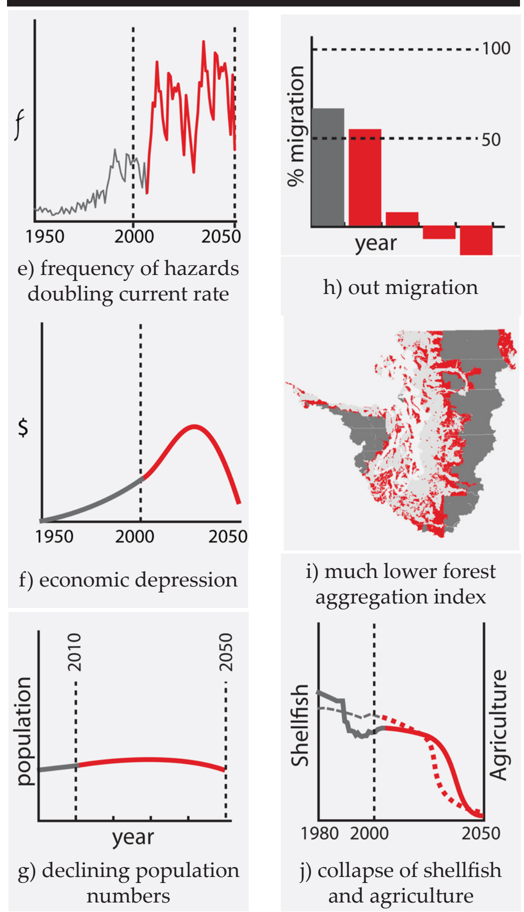
Increasing variation in summertime and wintertime precipitation levels led to a high magnitude and frequency of natural hazards rapidly escalating at unprecedented levels. The entire region becomes prone to disasters, from flooding to landslides, fires and droughts. Even volcanic activity had increased. Each new disaster wreaked havoc on the Sound's aging and insufficient infrastructure, pushing past engineered capacity levels. Treatment plants spilled untreated sewage during wintertime floods. Roads were ripped away as landslides liquefied structural soils. Frequent fires tested the limits of the region's firefighting capacity. Wells drew deeper, contaminating rural drinking water with arsenic. As the frequency of disasters rose and the quality of life in the region declined, the Puget Sound unique niche as a scenic healthy region was lost.

Many industries that had made the Sound their home left after a decade of escalating disasters. With only a few industries remaining in the region, the economy destabilized and became vulnerable to market swings. By 2030 the region was hit with a devastating depression, rising unemployment levels and rising costs (Figure 6.7f). Thousands left the region to look for jobs and for the first time in decades the percentage of people migrating out exceeded those moving in (Figure 6.7g,h). The Sound's population began to drop. As the region's government was left to repair a growing numbers of physical and social problems, available funds for capital investments fell alongside declining GDP rates.

Deregulation exacerbates environmental degradation

In an effort to catalyze economic activity, politicians pushed for regulatory reform, deregulating industry and providing subsidies to build in the region. Economic activity was temporarily restored in the shape of sprawling development and increasing environmental pollutants. At first the region experienced a general trend of people moving into natural areas to enjoy more privacy, more land, convenient services, and the natural beauty. As regulation relaxed, new development pushed further into natural lands outside of urban growth areas. By the 2050s, the areas surrounding the urban core had higher percentages of the regional population than the urban core, and the ratio of people per impervious area in the basin fell. Logging exceeded past limits in order to make it economically feasible and to create fire breaks (Figure 6.7i). Agricultural fields were sprayed with newer more toxic pesticides to try to combat stronger pest outbreaks (Figure 6.7j). Fisherman harvested further offshore as shoreline stocks were depleted. Industry resorted to short-term less costly methods in order to stay in the red. Unfortunately increased effort was echoed by declining yields. While deregulation created a short-termed spurt of economic activity the implications on the Basin far outweighed the benefits.

Figure 6.7 Collapse indicators *(Cont.)*



e) frequency of hazards doubling current rate

h) out migration

f) economic depression

i) much lower forest aggregation index

g) declining population numbers

j) collapse of shellfish and agriculture

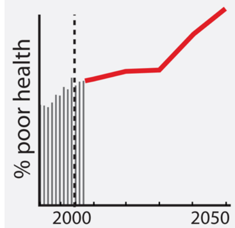
Deregulation exacerbated environmental degradation as land cover change and pollutants increased the level of perturbations on an already stretched ecosystem. New homes fragmented forestland, and the greater amount of impervious surfaces led to both increased urban runoff and decreased infiltration rates within the Basin. Intensive logging made remaining forestlands more vulnerable to pest outbreaks and fires, further reducing the region's forest cover and magnifying hydrological disasters. Higher toxicity levels in waterways, coupled with offshore fishing, low water levels and higher temperatures pushed dozens of aquatic species to extinction. As the frequency of catastrophe continued to decrease the region's quality of life, more and more industry left the region.

Scarcity in the Sound

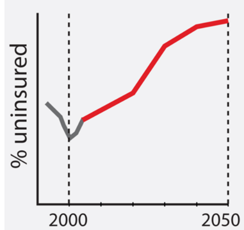
By 2050 the Sound experienced a complete collapse of both shellfish harvesting beaches and agricultural lands in the Basin. While many shellfish beaches were destroyed from fluctuating sea levels, those that remained were often contaminated by toxic pollutants. Agriculture lost its economic feasibility as costs rose due to drought and pest outbreaks. When housing developers offered to purchase farmlands, farmers reticently conceded. The Pacific Northwest forest also collapsed as increasing development pressures and unsustainable logging practices left forests vulnerable to fires and pest outbreaks. As the region's food and open space resources dwindled, the overall health status of Puget Sound residents fell. Increasing rates of epidemics, pest outbreaks and poor nutrition flooded medical services, while high unemployment levels left the majority of residents without health insurance (Figure 6.7k.l).

The economic depression left little to no investments focused within the region. While the region's skilled workers sought jobs outside the region, the percentage of adults without an advanced degree fell (Figure 6.7m). Meanwhile, as long-term investments declined, per capita funds for educational institutions dropped (Figure 6.7n). The majority of the available money was put into sewer and water provision. Further, the new infrastructure was generally reactive in trying to control hydrological change, and over time was found ineffective at providing reliable water and waste removal to citizens. After decades of disinvestments and hazards, the Region's transportation and energy infrastructure became ineffective in providing any benefits and was abandoned.

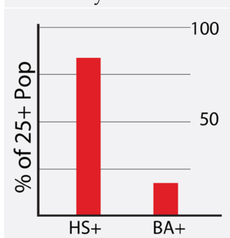
Figure 6.7 Collapse indicators *(Cont.)*



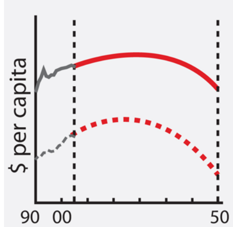
k) an unhealthy population



l) less insured than today by 2040's



m) out migration of higher education



n) education spending falls with decreasing funds

Scarcity, depression and vulnerability

Politicians and citizens relied on the premise that the continuously smaller yields per effort, and greater variability in natural conditions were simply fluctuations of the natural cycle, and that if people merely explored further, new resources would prove abundant. After all, natural ecosystems still dominated the earth's land mass and have been around for centuries, while human impact was still minimal. This perception masked the numerous indicators pointing to imminent system collapse. When multiple critical thresholds were surpassed, the Sound's ecosystem as characterized in 2000 collapsed. The ecosystem left behind was dominated by significantly different characteristics.

Scarcity of resources started with declining summertime water quantities, but by 2050 could be characterized by scarcity of all resources, including fish, energy, forests, jobs, health care, education and safety. The Region's resource scarcity led to economic depression as businesses searched for a high quality of life for their employees. Further, the economic depression distracted the attention of citizens and governments from ecological issues. Disinvestment and further extraction led to increasing levels of ecological degradation. As the tipping point was surpassed, the system lost its ability to absorb perturbations, leaving the remaining residents of the Sound vulnerable to new catastrophes.

An alternative Sound is not longer vulnerable to increasing pressure

By 2050, the Sound maintained an alternative equilibrium state characterized by heavily reduced ecosystem functions and services. The amount of restructuring required to restore ecological function in the system was tremendous. Salmon no longer lived within the Sound's stream, orcas no longer migrated through the San Jaun De Fuca Straight, forests no longer covered the foothills of the Cascades and the Region's surplus of high quality drinking water was diminished. By the time managers in the Puget Sound decided to act it was too late, and the Puget Sound system had collapsed. Characteristics of the resulting ecosystem were quite different from the ones seen in 2000. The functions supported were minimal in comparison. The sound no longer provides habitat for over 200 species of fish and marine mammals. It was no longer an economic engine for fishing and shellfish harvesting. It no longer functioned to regulate gas exchange, nutrient cycles, diseases, floods, climate and waste. It no longer reflected cultural symbols such as the bald eagles to the migrating salmon. The restoration strategies described around the turn of the century could not work with this ecosystem. The amount of effort required to return to system to its pre-collapse state was now much greater. The new Puget Sound, while not producing the essential functions previously valued by citizens, had reached an alternative equilibrium that was relatively stable.

ADAPTATION

Challenges of a dry Sound are met with a collective response

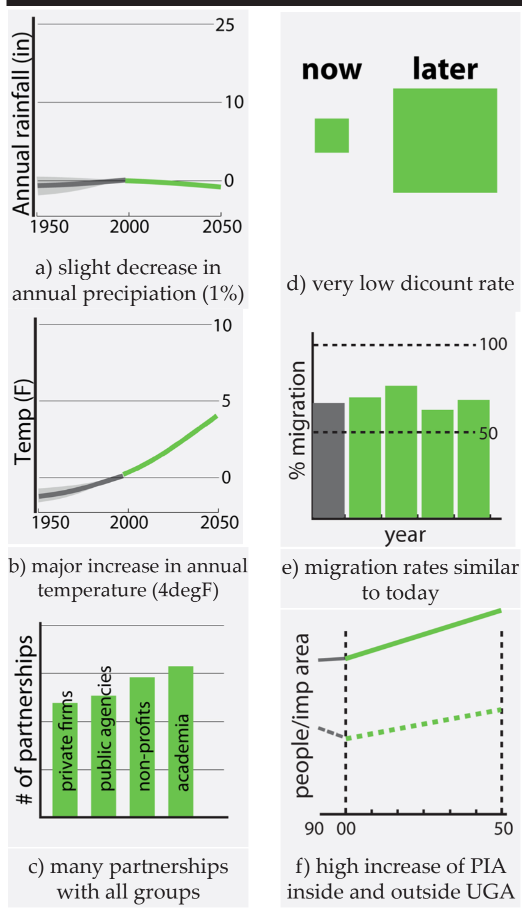
Despite expert knowledge of potential climate change early in the century, government initially failed to acknowledge the full implications of lower annual precipitation. The Puget Sound, a region historically characterized by water, was drying up. The region experienced less rainfall, less snowpack and warmer temperatures (Figure 6.8a,b). Exacerbating the situation, the region had more people, more demand on water resources and a degrading ecological system. As the signs of ecosystem instability and potential crises instilled fear, a strong government leadership catalyzed the regional interest and engagement towards change. The Puget Sound developed a deeper appreciation of the interdependence of individual actions within the Basin. People understood that 'what drains from my sink flows into my river, the health of my neighbor interests my family's well-being, where I shop affects my local economy, the health of my region influences my lifestyle'. As societal goals become more closely aligned, people learned they could affect change more positively by acting collectively instead of independently.

Shared responsibility leads to cooperation

In the early part of the century the region experienced rapid change; resources became scarce, fluctuations of energy, water, flora and fauna increased, and the uncertainty of a perilous future loomed in the minds of residents. These events helped the residents of the Sound build a shared understanding of individual obligations and collective action towards protecting the future of this region (Figure 6.8d). Increasing adversity was met with great leadership, cooperation and insight. The Puget Sound's residents were able to meet the challenges created by previous generations and became more adaptive to changing environmental conditions.

Governance was heralded as a key actor of change in the Region. The new emerging governance system was a national model reflecting collaboration between regional partnerships and local grassroots activism. Like Roosevelt's legendary 'First 100 Days' the Sound's government provided relief by redistributing resources and encouraging active involvement. Strong partnerships emerged between the public and private sectors, combining efforts and encouraging cooperative thinking. Meanwhile a surge of local grassroots movements initiated efforts to improve ecosystem stability and enhance social equity. Even individual households decreased their own consumption just as they would in a drought or recession. Social networks were leveraged to share resources and knowledge. Responsible ecological behavior was kept in check through a strong environmental accountability and a strong display of social policing.

Figure 6.8 Adaptation indicators



a) slight decrease in annual precipitation (1%)

d) very low dicount rate

b) major increase in annual temperature (4degF)

e) migration rates similar to today

c) many partnerships with all groups

f) high increase of PIA inside and outside UGA

Infill, diversity and equity

While the Puget Sound region continued to grow, pulling skilled workers from across the globe, new growth was coordinated through foresight and local investments (Figure 6.8e). To accommodate incoming families existing houses were retrofitted to be more energy efficient and accommodate changing household structure. Denser developments provided more efficient infrastructure for water, transportation, energy and communication. Urban infill also led to lower forest fragmentation and higher people per impervious area ratios (Figure 6.8f). Further, areas outside the urban core were retrofitted, restoring natural land cover in order to regain the infiltration capacity of underlying soils.

Most neighborhoods were also characterized by a high diversity of culture and age groups. The residents of the Puget Sound invested in neighborhood scale improvements such as access to natural resources, sites of civic engagement and assistance, and infrastructure for processing and recovering neighborhood waste and energy.

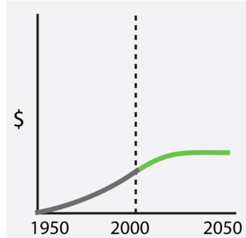
In the 50 years since the turn of the century, the region had grown to rely more heavily on natural and social capital than production. The Gross Domestic Product was no longer believed to portray economic prosperity. While production rates declined, community wealth increased (Figure 6.8g). A larger emphasis was placed on shared community resources instead of private property, on cooperation instead of competition, on volunteering and participation instead of long work weeks. While the Sound was home to a highly diverse population, there was a high level of equity among its residents (Figure 6.8h).

Investments secure a safe future for future generations

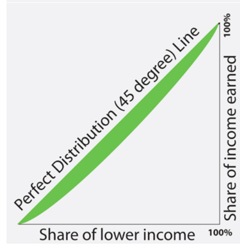
Government leadership and citizen engagement supported region-wide investments that promoted the sustainability of the Puget Sound basin. Residents and businesses invested in local resources, including the Sound's people and landscapes (Figure 6.8i). Educational attainment was valued as essential to increasing awareness and supporting change in the region. By 2050 all adults had a high school diploma and more than 50% of residents twenty-five and over had received advanced degrees (Figure 6.8j). The per capita spending for both K-12 and higher education continued to rise every decade (Figure 6.8k). Public health was another shared value. By 2020 all residents could subscribe to free universal health care (Figure 6.8l). Further, foods with high nutritional values became accessible to all, and a reduced consumption of high energy foods led to reduced obesity levels and higher health status among the population.

In an effort to live locally and sustainably, healthy residents supported healthy ecosystems and understood the connections between their bodies and their landscapes. Major clean up efforts reopened the entire Puget Sound coastline to shellfish harvesting. Vast agricultural areas were preserved, while urban agriculture had taken root as well (Figure 6.8m). Residents reduced their reliance on imports, in an effort to support local industry and to ensure that sustainable approaches were utilized. The region invested regional dollars towards extensive ecological buffers and uninterrupted wildlife corridors. Bike paths and hiking corridors connected different areas in the Sound region and provided convenient access to recreation opportunities and alternatives to motorized transportation.

Figure 6.8 Adaptation indicators *(Cont.)*

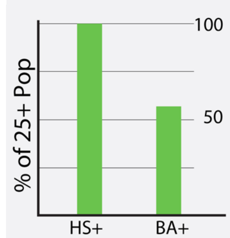


g) reduced growth of GDP over time

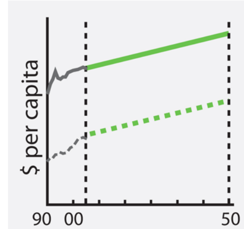


h) high equity among the population

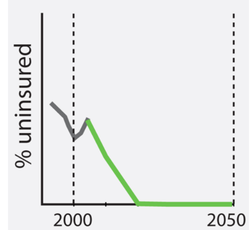

i) sharing high at local level



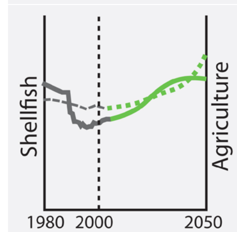
j) increased educational attainment



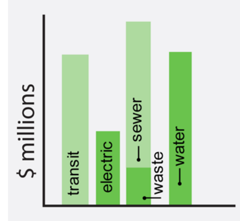
k) increased spending per capita on education



l) all insured by 2020's



m) more shellfish beaches open, more Ag.



n) increased $s on sewer and water

The Sound adapts to dynamic conditions

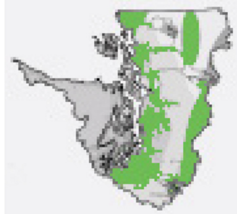
While proactive and long-term solutions provided equitable access to resources and services, lower annual precipitation rates left the Sound facing new and numerous challenges. Most investments went into water provision, especially re-allocating wintertime flows during periods of summertime droughts (Figure 6.8n). Water consumption rates were also reduced through more efficient technology and voluntary reductions. A second major investment came in the form of renewable energy provision. As the cost of hydropower grew alongside increasing fuel prices, the region plugged its 6 million residents into sun and solar powered energy sources.

Vulnerabilities to natural disasters were greatest along the coast and at higher elevations including fires, landslides, flooding and erosion. Residents were provided incentives to relocate into lower vulnerability areas. Coastline and foothills were restored through re-vegetation, removal of impervious surfaces and breakdown of armaments (Figure 6.8o). Over time the coastline and foothills became more resilient, able to absorb higher levels of perturbations. As vulnerable human developments and supporting infrastructure were minimized within these areas, when large natural fluctuations occurred, the cost of remediation was reduced (Figure 6.8p).

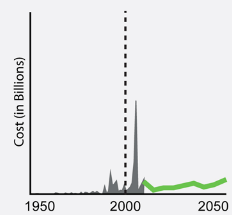
Challenge, interdependence, precaution

The first half of the 21st century brought many ecological, social and economic challenges to the Puget Sound. However, instead of retreating to reactive and individual solutions, a strong leadership and collectivist attitude brought the residents of the Sound together to cooperatively invest in the region's future. A large element supporting their decisions came from understanding the interdependence of actions, both among the various stakeholders within the Sound, and between people and the natural environment. Human behavior was altered to support an equitable sharing of the region's resources, both across the region, and into the future. Further, investments in conserving and restoring contiguous and extensive natural areas was considered an essential element to ensuring sustainable ecosystem functions. The 'precautionary principle' played a critical role in resource management. When scientific uncertainty was unable to dictate how much of an area should be conserved or how many fish could be harvested per season, policy makers chose to err on the side of caution. Reflecting on the challenges brought on by climate change and the uncertainty associated with precipitation levels, residents of the Sound saw nature as unpredictable. As climate impacts vividly pointed to anthropogenic origins, residents of the Sound sought to minimize human alterations of the system whenever possible. Judging by their high quality of life, minimizing human impact on natural resources proved a successful strategy.

Figure 6.8 Adaptation indicators *(Cont.)*



o) less vulnerable at coast and mountains



p) decreased magnitude of events

Wider buffers provides room for adaptation

By 2050 the resilience of the Puget Sound ecosystem was high despite frequent and significant perturbations. As natural areas were protected and expanded, their ability to absorb larger pressure sources grew. Further, as the human behavior and regional infrastructure adapted to changing conditions, ecosystems were provided the freedom to fluctuate without constrain. The greatest sources of pressures in the region were summertime water competition, high cost of energy, isolationism and reliance on consensus. While the first two were largely minimized by reducing consumption rates and relying on adaptive, efficient infrastructure based on sustainable resources, the latter two reflected social issues that threatened the Sound's collectivist ideology. As social cohesion in the region grew, it effectively raised barriers to entry for new in-migrations. Like the critique of many European cities, increasing collectivism stifled divergence and independence. The longer the region localized and strengthened existing institutions, the less resilient society became to outside change. Further, as citizen activism grew, consensus became a touted decision-making tool. However, as the number of decision makers grew alongside a divergence of knowledge, achieving consensus became exceedingly difficult, stalling policy reform.

Cross-comparison

The suite of scenarios aims to create divergent and internally consistent stories based on the identified uncertain key drivers: climate change and human perceptions and behavior. Table 6.3 compares the future trajectories of the key drivers, the supporting driving forces, the storylines and the system state of the six scenarios. The comparison highlights both the divergence and internal consistency among the scenarios' key elements.

The plausible interactions of the two key drivers produced six highly differentiated stories, from a 'Forward' future of minimal climate impacts and collectivist behavior to a 'Collapse' of the Puget Sound ecosystem resulting from water scarcity and individualistic short term behavior. The other four scenarios don't merely reflect intermediate points along the spectrum of best to worst case futures, but rather explore significantly different conditions. While Order and Innovation both result in a 'medium' resilience ecosystem, the conditions leading to that system are divergent, from highly escalated and fluctuating precipitation patterns to almost no change from the status quo, or from a modest growth in population to a more than doubling of the current population in the Basin, and from a complete restructuring of the region's infrastructure to a disinvestment in public resources. 'Barriers' and 'Adaptation' both experience similar conditions: a limited increase in population and economic growth as well as significant climatic impacts, but their futures diverge through different reactions to change: 'Barriers confronts change with a reactive and rigid approach that results in high pressures and a low resilience; 'Adaptation' reflects medium pressures and high resilience in a story of a society that meets new challenges with a cooperative and flexible response.

		FORWARD	ORDER	INNOVATION	BARRIERS	COLLAPSE	ADAPTATION
KEY DRIVERS	**Climate Impacts**	minor changes, little impact	minor changes, little impact	wet and hot, major fluctuations	wet and hot, major fluctuations	dry and hot, historical variance	dry and hot, historical variance
	Human Percep. and Behavior	collectivist and long	individualistic and long	individualistic and long	individualistic and short	individualistic and short	collectivist and long
TRAJECTORIES	**Growth Rate**	faster, increase	same, increase	faster, increase	slower, increase	decline	same, increase
	Socio-economic Characteristic	educated, skilled, compact	aging, enclaves, satellite	young, skilled, urban	divided	out-migration, recession, sprawl	community, balanced, infill
	Governance	strong; science-policy partnerships	strong; command and control	weak; private public partnerships	weak; autocratic	weak; ineffective	strong; emergent
	Regional Investments	high; proactive and adaptive	high; service and extensions	high; experimental	low; rigid and fragmented	low; reactive and short-sighted	high; retrofits and redesign
STORYLINE	**In Three Words**	Hybrid, Equity, Flexibility	Consumption, Control, Conflict	Inspiration, Freedom, Progress	Division, Safety Reaction	Scarcity, Depression Vulnerability	Challenge, Precaution Interdependence
	World View	Adaptive management can simultaneously bring economical, social & ecological resilience.	A tragedy of the commons approach emerging from a zero-sum perspective and lack of leadership	Technological innovation will create more efficient solution to attain a greater carrying capacity.	Free market enterprise can most effectively regulate consumption behavior, producing optimal conditions.	Current fluctuations merely reflect natural variation and further exploration will produce new resources.	Maintaining buffers for error will increase the resilience despite high uncertainty
	Human-Nature Relationship	Human and nature are interdependent	Nature is malleable given the right values and timing.	Humans can produce nature	Nature is there for humans to consume	Nature is infinitely forgiving	Nature is unpredictable, humans should minimize their impact
	Main Emphasis	knowledge and collaboration	policy	technology	free market economy	perseverence and exploration	networks and feedback
	Future Outlook	optimist	skeptic	optimist	skeptic	skeptic	optimist
SYSTEM STATE	**Sources of Pressure**	low; growth management	medium; taxes, bureaucracy, fragmentation	medium; hydrological changes, unintended consequences, resource distribution	high; hydrological disasters, crime and poverty, rising costs	high; resource scarcity, economic decline, public health crises	medium isolationism, free-riders, exclusivity, consensus
	Ecosystem Resilience	high	medium	medium	low	alternative	high

Table 6.1 Comparison of the six scenarios

7. Implications and Next Steps

Linking the six scenarios to the nearshore ecosystem
This report describes six scenarios for this region by exploring plausible future conditions. While these futures are developed at the Puget Sound scale they are developed by focusing on major drivers influencing the nearshore ecosystem function. They are conceptualized to characterize divergent trajectories within which an assessment of the nearshore ecosystem function under alternative restoration strategies can be conducted. They constitute the assumptions for a set of predictive models that can be used to assess the impacts. Building explicit connections between the future scenarios and nearshore ecosystem conditions will require selecting a suite of models and identifying specific metrics to be used to compare the restoration strategies The scenarios provide key elements to develop conceptual models and articulate key hypotheses of the relationships among the 32 indicators identified by the participating experts (i.e. economic equity, investment in education, governance structure, and temperature change) and specific nearshore ecosystem functions.

For each scenario, we describe the 'system state', including both the pressure and ecosystem resilience that characterizes that future. Here we highlight, based on the input provided by the experts hypothesized relationships between the future conditions and overall ecosystem functions. Further by describing the pressures and resilience, each scenario begins to connect he trajectories of future conditions and the opportunities and challenges for nearshore ecosystem restoration. These initial connections are largely based on the relationships identified through panel interviews. These are not meant to systematically generate a formal integrated modeling framework for testing hypotheses of changes in the nearshore ecosystem. This modeling framework will require a substantial collaborative research informed by these scenarios. In this final section we provide an initial basis to develop such steps by developing conceptual models linking the 32 indicators to nearshore ecosystem functions the hypothesized system state of each scenarios can be tested and evaluated.

The relationship between the indicators and the nearshore ecosystem can be direct or indirect, can be reinforced through positive feedback loops, or dampened by natural controls, they can be well established or highly uncertain. Some relationships are clear and direct, for example, based on past observations we understand that the amount of upland connected forest in a drainage basin influences water quality (Turner et al, 2001). Other relationships are indirect and uncertain, for example higher educational attainment levels have been previously linked to longer future valuation, affecting the conservation of natural lands, which can enhance migration corridors for birds who feed along shorelines and ultimately the food-web of nearshore habitats. Positive feedbacks are critically important to document in order to determine future nearshore ecosystem conditions. For example, higher nutrient levels may lead to algal blooms which reduce light penetration to the sea floor, which harm eelgrass beds and reduce consumption of algae, which further increases extent of algal blooms. Many of these conceptual models linking regional indicators with nearshore ecosystem conditions have not been documented; many others are still not well developed due to knowledge fragmentation among different disciplines. The key to understanding the implications of each scenarios on the nearshore must start by identifying what scientists know about these relationships, and connecting them through an integrated suite of models linking the scenario indicators and selected nearshore ecosystem function metrics. While mapping these relationships may show several missing links and gaps in scientific knowledge, this process will enable restoration managers to explicitly describe their assumptions and their impact on altering the accuracy of assessing the future condition under each scenario.

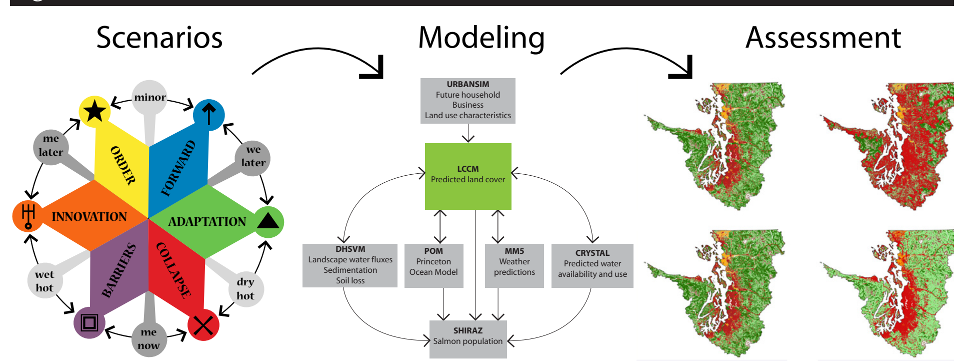
Next steps: integrated models, assessing nearshore ecosystem functions, and evaluating alternative restoration strategies
Once such conceptual models are created the PSNP can begin to identify and integrate spatially-explicit models to link indicators to nearshore ecosystem function and assess impacts by changing the initial assumptions laid out within alternative scenarios. These models are intended to quantify specific conditions, as opposed to qualitative describe relationships. Only available and relevant models will be integrated, as many spatially-explicit and quantitative nearshore ecosystem models do not currently exist, and attempting to integrate too many models will likely prove time consuming and inappropriate. Based on preliminary evaluations of the scenarios the UERL has recommended the integration of a climate change, hydrology and land cover-land use model. Additional complementary models may include marine circulation models, habitat succession models and populations.

Once the models are integrated, the scenarios will serve to alter boundary conditions and specific parameters in model equations, expanding assumptions based on past-observations. For example, while land-cover change models typically assume agriculture can shift to urban land, the reverse relationship has not being typically observed in the past and may not be one of the transitions modeled, 'Adaptation' may alter this assumption to enable urban agriculture to develop. The 32 indicators (and highly correlated assumptions) will function to effectively alter model input changing the implications for future nearshore ecosystem conditions. The output of the model will be spatially explicit maps that can be utilized to assess nearshore ecosystem functions.

Before assessing the implication of each scenario on nearshore ecosystem function, scientists must make the relationship between model outputs, namely metrics, and the nearshore ecosystem functions explicit. For example, model outputs may include miles of armored shoreline, acres of upland forests, or extent of salt-water intrusion into estuaries. On the other hand, nearshore ecosystem functions (or values) can include the population size of juvenile salmon, acres of eelgrass beds, or miles of fine-grained beaches. To facilitate this process the UERL has designed relational database which systematically identify the most relevant nearshore ecosystem metrics for assessing future conditions. The relational database operates under the assumption that the alterations of natural hydrologic, geomorphologic, and ecological processes impair important nearshore ecosystem structures, which are in turn responsible for ecosystem goods, services and functions that have a societal value (Simenstad, 2006A, p v.) Therefore, the database explicitly links nearshore ecosystem metrics to nearshore ecosystem functions (or values) through nearshore ecological structures and processes. For example, meters of armored shoreline can be connected to sediment delivery (process) and extent of shoreline vegetated buffer (structure) that results in altered forage fish spawning occurrence and success (function). Each database component is further connected to multiple additional ecological structures, processes and functions. For example, marsh vegetation is also related to salinity regimes, temperature ranges, nutrient concentrations, and forage fish, tidal fluctuations, nutrient exchange, and upland stream inflow. Since the interaction between structures, processes and functions is spatially driven, a future version of this database will be spatially explicit. Further, the sensitivity and thresholds of ecosystem functions to specific metrics will be addressed in future versions. Currently, the database is intended to highlight gaps in research knowledge about the relationships among nearshore ecosystem metrics, structures, processes and functions. In addition, database will allows the FWO team to select the metrics which are the most appropriate for capturing a wide range of nearshore ecosystem functions, which in turn will influence the final selection of the quantitative models. After the models are integrated and run, the output metrics can be transformed into spatially explicit nearshore ecosystem assessments, clearly laying out the underlying assumptions.

The efficacy of alternative strategies in improving nearshore ecosystem functions can be evaluated by re-running the models under the set of new conditions described in the scenarios. Metric outputs for each strategy under each alterative scenario can be compared to baseline conditions (the value of each metric within each scenario when no restoration strategies are employed). Strategies can be compared in terms of their ability to positively affect change in nearshore ecosystem metrics, and thereby nearshore ecosystem functions. Assuming the scenarios significantly alter the opportunities and challenges associated with improving nearshore ecosystem conditions under alternative restoration strategies, their evaluation will be different. In short, some strategies will be better equipped to improve some metrics under specific scenarios more aptly than others. The major benefit of the scenarios is helping decision makers evaluate which strategies are the most robust under all plausible future conditions, and which strategies should be utilized as a component of an adaptive management portfolio if future conditions begin to resemble the trajectories of one of the six scenarios. The final cost-benefit analysis comparing multiple strategies will be validated by knowing the risk associated with each strategy under a full spectrum of plausible future uncertainties. The final selected strategy or portfolio of strategies will be defended by the understanding that it is flexible and effective enough to benefit the focal issue, despite a great uncertainty associated with future conditions (Figure 7.1).

Figure 7.1 Scenarios to models to assessment



Three scenarios, three strategies, three metrics

While specific conceptual models connecting the scenarios to nearshore ecosystem functions will require a new step and further research , the potential implications of developing multiple scenarios to describe alternative nearshore ecosystem conditions is essential to communicating the benefits of scenario development. This section highlights how alternative future conditions can provide variable opportunities and challenges for nearshore ecosystem function and affect the benefits and costs of alternative restoration strategies through examples. A systematic assessment of how future conditions may affect nearshore ecosystem functions, nor fully developed strategies.

In this example, the scenarios, strategies, and metrics were each selected based on their divergence, towards an effort to explore a wide variability of implications. The three scenarios include Order, Barriers and Adaptation. The three scenarios capture the most divergent climatic changes and human perceptions and behavior approaches. They further look at three different challenges in response to change, command and control coupled with fragmentation (Order) reactive and short-term solutions (Barriers) and flexible and sustainable cooperation (Adaptation). Of course the other three scenarios (Forward, Innovation and Collapse) could have been selected instead, representing significantly different challenges and opportunities including a fast vs. declining growth rate, and the utility of increased efficiency. The three strategies include the removal of shoreline armoring, coastline vegetative buffers and increasing the detention capacity of the Basin. The three strategies focus on three different processes, namely geomorphology, hydrology and biology. However, due to the interconnected nature of nearshore ecosystem processes, there is still considerable overlap in their benefits. Lastly using the three metrics juvenile salmon population numbers, acres of eelgrass beds, and miles of fine gravel beaches we assess changes in nearshore ecosystem values, through divergent constituencies (animal, plant and substrate). Table 7.1 describes a conceptual model connecting the three scenarios, strategies and metrics in terms of changes in drivers, relevant processes and structures, and associated relationships.

For the purpose of this example, future changes in each of the three metrics can be assessed under each scenario. In general, 'Barriers' reduces metric values, while 'Adaptation' maintains or even enhances metrics values. 'Order' stands somewhere in the middle, with some degradation of metric values, but not as severe as 'Barriers'. While all three metrics are somewhat interrelated, there are some hypothesized distinctions among their impacts within each scenario.

Metrics	marsh vegetation	adequate habitat acreage	gravel, sediment supply
Structural needs	detritus food-web	water quality (light, salinity, temperature)	tides and water flow
	suspended sediments	nutrient input levels	vegetation for anchoring
	water quality (temp, salinity, dissolved oxygen, no toxins)	suspended material levels	

Related processes	salmon	eelgrass	beaches
tidal fluctuations (inundation, dessication, salt-water intrusion, velocity)	√	√	√
nutrient exchange and availability	√	√	
sediment exchange, delivery and erosion	√	√	√
upland inflow (water quality and rate)	√	√	√ (rate)
predators and competitors	√	√	
marine water light and temperature regulation	√	√	

Driving Forces	Potential influences on nearshore ecosystems
Climate Change	tidal fluctuations, temperature, light, salinity, upland precipitation, suitability for
Human Behavior	disposal of contaminants and wastes, land alterations, and resource extraction.
Demographics	increased magnitude of impacts, more houses, more activity, higher consumption rates, more fishing.
Development Patterns	land coverage, impervious surfaces, sediment exchange, overland flow rates
Economy	International trade, marine transport, contamination, shading, disruption
Governance	land development and permitting, shoreline armoring and vegetation removal.
Natural Hazards	sediment exchange, water quality, and bythemetry
Technology & Infrastructure	contamination rates, extraction efficiency

Restoration Strategies	What does it entail?	Potential benefits	Potential limitations
Removal of Shoreline Armoring	replace hardened shoreline structures with natural slopes or soft walls	Restore sediment and nutrient exchange between bluffs and beaches	Shoreline homes and structures may lose erosion protection
Two-hundred foot coastline buffer	Ensure that all coastlines within the Basin are protected by a 200' native vegetation buffers	Enrich the water with nutrients and energy, from large woody debris to micro-organisms	increased tidal fluctuations may scour new vegetation, private property along shoreline
Increased detention capacity of Basin	Increase the ability of the Basin to detain water using various approaches from green roofs and to detention ponds.	Slow runoff during large precipitation events in order to prevent surface contaminants from being picked up during first flush and reduce CSO events	Keeps water out of natural waterways; water can cause damage to property and infrastructure

Table 7.1 Conceptual model linking strategies to metrics

For example, despite potential increases in infiltration and natural land cover, salmon numbers may be significantly reduced in 'Adaptation' due to near-drought summer streamflows.

Each scenario poses specific opportunities and challenges for different restoration strategies (Table 7.2). In 'Barriers', high tidal fluctuations and major winter floods severely impact shoreline property making the removal of shoreline armoring for the purposes of protecting 'fine gravel beaches' not politically palatable. On the other hand, due to large wintertime precipitation and consequent floods increasing the detention capacity of the Basin would not only protect public health and property, but would also reduce the number of sewer overflows and the transport of contaminants carried through high velocity urban runoff. Under the 'Order' scenario the removal of shoreline armoring could be most palatable, as climate impacts are minimal (reducing vulnerability) and new planned developments can keep structures further from the shore, improving marketability as scenic and protective. Increasing the detention capacity of the Basin would be less effective as it generally relies on creating costly region-wide solutions benefiting specific sites. Lastly, in terms of 'Adaptation', removing shoreline armaments may be the most productive strategy as houses move away from the coastline and major tidal fluctuations make beach formation require the flexibility of upland migrations. On the other hand a vegetative buffer may actually introduce pest-outbreaks and greater competition for native species as increased temperatures and tidal fluctuations alter shoreline conditions.

The three strategies highlighted above are necessarily simplified and stylized mechanisms for improving nearshore ecosystem functions. The assessments presented above don't take into account the complex interactions and uncertain relationships among future conditions. For example, scientists are still unsure

Restoration Strategy	★ Order			☐ Barriers			▲ Adaptation		
Baseline conditon	S	FG	EG	S	FG	EG	S	FG	EG
Removal of shoreline armoring	S	FG	EG	S	FG	EG	S	FG	EG
Coastline buffer	S	FG	EG	S	FG	EG	S	FG	EG
Increased detention capacity	S	FG	EG	S	FG	EG	S	FG	EG

S = salmon **FG** = fine gravel **EG** = eelgrass   Worse — Better

Table 7.2 Strategy evaluation

if rising marine temperatures will increase or decrease the overall amount of eelgrass habitats, or if removing shoreline armoring without alleviating upland fragmentation and pollution may improve or harm nearshore beaches. Only through modeling the complex interactions with spatially integrated models can assessments incorporate uncertainty and truly reflect the implications of each scenario on nearshore ecosystem functions, and the opportunities and challenges affecting restoration strategies.

Initial set of challenges and opportunities affecting nearshore ecosystem restoration strategies.

While a systematic assessment of nearshore ecosystem functions under each scenario would require further research, some initial statements about the implications of each scenario on restoration strategies have already began to emerge. The following ten questions reflect the UERL's initial messages about the scenarios' influence on nearshore ecosystem restoration. This message must be understood in terms of their current bias, having not yet been afforded the verification by participating experts.

1. If upland areas become developed increasing the percentage of impervious area in the region, what are the implications on nearshore ecosystem restoration priorities?
2. If flooding and erosion make armoring and dyke removal not politically feasible, what other options are available for reconnecting waterways?
3. What challenges and opportunities does new innovation bring to the horizon over the next 50 years that can help 're-design' the type of shoreline restoration we conduct?
4. What are the unintended consequences of restoration strategies under alternative scenarios?
5. How do shoreline restoration strategies align with hazard or crisis management?
6. How can restoration strategies adapt to changing ecosystem conditions such as increased salinity, decreased summer flows and higher nutrient levels? What does a resilient Puget Sound look like under alternative baseline conditions?
7. If restoration strategies could incorporate adaptive management such that we had the capacity to test out hypotheses, what should we test?
8. How do we manage shoreline ecosystems under dynamic conditions?
9. Are restoration goals better met though consistent region-wide enforcements or flexible community-level cooperative agreements?
10. How can restoration strategies incorporate the benefits and limitations of an active public participation?

Implications of developing scenarios

Challenging underlying assumptions

One of the most difficult tasks within the scenario development process is persuading participants (managers, scientists, and other stakeholders) to challenge their underlying assumptions about how systems function and how they will evolve in the future. Most often these assumptions have become buried under the guise of 'truth' or 'precedence' and have formed the basis for agency models, assessments and solutions. The scenario process helps to make assumptions explicit. Five assumptions stand out as being significant in creating false predictions for this region's future:

The first is that human behavior will not change. Some form of this comment was heard from the majority of participants at some point during their interviews. A slight variation of this comment was, 'human behavior will only change if a major disaster occurs'. However, evidence of change in human behavior is not only historically accurate, but also spatially accurate. Human behavior changes as new information is available, as educational attainment rises, as income levels change, as a population ages, as the cultural diversity within a population changes. The Puget Sound of the Gold Rush years is not the same place it is today, largely due to changes in human behavior and perceptions.

A second assumption is that climate impacts will increase annual precipitation within the region. This brings up the issue of probability versus plausibility. While the majority of climate models downscaled for this region reflect increasing annual precipitation, two models predict less rainfall. The difference between an 8% increase and a 1% decrease is like comparing rainfall west of the Cascades to the rainfall east of the Cascades. Attempting to develop strategies reliant on the hydrological cycle without addressing this incongruency is extremely limited.

A third assumption, generally found among natural scientists, but challenged by spatial planners, is that a greater concentration of people leads to greater impact. The assumption here is that the more people that move into the Basin, the greater the negative implications for the nearshore ecosystem. This assumption is also related to the general dichotomy that we found in the natural science between humans and nature. While humans have historically caused harm to ecological processes, there are examples of coupled human natural systems on limited scales where humans have also benefited ecological systems. The UERL studies coupled human-natural systems with the hypothesis that a hybrid human-nature relationship could simultaneously benefit humans and ecosystems.

A fourth assumption is that the economy is stable and therefore will continue to grow. The assumption creates the basis for the Office of Financial Management's models, for UrbanSim's models of the Puget Sound, for the Cascade Agenda and many other organizations' models and goals. The Boeing crash and Dot com crash are generally regarded as periods of instability, when the region was dominated by a few very large firms. However, as some economists are pointing out, the potential for some of the Region's largest industries to leave within the next 20 years is certainly plausible, if not probable. Boeing has no plans past the Dreamliner, and Microsoft and Amazon are being pursued by cities around the globe as clean high wage industries. The potential pressure created by an economic recession may rapidly overshadow ecological decisions.

Lastly, the fifth assumption is that regulations affect development patterns. While the discipline of planning greatly rests on this assumption, it has generally been disproved. Development patterns generally represent emerging phenomena controlled by individual actors who alter the landscaping according to a complex set of decisions, only a few of which represent regulations. These decisions include both rational and emotional elements, from market prices to living close to a family or hving a scenic view. Ironically, many regulations ultimately reinforce behaviors they sought to deter, whether increasing the value of living close to critical areas, or developing low density houses outside of growth boundaries.

Defining a complete set of driving forces

Driving forces represent the major elements influencing future conditions. Ecological assessments generally rely on a predetermined set of driving forces including development patterns, demographics and governance and, more recently, climate impacts. Other driving forces, such as technology and infrastructure, public health and hazards are incorporated within a specific assessment: for example, Shellfish harvesting beaches often involve impacts on human health. One of the greatest utility of applying the scenario planning approach has been the ability to start the assessment by relying on a diverse set of regional experts to identify and define a complete set of driving forces to direct this project. Despite the dominance of the ten key drivers, all ten driving forces were instrumental in creating compelling and internally consistent stories. Reflecting on the final scenario narratives, it is difficult to imagine developing the plots without any of them. How would 'Barriers' be developed without exploring the role of economic inequity, or 'Innovation' without the investment in regional infrastructure?

Placing the role of ecosystem managers in perspective

Ecological assessments often start from the perspective of a strategy, as opposed to a problem. Managers develop an approach to solve a pre-existing or emerging condition with a set of assumptions about the nature of the problems and the best solutions. The assessment process is often developed as a basis for gaining acceptance for this strategy; as a tool to prove that the strategies will work instead of testing the validity of its assumption. The assessment therefore functions to reaffirm preconceived notions about how the future would turn out. The problem with this perspective is that it does not provide room for managers to creatively explore their options. Further, by revolving the future around the strategy, it erroneously places the managers in the center of influencing change. However, the efficacy of strategies most often depends on factors beyond the immediate control of the manager and multiple key elements must fall in place in order for a strategy to function as planned. Rather than dismissing these elements as uncontrollable, it is exactly these types of uncertainties that must in integrated in order to conduct a fully accountable assessment.

Integrating uncertainty into the decision making process

A general assumption is that managers need an accurate prediction of the future condition in order to make a decision. An accurate prediction allows the manager to select the most effective strategy without any risk. However, most decisions involve irreducible uncertainties such that an accurate prediction is merely a fallacy predicated on probability distributions based on past observations. The most probable futures do not provide sufficient information for making effective decisions. Strategic decisions benefit from looking at the bounds of plausible futures, or the most divergent paths the future can move into. In other words, when the future is uncertain, decision makers are better off integrating uncertainty into their risk assessment than relying on a single wrong prediction. The question that managers should ask themselves is: Which strategy is most effective under alternative futures?

The Puget Sound Scenarios focus on climate change and human perceptions and behavior as the most important and uncertain driving forces used to represent the scenario logics. Ranking these two drivers represents the most challenging and likely most relevant step of the scenario planning process. If the two drivers were different, the scenarios would have inevitably turned out much differently. Reflecting back on the scenarios, these two drivers were appropriate for isolating the most divergent future for this region. Their success emerges largely from their hierarchically significant role, cascading their influence on other driving forces. Climate impacts, for example, are controlled by global changes that cannot be reduced to any of the other nine driving forces. On the other hand, climate impacts in this region are predicted to significantly alter development patterns, the economy, public health, natural hazards and infrastructure. Human perceptions and behavior may not necessarily be the next most uncertain driver. However, human behavior ultimately affects almost all other drivers, including knowledge and information, technology, demographics, public health, the economy, and development patterns. Secondly, the two drivers form a divergent coupling, as one generally represents natural based changes, while the other represents human based changes. Lastly, in terms of long-term regional influences on the nearshore ecosystem, no two drivers accurately represent the divergent trajectories plausible for this region. The uncertainty integrated by the crossing of these two drivers was successfully able to incorporate divergent trajectories of the economy, development patterns and natural hazards.

References

Alberti, M., J. Hepinstall, M. Russo, and B. Coburn. 2005. CTED Landscape Benchmarks Project. Washington State Commerce Trade and Economic Development.

American Heritage Dictionary online. "Public health". Last Accessed Dec 2007.

Ammons, D. 2007, February 7. Health care for all: Gregoire's plan: Governor and legislative leaders commit to coverage within 5 years. Seattle Post Intelligencer. np.

Arrow, K., B. Bolin, R. Costanza, P. Dasgupta, C. Folke, C.S. Holling, B.O. Jansson, S. Levin, K.G. Mäler, C. Perrings, and D. Pimentel. 1996. Economic growth, carrying capacity and the environment. Ecological Applications. 6(1): 13.

Bellah, Robert N. 1985. Tokugawa Religion: The Values of Pre-Industrial Japan (2nd edition under the subtitle: The Cultural Roots of Modern Japan). New York: Free Press. (Orig. pub. 1957).

Bhatt, S. 2005, May 16. Closures tied to teacher's contract. The Seattle Times.

Booth, D.B. 1991. Urbanization and the natural drainage systems impacts, solutions and prognoses. Northwest Environment J (7): 93–118.

Bureau of Economic Analysis [BEA]. 2007. Regional Economic Accounts. U.S. Department of Commerce. http://www.bea.gov/regional/index.htm. Last accessed Jan 2008.

Canning, D.J. 2007. Vertical Land Movements in Western Washington and Adjacent Areas. (In press).

Carpenter,S., B. Walker, J. M. Anderies, and N. Abel. 2001. From metaphor to measurement: Resilience of what to what? Ecosystems 4: 765-781.

Cascio, J. 2004, March 2. World Changing Scenarios. World Changing: Planet. http://www.worldchanging.com/archives/000433.html. Last Accessed Feb 7, 2007.

Center for Disease Control [CDC] Behavioral Risk Factor Surveillance System. 2007. http://www.cdc.gov/brfss/ Last Accessed Dec 2007.

Center for Research on the Epidemiology of Disasters [CRED]. 2008. EM-DAT Emergency events Database. http://www.cred.be/ Last Accessed Jan 2008.

Chase, R. 1999. Foreign imports and the Washington State economy. Prepared for Washington State community. Trade and Economic Development.

Climate Impact Group [CIG] About Pacific Northwest Climate. JISAO, CSES, http://cses.washington.edu/cig/pnwc/pnwc.shtml last accessed Dec, 1, 2007.

Costanza, R. 2000. Visions of alternative (unpredictable) futures and their use in policy analysis. Ecology and Society (l4):1.

Cowell, F. A. 2000. Measurement of inequality in Atkinson, A.B. and F. Bourguignon (ed.) Handbook of
Income Distribution. Amsterdam: North Holland.

Daly, H. E. 1991. Steady State Economics. 2ed. Washington: Island Press.

Danson, M.W. 1998. Sustainable wealth creation at the local level in an age of globalization. Regional Studies. 32/9: 863-877.

De Moll, L., S. Bender, S. Johnson, L. Johnson, and R. Epstein. 1977. Rainbook: Resources forAppropriate Technology. New York: Schocken.

Department of Water Resources. 2005, December. California Water Plan Update 2005: A Framework for Action. Bulletin 1560-05. Strategic Plan. Volume 1. http://www.waterplan.water.ca.gov. Last Accessed Jan 26, 2007.
G. (1998). Scenario Planning: Managing the Future. New York: John Wiley & Sons.

Energy Information Administration [EIA] 2006. energy Cost Per State. http://www.ifenergy.com/50226711/eia_energy_cost_per_state.php Last Accessed Jan 2008.

Finlayson, D. 2006. The geomorphology of Puget Sound beaches. Puget Sound Nearshore Partnership Report No. 2006-02. Seattle, Washington: Washington Sea Grant Program, University of Washington.

Fisher, R.C. 1997. The effects of state and local public services on economic development. New England Economic Review. March/April 1997.

Frank, L. 2007. King County HealthScape Project. King County AIMs High. Walkability Index. http://www.metrokc.gov/aimshigh/kingstat.asp.

Fresh, K.L. 2006. Juvenile Pacific salmon and the nearshore ecosystem of Puget Sound. Puget Sound Nearshore Partnership Report No. 2006-06. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington. Available at www.pugetsoundnearshore.org.

Fresh, K., C. Simenstad, J. Brennan, M. Dethier, G. Gelfenbaum, F. Goetz, M. Logsdon, D. Myers, T. Mumford, J. Newton, H. Shipman, and C. Tanner. 2004. Guidance for protection and restoration of the nearshore ecosystems of Puget Sound. Puget Sound Nearshore Partnership Report No. 2004-02. Seattle, Washington: Washington Sea Grant Program, University of Washington, Seattle, Washington. Available at http://pugetsoundnearshore.org.

Gelfenbaum, G., T. Mumford, J. Brennan, H. Case, M. Dethier, K. Fresh, F. Goetz, M. van Heeswijk, T.M., Leschine, M. Logsdon, D. Myers, J. Newton, H. Shipman, C.A. Simenstad, C. Tanner, and D. Woodson. 2006. Coastal habitats in Puget Sound: a research plan in support of the Puget Sound Nearshore Partnership. Puget Sound Nearshore Partnership Report No. 2006-1. Published by the U.S. Geological Survey, Seattle, Washington. Available at http://pugetsoundnearshore.org.

Glick, P, J. Coulgh, and B. Nunley. 2007. Sea-level rise and coastal habitats in the Pacific Northwest: an analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon. National Wildlife Federation.

Goetz, F., C. Tanner, C. Simenstad, K. Fresh, T. Mumford, and M. Logsdon. 2004. Guiding Restoration Principles: Puget Sound Nearshore Partnership. Seattle, Washington: Washington Sea Grant Program, University of Washington.

Graube, M. 2006. Puget Sound: Saving a Northwest gem. Northwest Science & Technology, Fall.

Gregoire, Chris. 2007. Governor Gregoire Introduces Healthy Washington Initiative: The Next Washington. http://www.governor.wa.gov/. Last Accessed Feb 11, 2007.

Griggs, G.B., 2005. The impacts of coastal armoring. Shore and Beach 73(1):13-22.

Grossman, G. 1995. Population and growth: What do we know? in I. Goldin and L.A. Winters (eds.) The Economics of Sustainable Development. Cambridge: Cambridge University Press.

Guha-Sapir, D., D/ Hargitt and P. Hoyois. 2004. Thirty Years of Natural Disasters 1974-2003: The Numbers. Centere for Research on the Epidemiology of Disasters. UCL Presses Universitaires de Louvain.

Harris, A.H., W.N. Evan, and R.M. Scwab. 2000. Education spending in an aging America. Journal of Public Economics 81 (2001): 449–472.

Headrick, D. R. 1990. Technological change in B. L. Turner II, R.W. Kates, J.F. Richards, J.T. Mathews, and W.B. Meyer (eds). The Earth As Transformed by Human Action. Cambridge: Cambridge University Press.

Heylighen, F. 2000. Principia Cybernetica URL= http://cleamc11.vub.ac.be/ASC/DISCOU_RATE.html. Last Accessed Jan 2008.

Hodgson, T. 2003. Strategic thinking with scenarios. Metabridge DOI:

Housing Partnership. September 1998. Housing Affordability in the Puget Sound Metropolitan Area.

Hurwitz, S., K. Kipp, S.E. Ingebritsen, and M.E. Reid. 2003. Groundwater flow, heat transport, and water table position within volcanic edifices: Implications for volcanic processes in the Cascade Range. Journal of Geophysical Research. 108..

Inkeles, Alex, ed. 1993. On measuring democracy. Its consequences and concomitants. New Brunswick, NJ:Transaction Publishers.

Intergovernmental Panel on Climate cChange [IPCC]. (2000). Emissions Scenarios: Summary for Policymakers, a special report of the IPCC Working Group III. http://www.grida.no/climate/ipcc/spmpdf/sres-e.pdf. Last Accessed Jan 26, 2007.

Jackson, R.J. MD and C. Kochtitzky. MSP. 2005, April 27. Creating A Healthy Environment: The Impact of the Built Environment on Public Health. Center for Disease Control and Prevention. http://www.cdc.gov/healthyplaces/

Johannessen, J. and A. MacLennan. 2007. Beaches and Bluffs of Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-04. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington. Available at www.pugetsoundnearshore.org.

Kirshner, A. and L. Thadden. 2004. Educational Attainment in Washington State: 1990-2000. EB1944e WSU Extension, Washington State University, Pullman, WA.

Leschine, T.M., and A.W. Petersen. 2007. Valuing Puget Sound's Valued Ecosystem Components. Puget Sound Nearshore Partnership Report No. 2007-07. Seattle, Washington: Seattle District, U.S. Army Corps of Engineers. Available at www.pugetsoundnearshore.org.

Lindgren, M. and H. Bandhold. 2003. Scenario Planning: the link between future and strategy. New York: Palgrave, Macmillan.

Linkov, I., F.K. Satterstrom, G. Kiker, C. Batchelor, T. Bridges, and E. Ferguson. 2006. From comparative risk assessment to multi-criteria decision analysis and adaptive management: Recent developments and applications. Environment International 32(8): 1072-1093.

Liu, J., T. Dietz, S. Carpenter C. Folke, M. Alberti, C. Redman, S. Schneider, E. Ostrom, A. Pell, J. Lubchenco, W. Taylor, Z. Ouyang, P. Deadman, T. Kratz, and W. Provencher. 2007. Complexity of coupled human and natural systems. Science 317 (5844): 1513-1516

Lynn, B. 1998. Nearshore Habitat Loss in Puget Sound: Recommendations for Improved Management. Washington Nearshore Habitat Loss Work Group, Puget Sound / Georgia Basin International Task Force.

Meadows, D.H. 1972. The Limits to Growth: A Report for The Club Of Rome's Project on the PredicamentOf Mankind. New York: Universe Books.

Merriam Webster On-line dictionary. “Knowledge” Last Accessed Nov 2007

Millennium Ecosystem Assessment [MEA]. 2003. Ecosystems and Human Well-Being: A Framework for Assessment. Island Press.

Municipal Research and Servcies Center [MRSC]. 2003. Agricultural Lands. http://www.mrsc.org/subjects/planning/aglands.aspx. Last Accessed Feb 7, 2007.

National Aeronautics and Space Administration [NASA]. (2004, March 24). NASA uses a "SLEUTH" to predict urban land use. NASA: Centers: Goddard Home: News. http://www.nasa.gov/centers/goddard/news/topstory/2004/ 0322sleuth.html#top. Last Accessed Feb 7, 2007.

Office of Forecast Council. 2005. Washington State Economic Climate Study. OFM. (2004, July). Economic Impacts of Military Bases in Washington. http://www.ofm.wa.gov/economy/military/default.asp. Last Accessed Feb 7, 2007.

Office of Financial Management [OFM]. 2005A. Long-Term Forecasts of Washington Population and Net Migration. The 2005 Long-Term Economic and Labor Force Forecast for Washington. http://www.ofm.wa.gov/economy/longterm/2005/. Last Accessed Feb 7, 2007.

OFM. 2005B. Population Change and Net Migration. Washington Trends. http://www.ofm. wa.gov/pop/. Last Accessed Feb 7, 2007.

OFM. 2005C. Introduction. Washington Trends. http://www.ofm.wa.gov/pop/. Last Accessed Feb 7, 2007.

OFM. 2005D. Average Wages, Washington and the U.S.. 2005 Data Book. http://www.ofm.wa.gov/databook/. Last Accessed Feb 7, 2007.

OFM. 2006. 2025 County Projections. http://www.ofm.wa.gov/trends/htm/fig301.asp. Last Accessed Feb 7, 2007.

Peterson, G.D., T.D. Beard, B.E. Beisner, E.M. Bennet, R.R. Carpenter, G.S. Cumming, C.L. Dent, and T.D. Havlicek 2003. Assessing future ecosystem services: A case study of the Northern Highlands Lake District, Wisconsin. Conservation Ecology 7(3).

Peterson, G. D., S.R. Carpenter, and W. A. Brock. 2003. Uncertainty and the management of multistate ecosystems: An apparently rational route to collapse. Ecology 84(6): 1403-1411.

Peterson, G. D., Cumming, G.S. and S.R. Carpenter. 2003. Scenario planning: a tool for conservation in an uncertain world. Conservation Biology 17(2): 358-366.

Puget Sound Partnership [PSP]. 2007. Puget Sound Conservation and Recovery Plan. State of Washington. www.psp.wa.gov/our_work/pscrp.htm.

Puget Sound Nearshore Partnership [PSNP]. 2004. Puget Sound Nearshore Partnership Work Plan: A Strategy for Restoration of the Puget Sound. http://www.pugetsoundnearshore.org/techical_papers/ strategicworkplanfinal.pdf. Last Accessed Feb 7, 2007.

PSNP. 2006A. 'About the Nearshore Partnership'. http://www.pugetsoundnearshore.org/what.htm. Last Accessed Feb 7, 2007.

PSNP, 2006B. 'What is The Puget Sound Nearshore and What is the Problem with It?' http://www.pugetsoundnearshore.org/what.htm#preface. Last Accessed Jan 2008.

PSNP. 2007. Report No. 2007-05. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington. Available at www.pugetsoundnearshore.org.

Puget Sound Regional Council [PSRC]. 2005, July 7. Vision 2020 + 20 Update: Issue Paper on Energy Consumption and Infrastructure Capacities. http://www.psrc.org/projects/vision/pubs/energy.pdf. Last Accessed Feb 7, 2007.

Randall, D. and C. Ertel. 2005, September. Moving beyond the official future. FT Mastering Risk. 10-11.

Rapport, D.J. 1998. Assessing ecosystem health. Trends in ecology and evolution. 1998 (1310): 397

Raskin, P., Monks, F., Ribeiro, T., Vuuren D. and M. Zurek. 2006. Global scenario in historical perspective. Global Assessment Reports 2: Scenarios Assessments. Island Press.

Ratcliffe, J. S. 2000. Scenario building: A suitable method for strategic construction industry planning? Property Management 18(2): 127 - 144

Ryscavage, P. 1999. Income Inequality in America: An Analysis of Trends. M.E. Sharpe. Armonk, New York.

Sack, R. D. 1990. The realm of meaning: The inadequacy of human-nature theory and the view of mass consumption, in B.L. Turner II, W.C. Clark, R.W. Kates, J.F. Richards, J.T. Mathews, J.T., and W.B. Meyer (eds.). The Earth As Transformed by Human Action. Cambridge: Cambridge Univ. Press.

Schwartz, P. 1991. The Art of the Long View. New York: Doubleday/Currency.

Sightline Institute. 2006. Cascadia Scorecard. 2006. Sprawl and Transportation.

Simenstad, C, M Logsdon, K. Fresh, H. Shipman, M. Dethier, and J. Newton. 2006A. Conceptual model for assessing restoration of Puget Sound nearshore ecosystems. Puget Sound Nearshore Partnership Report No. 2006-03. Seattle, Washington: Washington Sea Grant Program, University of Washington. Available at http://pugetsoundnearshore.org.

Simenstad, C., D. Reed, and M. Ford. 2006B. When is restoration not? Incorporating landscape scale processes to restore self-sustaining ecosystems in coastal wetland restoration. Ecological Engineering 26: 27-39.

Snover, A. K., P.W. Mote, L. Whitely Binder, A.F. Hamlet, and N.J. Mantua. 2005. Uncertain Future: Climate Change and its Effects on Puget Sound. A report for the Puget Sound Action Team by the Climate Impacts Group Volume, DOI.

Thomas, C. Personal communication August 2007.

Tocqueville, Alexis de. 1835-1840/2000. Democracy in America. Chicago: Chicago University Press.

Triandis, Harry C. 2001. Individualism-collectivism and personality. Journal of Personality. 69(6): 909.

Turner, M.G., Gardner, R.H. and R.V. O'Neill. 2001. Landscape Ecology in Theory and Practice: Pattern and Process. Springer, New York.

United Nations Environment Programme [UNEP]. 2006. Marine and coastal ecosystems and human wellbeing: A synthesis report based on the findings of the Millennium Ecosystem Assessment. UNEP 96.

Urban Ecology Research Laboratory [UERL]. 2006. Regional Geographic Initiative: Landscape Composition and Configuration at the Basin and Sub-Basin Level. Environmental Protection Agency, Region 10. University of Washington. June 2006.

United States Census Bureau. American Factfinder. http://www.census.gov/. Last Accessed Dec 2007.

United Stated Geological Survey [USGS]. 2004, October. Spatial Decision Support Systems for Landscape Ecological Evaluations in the Southwest Florida Feasibility Study. Fact Sheet 2004- 3113. http://pubs.usgs.gov/ fs/2004/3113/pdf/fs-2004-3113-DeAngelis.pdf. Last Accessed Feb 10, 2007.

Van der Heijden, K. 1997. Scenarios, Strategies and the Strategy Process. Brueklen: Nijenrode University Press.

Walkscore. http://walkscore.com/Last Accessed Jan 2008.

Washington Department of Health. Office of Shellfish and Water Protection. http://www.doh.wa.gov/ehp/ts/WW/default.htm. Last Accessed Jan 2008.

Washington Education Association. 2006. Issue Positions: Public Education issues. http://www.washingtonea.org. Last accessed Dec 6, 2006.

Washington Military Department Emergency Management Division. 2007. Natural Hazards. http://emd.wa.gov/hazards/haz_natural.shtml. Last Accessed Jan 2008.

Washington State Legislature. http://www.leg.wa.gov/legislature. Last Accessed Jan 2008.

Weiskel, P., Howes, B. and G. Heufelder. 1996. Coliform contamination of a coastal embayment: Sources and transport pathways. Environmental Science and Technology 30(6): 1872-1881.

Wolff, E. 2004. What Has Happened to The Quality Of Life in The Advanced Industrialized Nation. Edward Elgar Publishing.